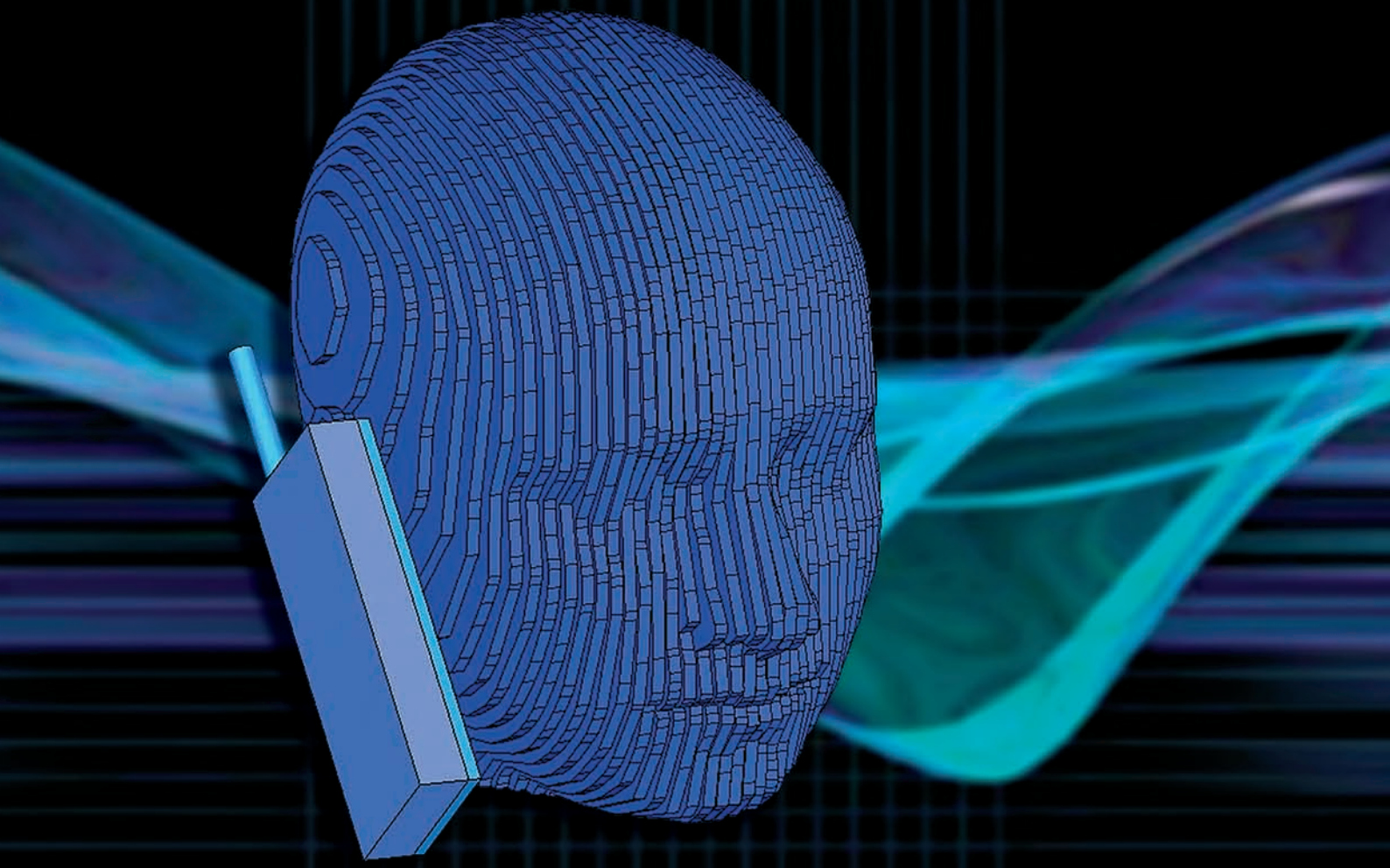
EUROPEAN COMMISSION

Community research

Health and electromagnetic fields



EU-funded research into the impact of electromagnetic fields and mobile telephones on health

The 20th century witnessed an explosion of technological applications that rely on electricity and thus produce electromagnetic fields. And there will be even more of these innovative technologies in the 21st century. We cannot avoid this, nor would we wish to, because technology makes our lives healthier, wealthier and safer – it is a major contributor to the economic and social progress that enhances our quality of life.

However, while electric fields have been a vital part of our daily life for over a century now, and have not shown clear evidence of ill effects on health, they are becoming more pervasive. This is seen in the massive growth in the use of mobile telephones – there are 1.6 billion in use today in the world – each one with its own electromagnetic field. This is a subject of growing concern to Europe's citizens who are unsure if mobile telephones are safe for themselves and their children.

While there is no proven evidence that very weak electric and magnetic fields can affect our health, we have a duty to be sure of this, so that the public and regulators can make informed decisions about their use. For this reason, the European Commission's Directorate-General for Research funds research into the potential health effects of long-term exposure to electromagnetic fields. Because this research is looking for weak effects that could accumulate over a long time period, actions at the European level are particularly effective: coordinating new research based on shared knowledge and building co-operation between widespread centres of expertise.

This publication describes the background to research on the health impacts of electromagnetic fields and gives some examples of research projects funded by the Commission. It also places this research in the context of EU policies and initiatives at international level. The European Commission has funded research in this area since 1999 and has proposed to continue it in future RTD Framework Programmes. Only thorough and well-validated scientific research will allow policy-makers and legislators to establish the safety standards that will protect our citizens while allowing technology to continue to improve our quality of life in the future.

Christian Patermann

Director of Biotechnology, Agriculture and Food Research

What are electromagnetic fields?

Electric and magnetic fields are all around us – for example, natural electric fields in thunderstorms cause lightning to leap across the sky, and man-made electric fields are found in the fluorescent lamps that light our streets. Magnetic fields are also well known to us; the Earth's magnetic field causes a compass needle to point North and helps many birds and fish to navigate. These electric and magnetic fields are linked because whenever an electric current flows in an electric field, then a magnetic field is generated. Together they form an electromagnetic field, or EMF. An example of this is found in our homes, in hi-fi systems, where an electric field, or voltage, drives a varying electric current which produces a varying magnetic field that causes the speaker cone to vibrate and reproduce sounds.

Electromagnetic fields can be described as a series of waves that oscillate at a particular frequency and have a certain distance between one wave and the next – the wavelength. EMFs have a very wide range of frequencies, extending from low-frequency electricity supply lines with wavelengths of some hundreds of metres, through the radio and visible light frequencies, to very high-frequency medical X-rays with wavelengths measured in trillionths of a metre. This range is shown in the electromagnetic spectrum in diagram 1.

The electromagnetic spectrum in diagram 1 shows a number of important divisions based on the properties and applications of the different frequencies. The simplest division is into ionising and non-ionising electromagnetic radiation. Ionising radiation includes ultraviolet rays, X-rays and gamma rays. They are called 'ionising' because the individual waves can break the chemical bonds between atoms to produce ions. Non-ionising radiation cannot break chemical bonds; however, it does interact with matter in other ways. In particular, it can create a heating effect in materials if it carries enough energy.

Key points:

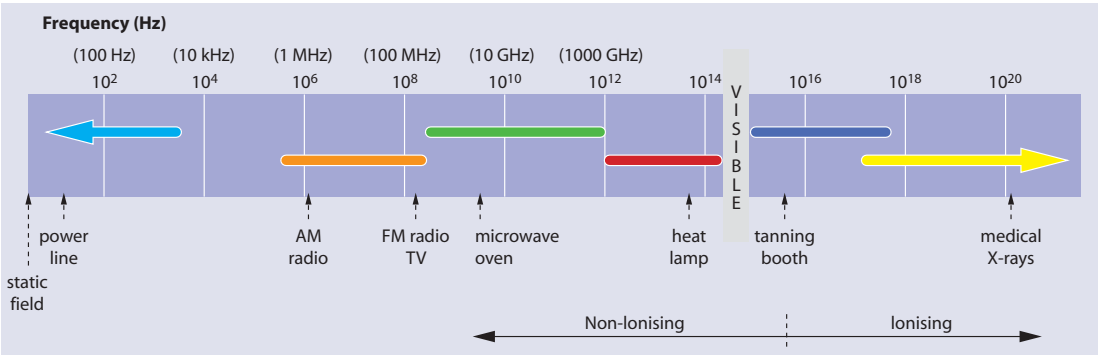
EMFs occur naturally and they are generated and used by us for many purposes.

Ionising EMFs can break chemical bonds and thus cause radical changes in materials.

Non-ionising EMFs do not break chemical bonds, but they can cause heating.

EMFs are characterised by their oscillation frequencies, measured in hertz.

Diagram 1: The electromagnetic spectrum



The electromagnetic spectrum is a continuous range of frequencies that are measured in hertz (Hz), as explained in box 1. This continuous spectrum is divided according to the use that is made of various parts – for example, the infrared range that is used for TV remote controls, the microwave range used for cooking, and radio-frequency (RF) waves that carry radio and television signals. At the extra-low frequencies (ELF) are the power lines and pylons of the electricity grid that supplies electricity to homes and factories. These different parts of the electromagnetic spectrum are marked in diagram 1 together with some of their applications.

Radio frequencies and microwaves are of particular interest when we come to consider the possible effects of EMFs on human health.

Diagram 2 shows more detail of this part of the electromagnetic spectrum between 100kHz and 10GHz. As the spectrum shows, this range contains many of the frequencies that are used for communication purposes, such as television signals, AM and FM radio broadcasts, police and ambulance wireless communications, and the frequencies used for mobile telephones between 800MHz and 1800MHz.

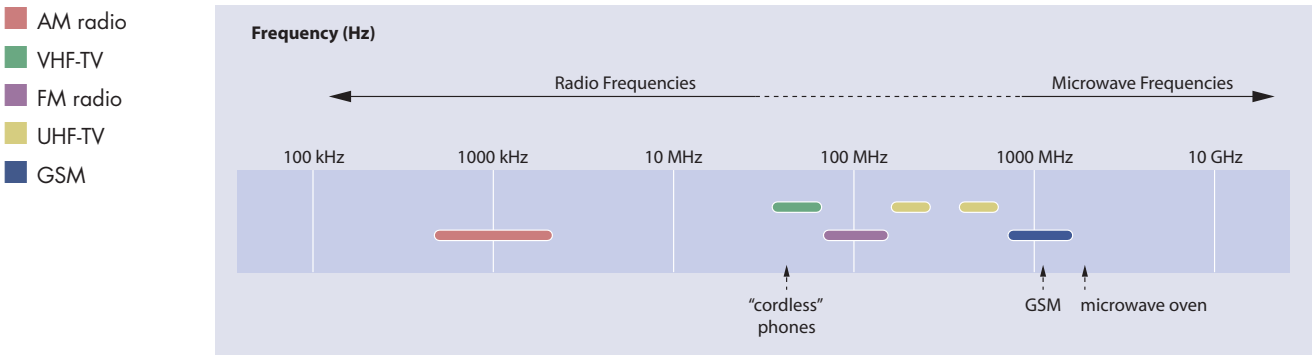
Box 1

Frequency is measured in hertz (Hz), which is the number of times the electromagnetic field oscillates in one second, so an EMF with a frequency of one megahertz (MHz) oscillates 1 million times per second. Everyday examples include: the electricity supply from a domestic wall plug, which has a frequency of 50Hz, oscillates at 50 times a second; and a 900MHz mobile telephone uses radio waves that oscillate 900 million times per second.

Electric fields are measured in volts per metre (V/m). The strength of electric fields decreases with the distance from the source, and they can be blocked by walls, buildings and other materials.

Commonly occurring magnetic fields are measured in microtesla (μT). One μT is a millionth of a tesla, which measures the density of the magnetic field. Magnetic field strengths also decrease with distance from their source, but they are not shielded much by walls and buildings.

Diagram 2: The wireless communications spectrum



What are the sources of EMF?

Electromagnetic fields are all around us and in everyday life we are all exposed to EMFs from a variety of sources. There are natural sources such as the Earth's magnetic field and sunlight that contains visible, infrared and ultraviolet frequencies.

There are also many man-made sources of non-ionising EMF generated wherever an electrical current flows. In our homes, EMFs arise from microwave ovens, hairdryers, the electric wiring in the house, and remote control devices, among others. In the workplace, they are generated by computer screens, industrial electric furnaces, electric motors, and anti-theft systems. And on the street, we are bathed in weak EMF from electric train and tram cables, power lines, radio-frequency communication antenna for the emergency services, and now, with the growth of wireless networks, by EMFs from Wi-Fi and 'Bluetooth' type technologies. An important feature is that although there are many sources, they are very weak.

Mobile telephones are a particular source of EMF that has grown rapidly as people appreciate the many benefits they bring to their lives. Mobile telephone technology generates EMF in two ways: first from the antennae that are placed around our cities, towns and motorways; and secondly from the telephones themselves which transmit our conversations to the antennae.

How these EMFs interact with biological organisms depends on their energy and frequency. Human bodies are transparent to some frequencies and not to others. For example, sunlight only penetrates 'skin deep' and is mostly absorbed, whereas magnetic fields can largely pass through the human body. Energy is also important, which is why we put on sunscreen creams to protect ourselves in strong sunlight. For similar reasons there are recommended exposure limits for other EMF frequencies, for example the fields emitted by computer screens in workplaces. Table 1 shows some common domestic sources of EMF and the electric and magnetic fields they generate. It demonstrates that these everyday sources generate EMFs well below the guidelines of the International Commission on Non-Ionising Radiation Protection (ICNIRP), which form the basis for current European Union exposure limits.

Table 1. Typical field strengths from household appliances compared to ICNIRP recommended limits

Electric appliance	Electrical field strength in volts/metre at 30cm	ICNIRP recommended exposure limit in volts/metre
Stereo receiver	180	5 000
Electric iron	120	5 000
Toaster	80	5 000
Electric oven	8	5 000

Electrical appliance	Magnetic field strength in microtesla at 30cm	ICNIRP recommended exposure limit in microtesla
Electric oven	1 to 50	100
Microwave oven	4 to 8	100
Vacuum cleaner	2 to 20	100
Electric shaver	0.08 to 9	100

EMF: The benefits and concerns

Some of the non-ionising fields we encounter in daily life result from the deliberate use of EMF to achieve particular benefits. They are used extensively in medicine for diagnosis and treatment, for example in magnetic resonance scanners to study the brain and in irradiation for bone repair and cancer treatment. A major indirect source of non-ionising EMFs is the electricity supply grid that we depend on to light buildings and streets, to power our kitchens and televisions, and to run the lifts, trains, computers and industrial machinery that our society needs. Power stations send electricity through overhead and underground cables and substations to our cities, factories and homes – a vital network of flowing electric current that generates EMFs all around us.

The fastest growing source of exposure to EMFs is communications, in particular mobile telephony. Although television and radio antennae have been with us for a long time, more recently, the massive growth in mobile telephony is a major success story in which the European GSM standard leads the world. The mobile telephony sector has increased employment in the EU; it has improved personal security, in particular for the young; emergency services are faster; business is more efficient; and it helps fulfil our individual need to communicate when and where we want to, by speech, text message, email, and more recently with images.

A cause for concern?

Exposure to non-ionising electromagnetic fields is unavoidable in today's society and this exposure is growing mainly because of mobile telephones which are held close to the head, and also to the high density of mobile telephone antennae in our towns and cities. Therefore, the question as to whether or not they can damage our health is an important one. The effects of long-term exposure to low-intensity EMF are not at all well known – and it is exposure to this type of fields that is growing.

The difficulties in evaluating the effects of long-term low-level exposure to potential environmental hazards are not new; for example, the low concentrations of chemical and biological agricultural residues that get into the food chain have been active research areas for many years. A major problem in this research is that the effects can be cumulative; they build up in the body over time. This means that research into the hazards they pose is long-term and painstaking – and it is further complicated when the long-term research is overtaken by new technologies. Much of this research is into the 'genotoxicity' of ELF and RF-EMF from electricity power lines and mobile telephones respectively. A genotoxin is an agent that can damage DNA and possibly lead to cancer. So far, no convincing links between exposure to low-level EMFs and damage to health have been found.

Awareness of the possible risks of mobile telephones has raised public concern, which has been echoed by the European Parliament. In addition, the spread of antennae through our towns is raising objections, not just for aesthetic reasons but also because of fears about their potential harmful effects. While industry has done much to limit the exposure to EMF from telephones and antennae, public fears are delaying the deployment of next-generation mobile telephone systems.

Europe's response to concerns about EMF

Electricity and EMFs bring countless benefits to society. We cannot do without them, yet we do not know the consequences of long-term exposure to EMFs, if indeed there are any. Therefore, research is needed to understand the risks and set appropriate safety standards. Such research forms part of the European Framework Programmes for Research and Technology Development. Eight major projects were funded under the Fifth Framework Programme (FP5) between 1998 and 2002, and this funding is continuing in FP6 (2002-2006). The majority of these research projects focus on EMF from mobile telephones and are cancer-related, a smaller number investigate possible effects on hearing, memory and behaviour.

Research in this field is mainly of three types: *in vitro* research is based on laboratory experiments using biological materials, for example, cell cultures; *in vivo* research is performed on living organisms, such as rats or humans. These experimental approaches are complemented by epidemiological research that uses surveys and statistics to investigate the occurrence of disease and its relation to environmental factors, for example whether a particular cancer is more common in people living close to communications antennae. A further factor that adds to the time-consuming feature of these research projects is that research results must be replicated by others to confirm the reliability of the conclusions; a single result is not enough. In addition, the research must be published and reviewed so that other researchers can verify or criticise the results.

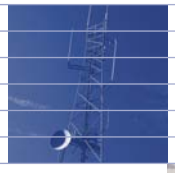
Some examples of these projects are:

The **Reflex** project studied how low-energy EMF interacts directly with biological materials in the laboratory *(in vitro)*. The researchers showed that exposing cells to ELF and RF electromagnetic fields could cause DNA to break apart and thus affect how cells develop. The key to this project lies in the standardised equipment that the partners, from all over Europe, used to do their experiments. This meant that several partners could independently confirm the experimental results. While these results do not prove that there are hazards from EMFs, they do indicate promising lines of investigation for further work.

The **Cemfec** project looked at how EMFs might interact with known cancer-causing chemicals that can be found in drinking water in minute amounts. The aim was to assess if the EMF frequencies typical of mobile telephones might have an indirect effect by increasing the genotoxicity of these environmental carcinogens. In this case, the study found that RF-EMF did not enhance the development of cancer.

The **Ramp2001** project studies the effect of RF-EMF from mobile telephone handsets on the nervous system, searching for any changes in memory and behaviour. By correlating experiments with theoretical modelling, the project tries to identify the mechanisms through which the nervous system could interact with EMF.

The **Guard** project investigated the effect on hearing of long-term exposure to RF-EMF, using both animal and human studies.



Support from industry

With strong public resistance to the siting of mobile antennae masts, the mobile telecommunications industry is naturally very concerned. The roll-out of new mobile technologies has been delayed and the wider take-up of beneficial new mobile services is slower than expected. The industry is well aware of the problems of risk communication and public perceptions and therefore contributes funds to research into the health effects of RF-EMF that is guided by the WHO international EMF project's research priorities. Industry funding contributions to national and EU research projects is provided in such a way as to ensure complete scientific independence. Worldwide, industry funding for EMF-health effects is comparable to public funding.

Interphone, a project led by the International Agency for Research on Cancer, is collecting extensive epidemiological data on mobile telephone use and the occurrence of cancers in the head and neck, for example brain tumours. Nine EU Member States are participating and parallel studies are running in Australia, Canada, Japan and New Zealand. Concentrating on age groups and regions with a long accumulated usage of mobile telephones, the researchers are using carefully controlled computer-assisted interviews to collect data.

The **Perform-A** project is using *in vivo* experiments to investigate whether EMF at mobile telephone frequencies, whether from handsets or antennae, can directly cause cancer in animals or promote the spread of pre-existing tumours. The Fraunhofer Institute for Applied Science in Germany is coordinating the six partners who are also performing important work to verify the results of Australian researchers who found increased cancer incidence in mice exposed to EMF.

A further group of projects focused on evaluating the potential hazards of EMFs used in the workplace, such as in medical diagnosis and from the pulsed electromagnetic fields produced by security systems employed in access control systems and supermarket checkouts.

Member States also fund their own national research programmes on EMFs and health. Many of these programmes are coordinated through the EU-funded COST281 framework that coordinates the national research programmes on the health implications of mobile telephony of the Member States and other countries. At present, 25 countries are cooperating within the COST281 framework.

This research effort is complemented by a large coordination action, **EMF-NET**, which brings together European and national EMF projects and researchers as a source of expertise and analysis for policy-makers and the general public. The aim of EMF-NET is not to produce new research, but the collection and interpretation of existing data from across the world. Given the difficult and long-term nature of this research, it is vital that the best use is made of existing information and expertise for the benefit of all. EMF-NET also supplies a 'fast-response team' to provide rapid advice to the European Commission on new research results and their relevance to public health and safety issues. EMF-NET also contributes to information activities for the general public. Research into potential health hazards from EMFs has been proposed by the Commission to continue in the Seventh Framework Programme for RTD that will run from 2007 to 2013.

Research with broad relevance

The co-operation and coordination of research groups from across Europe in investigating the potential hazards of EMF supports a number of EU policy areas, such as consumer and worker protection and industrial standards.

The European Commission's Directorate-General for Health and Consumer Affairs (DG SANCO) proposed EMF exposure limits for the general public in 1999 in a recommendation that was adopted by the Member States. This recommendation is based on the ICNIRP guidelines (see Table 1) that are supported by WHO , and include a 50 times safety factor for the general public. The recommendation is targeted at ELF and RF fields in particular and calls for the Member States to promote research into the possible carcinogenic hazards of EMF and for regular reviews of the exposure limits in the light of new research results. In addition, the recommendation calls for the Member States to keep the public informed on risks and the measures being taken to address them.

The Joint Research Centre of the European Commission supports DG SANCO's activities through management of the EIS-EMF project coordinating EU and national stakeholders in the provision of risk communication advice to public authorities.

Since EMFs arise from industrial equipment and consumer products, including notably mobile phones, EU product legislation ensures that, under normal usage conditions, products marketed in the EU meet the exposure limits of the Council Recommendation. Further, the Low Voltage Directive and the Radio Equipment and Telecommunication Terminal Equipment Directive apply to equipment that produces EMFs; and there are a series of European safety standards for the design and installation of base-station antennae. This legislation is managed by the Directorate-General for Enterprise and Industry.

Legislation for protection in the workplace is provided in a 2004 EU Directive prepared by the Directorate-General for Employment that sets limits to protect workers from the short-term effects of EMF exposure, and requires employers to regularly assess and record exposure levels as part of their risk assessment obligations.

In 1996, the World Health Organisation (WHO), recognising the rapid growth of public exposure to EMFs and increasing public anxiety and speculation, established the International EMF Project to assess the potential hazards to health from ELF and RF fields and to help initiate new research. WHO consolidates research results from the Member States, from EU-funded research projects and from other countries. As well as providing a database of EMF research for groups worldwide, the Organisation also reviews the data and will produce recommended EMF exposure limits in 2007.

Working for a safer environment

The issues arising from exposure to environmental electromagnetic fields are of intense public interest, in particular that of whether or not EMF from mobile telephones can damage health. The research needed to clarify these issues is under way and more will be needed in the future.

Research into the health effects of long-term, low-level exposure to environmental agents is difficult. The work itself can take a significant amount of time, which makes it costly. The effects being investigated are often difficult to detect in their early stages, and thus the results must be shown to be reproducible, preferably by other laboratories, again adding to the time and cost. It is for this reason that a coordinated and co-operative research effort is needed to avoid unnecessary duplication and to ensure that each research activity builds on earlier work. This is why research into the health effects of EMF benefits particularly from transnational co-operation.

Pooling energy and resources

In Europe, funding scientific research into the health effects of EMF exposure involves a broad spectrum of stakeholders. The European Union plays a key role as the long-term, costly nature of this research makes it vital to encourage co-operation and coordination between Member States' research teams to avoid repetition, share knowledge and match research competences. The ability to show the reproducibility of difficult experiments between laboratories, and the access to Europe-wide statistics, are real benefits that EU-funded co-operative research provides. The Member State governments play an important role in funding national initiatives and ensuring these efforts are complementary to other national research programmes. At international level, the EMF programme of the WHO ensures that research results are shared worldwide and used to guide a strategic research agenda that sets priorities and avoids unnecessary duplication. The mobile communications industry is also contributing to research funding, driven by the need to ensure safety and gain public acceptance for new technologies and infrastructures.

European funding for research on EMF-induced health effects has been proposed by the Commission to continue in the Seventh Framework Programme for RTD that will run from 2007 to 2013. This research will be guided by the knowledge gained in the earlier Framework Programmes, as well as by results from national and international research efforts. In Europe, the general public's exposure to environmental EMFs is currently defined by the EMF exposure limits advised by the International Commission on Non-Ionising Radiation Protection. The limits for mobile telephones are shown in table 2.

Table 2. ICNIRP exposure limits for EMF from mobile telephones

Frequency range	Whole body average SAR W/kg	Localised SAR (Head and Trunk) W/kg	Localised SAR (Limbs) W/kg
10 MHz to 10GHz	0.08	2	4

The Specific Absorption Rate (SAR) measures the amount of energy in watts that a body absorbs per kilogram in an electromagnetic field. For the general public these SAR safety limits have a 50 times safety factor for exposure to EMF from mobile telephones. GSM manufacturers provide public information on the SAR for each of the GSM models they produce

The European Commission is committed to reviewing these exposure limits regularly in the light of new research results taking into account the opinions of its Scientific Committees. These reviews will also rely heavily on the advice of the EU-funded scientific groups that are guiding and implementing much of the European research effort.

The Advice Pulsed Fields project:

Do electromagnetic fields generated by security devices have health effects?

While public concern about exposure to electromagnetic fields has centered on power lines and mobile telephones, other sources have not attracted the same attention. The Advice Pulsed Fields project looked at a family of sources that have been largely overlooked – security systems that operate by generating pulsed electromagnetic fields.

Go to the airport to catch a flight and you know you will be scanned at a security gate before you board. Leave a department store or a library, and the chances are you will be scanned before you cross the threshold. Travel on Taipei's public transport system, and you will be scanned, and if you have a valid travel card, it will let you onto buses and underground trains without even asking you to take your smart card out of your purse. Technical devices capable of searching you for things you should or should not be carrying are on the increase. They're frisking you for payment cards, stolen goods, weapons, equipment you have no right to remove from your employer's premises – and all without laying a finger on your person.

At the supermarket checkout – an electronic-article-surveillance (EAS) system

In the airport, the device responsible is a metal detector. At the shop or library exit, it is a device for electronic article surveillance (EAS). In Taipei's transport system, it is a device of a smarter kind presently experiencing rapid sales growth in the surveillance marketplace – a radio-frequency identification (RFID) system. They vary in their operating principles but these devices have one thing in common – pulsed electromagnetic fields (EMFs). They momentarily bathe you in an EMF in order to interact with, and thereby detect, the things they are searching you for – metal objects or magnetic strips or RFID tags. Operating frequencies span a spectrum from tens of hertz to several gigahertz. And so, like other EMF sources, there is the potential for adverse effects on human health.

The Advice Pulsed Fields consortium

The aim of the Advice Pulsed Fields project was to survey pulsed-EMF security-system technologies and produce advice for policy makers in the EU and its Member States. The consortium consisted mainly of a group of experts from the International Commission on Non-Ionising Radiation Protection (ICNIRP). They consulted widely with fellow experts, including several involved in the International EMF project coordinated by the World Health Organization (WHO), and in the US Food and Drug Administration (FDA).

The Advice Pulsed Fields research

The first phase of their work was a wide-ranging review of the technical characteristics of pulsed-EMF security systems and consideration of likely future developments. As part of the data-gathering process, the Finnish Institute of Occupational Health organised a workshop in Helsinki, where the project's participants were able to confer with delegates sent by manufacturing companies in the security sector.

In the second and final phase of the project, beginning at the Helsinki meeting, the team considered the known mechanisms by which electromagnetic fields and biological systems interact and the scientific literature on the effects of EMF exposure on cultured cells, animals, the central nervous system and humans, as well as on electrophysiological stimulation.

The team took special care to look into the potential for interactions between EMFs generated by security systems and medical devices. Although not common, damaging interactions of this kind have been

reported by patients and confirmed by scientists in laboratory studies. The devices giving most cause for concern are the implanted and portable ones used by ambulatory patients, including implanted defibrillators, heart pacemakers, neurostimulators and drug infusion pumps. Unlike hospital patients, whose environment is controlled, these patients are liable to come into contact with the same variety of pulsed EMFs generated by security systems as anyone else.

The Advice Pulsed Fields results

Since early in 2002, when the Advice Pulsed Fields team completed their final report[1], ICNIRP has adopted their findings and recommendations and published a summary as an ICNIRP statement[2]. In general, ICNIRP exposure guidelines were not exceeded. On the characteristics of security systems and devices, comprehensive information was not always available. Because of its importance in assessing public and occupational exposures, increased efforts at measuring exposure levels were recommended. Another recommendation was that technical information should be provided to purchasers. Information about potential exposure levels should also be routinely taken into account in the design of new systems. Exposure assessment was an area in which the team urged further research, notably to get a better picture of the properties of human tissues in electric fields.

A similar preoccupation with information provision pervades the team's recommendations relating to the potential for electromagnetic interference with medical devices. For one thing, more research is required to increase our understanding of the interactions between EMFs and medical devices. The team suggested setting up a European forum in which manufacturers of security systems and medical devices could harmonise their work. For another, they recommended that information about the EMFs generated by security devices be made public to enable informed choices to be made. The ultimate goal, they suggested, should be complete compatibility between security systems and medical devices.

1. ICNIRP. Possible health risk to the general public from the use of security and similar devices. Report of a Concerted Action within the project: 'Environment and health, health impact of electromagnetic fields' of the Fifth Framework Programme of the European Commission. An executive summary is available free of charge at http://www.icnirp.de/documents/ExSummary.pdf.
2. ICNIRP statement related to the use of security and similar devices utilising electromagnetic fields, *Health Physics*, Volume 87, Number 2, August 2004, available also at http://www.icnirp.de/documents/EASD.pdf

Project title:

Development of advice to the EC on the risk to health of the general public from the use of security and similar devices employing pulsed electromagnetic fields (Advice Pulsed Fields)

Project participants:

- Jürgen Bernhardt, International Commission on Non-Ionising Radiation Protection (ICNIRP), Germany (Coordinator)
- Ulf Bergqvist, University Linköping, Sweden
- Frank de Gruijl, University of Leiden, The Netherlands
- René de Seze, INERIS, France
- Maila Hietanen, Finnish Institute of Occupational Health, Finland
- Gianni Mariutti, National Institute of Health, Italy
- Ruediger Matthes, Federal Office for Radiation Protection, Germany
- Alastair McKinlay, National Radiological Protection Board, United Kingdom
- Colin Roy, World Health Organization, Switzerland
- Michael Repacholi, World Health Organization, Switzerland
- Gyorgy Thuroczy, National institute Radiobiology and Radiohygiene, Hungary

Project Reference: QLK4-CT-1999-01214

Duration: 01-02-2000 to 31-01-2002

The Cemfec project:

Can using a mobile telephone promote the action of chemical carcinogens?

While much research is aimed at uncovering whether electromagnetic fields transmitted from mobile telephones might cause cancers directly, there are more indirect mechanisms that could be at work. The Cemfec project members worked together to investigate the more indirect ways that using a GSM could promote the action of cancer-causing chemicals.

Mobile telephones transmit radio-frequency electromagnetic fields (EMFs) to communicate with the telephone network. Although these are low-power devices, the user's body absorbs some of the energy in these EMFs, in particular in the region of the head where the telephone is held. There are concerns that long-term exposure to these fields could pose health hazards and the risk of cancer is one of the main issues. Most cancer causing agents, called carcinogens, act by altering the genetic code carried by DNA in cells. Since mobile telephones transmit very weak EMFs, it is unlikely that they could directly cause damage to DNA. However, the general population is exposed to small amounts of known chemical carcinogens, so called environmental carcinogens whose presence in the environment, and particularly in the food chain, is monitored and strictly controlled at levels that are believed to be safe. The question arises whether the EMF from a mobile telephone could act indirectly, as a cocarcinogen; interacting with small, safe amounts of chemical carcinogens in human bodies in a way that promotes their toxicity and initiate cancer.

Exposure chambers for rats. The antenna for producing the electromagnetic field is at the centre of each chamber and individual cages for 24 rats are located radially around it

The Cemfec consortium

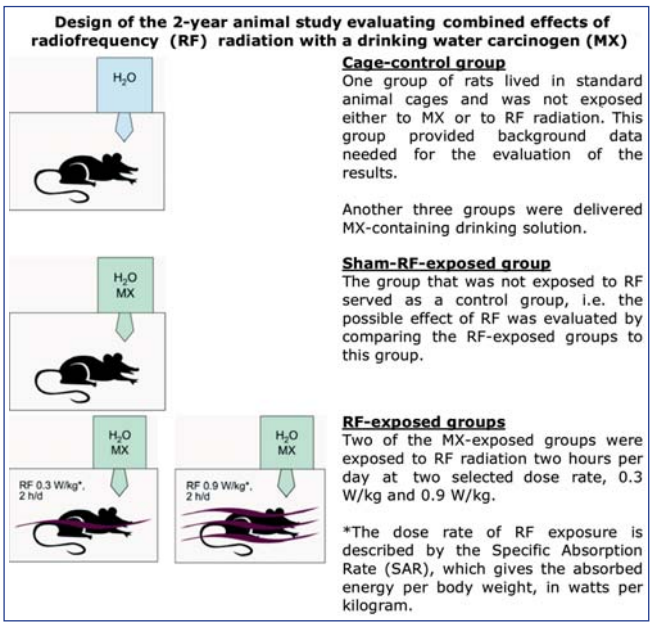
The Cemfec project brought together researchers from across Europe to investigate whether EMF transmissions from mobile telephones could act as a cocarcinogen. The four-year project was led by researchers from the University of Kuopio in Finland and included other partners from research organisations in Finland, Germany, Belgium and Italy, each of which is active in this research field and brought complementary knowledge and experience to the consortium.

The project partners designed and conducted experiments, both *in vivo* on animals[1] (rats) and *in vitro* using laboratory cell cultures. The cell culture experiments were done to see if exposure to EMF and chemical carcinogens could cause cancers directly at the cell level, rather than acting on the DNA the cells contain. The chemical carcinogen used in the experiments was 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone, also known as MX for short. MX is found in chlorinated drinking water all over the world and is an environmental carcinogen that is known to cause several types of cancer in rats when present in large enough concentrations. For the purposes of the Cemfec experiments the concentration of MX was kept low enough to avoid a direct carcinogenic effect as it was the interaction of MX with EMF to promote cancers indirectly that the researchers were seeking.

1. All experiments on rats were conducted in compliance with the OECD principles of good laboratory practice.

The Cemfec experiments

The experiments involved exposing the rats to MX in their drinking water and subjecting them for long periods to EMF, for two hours per day at the same radio-frequency (900MHz) and low power levels used in mobile telephone handsets. The *in vitro* cell cultures were also exposed to MX and RF-EMF. To ensure that other external factors did not play a role in the results, the partners used control groups of rats and cell cultures that were not exposed to MX and RF, or were exposed to just one of these. To conduct these long-term experiments in a controlled manner the consortium constructed special exposure chambers for the rats and cultures to ensure that the EMF and MX exposures were homogeneous and well characterised and that there was a low stress experimental environment for the animals.



Not all rats are exposed to the MX carcinogen and RF-EMF; others are used as 'control groups' to eliminate external factors that might influence the interpretation of the results.

The Cemfec results

Based on the observations of the Cemfec researchers, the experimental results showed that RF-EMF exposure typical of mobile telephones did not enhance the cancer-causing activity of the MX chemical carcinogen widely present in our drinking water. This same conclusion is drawn both from the animal, as well as the cell culture studies. The Cemfec result supports many of the other animal-based studies published so far, that show that exposure to the weak RF-EMF typical of mobile telephones does not have a carcinogenic effect.

Project title:

Combined effects of electromagnetic fields with environmental carcinogens (Cemfec)

Project partners:

- University of Kuopio, Department of Environmental Sciences, Finland (Coordinator)
- STUK – Radiation and Nuclear Safety Authority, Finland
- Fraunhofer Institute for Toxicology and Experimental Medicine, Germany
- The Flemish Institute for Technological Research (VITO), Belgium
- University of Genoa, 'Interuniversity centre for interaction between electromagnetic fields and biosystems, Italy

Project Reference: QLK4-CT-1999-01129

Duration: 01-02-2000 to 31-03-2004

The Guard project:

Can digital mobile phones affect hearing?

Most users of mobile phones hold them close to their ear during calls, so these organs could be particularly vulnerable to any biological effects that might be caused by the electromagnetic fields radiated by phones. The Guard project has pioneered investigations into the potential effects of digital mobile phones on hearing through experiments conducted first on live laboratory mammals and subsequently on humans. The results will prove useful in answering public concerns about cellular phones and health.

Mobile phones are an integral part of our busy lives in the 21st century, allowing us to keep in touch with family and friends and to be ever ready to make that critical emergency call that may save lives. They have even been credited with transforming the face of global news broadcasting by enabling ordinary people to contribute photographs and accounts of breaking stories, as the Indian Ocean tsunami and the London bombings of 2005 vividly demonstrated. However, hand in hand with the public enthusiasm for new-generation mobile phones comes public concern about the biological effects that may be caused by the radio-frequency electromagnetic fields (RF-EMFs) they generate.

Research funding bodies have responded by sponsoring scientific research into the possible health effects of mobile phone use. Yet one area that has been little studied until recently is the impact of RF-EMFs on hearing. It may seem an obvious point of concern given the proximity of hand-held devices to the ears, but research to date has focused to a large extent on brain cancers for obvious reasons. Proximity to the ear is not the only cause for concern, either. For example, scientists have long known that the hairs of the cochlea – a coiled tube in the inner ear with an important role in the transmission of mechanical vibrations to the auditory nerve – are sensitive to many external signals. There is also the potential for RF-EMFs to reach the central nervous system through the ear.

Positioning the exposure system during experiments

The Guard consortium

Knowing the time was ripe for research into this neglected question, nine research-performing organisations joined together in the Guard consortium. Through carefully designed, sensitive experiments, their specific aim was to detect any changes in hearing associated with low-intensity use of GSM mobile phones. The partners were especially interested in studying the effects on nerve cells involved in the hearing process and did so through studies of the auditory efferent feedback system, which is involved in the transmission of nerve impulses back from the brain to the ear.

Encompassing public health issues intertwined with modern communications technologies, the project was an unavoidably interdisciplinary enterprise calling on the expertise of specialists in disciplines including biology, biomedicine, engineering and physics. The partners – research institutes, universities and hospitals – came from seven European countries. Their coordinator was the Istituto di Ingegneria Biomedica ISIB of the Consiglio Nazionale delle Ricerche in Italy.

The Guard experiments

In the first part of the project, researchers exposed rats to RF-EMFs at two GSM frequencies, 900 and 1800 MHz, for two hours per day over a period of four weeks using loop antennas. They tested the animals' hearing before, during and after the exposure experiments via objective auditory tests. A standard technique in the study of hearing, these tests involve the measurement of otoacoustic emissions – low-intensity sounds generated by the inner ear in response to an auditory stimulus. The teams also investigated whether RF-EMFs at mobile-phone frequencies interfere with the uptake of chemicals that could have a toxic effect in

the ear, in this case the antibiotic gentamicin. Again, the animals, this time guinea pigs, were subsequently tested for otoacoustic emissions. The researchers also tested the responses of their auditory brainstem – nerve pathways in the brain that play a role in hearing.

Experiments with human volunteers followed, with the team concentrating on effects on the hearing system of normal hearing subjects and in the auditory efferent system. Just before and immediately after the subjects made ten-minute mobile-phone calls, researchers carried out behavioural hearing tests, which require a verbal response from the individual and measurements of otoacoustic emissions. The Nokia Research Center in Helsinki helped in the design of equipment for these experiments. The phone used for the ten-minute calls was a commercially available Nokia model connected to a positioning system allowing it to be held in comfortable proximity to the ear for the duration of the call. The researchers meanwhile were able to set exposure parameters from a PC connected to the phone. The researchers also investigated the effects of more repeated usage with comparative hearing tests carried out on two groups of mobile-phone users – a low-use group, whose members used mobile phones for less than five minutes per day, and a high-use group, whose members were on the phone for more than 30 minutes per day.

Exposure positioning system on dummy human head

The Guard results

The consortium released information about the experiments and their findings to the public, policy-makers and the scientific community on the project website[1]; as well as in newsletters, at national and international seminars and in workshops. After testing a total of 490 animals and 550 humans, the teams reported that they had detected no adverse effects on the hearing of the animals or humans. They drew attention, however, to a need for further investigation of potential effects of GSM mobile phones on the auditory efferent system and for future research on the effects on hearing of RF-EMFs generated by third-generation mobile-phone systems, which have not yet been studied.

1. See http://www.guard.polimi.it

Project title:

Potential adverse effects of GSM cellular phones on hearing (GUARD)

Project partners:

- Istituto di Ingegneria Biomedica ISIB, Consiglio Nazionale delle Ricerche, Italy (Coordinator)
- ENEA – Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Italy
- Institut National de la Sante et de la Recherche Medicale, France
- Laboratoire neurosciences et systèmes sensoriels, Université Claude Bernard Lyon, Centre National de la Recherche Scientifique, France
- University of Southampton, Institute of Sound and Vibration Research, United Kingdom
- District General Hospital of Thessaloniki – AHEPA, Department of Otolaryngology Head and Neck Surgery, Greece
- Kaunas University of Medicine, Institute of Biomedical Research, Laboratory of Neurologic Surgery, Lithuania
- National Center of Public Health 'Frederic Joliot-Curie' National Research Institute for Radiobiology and Radiohygiene, Department of Non-Ionizing Radiation, Hungary
- National Research Center for Audiology and Hearing Rehabilitation, Department of Experimental and Clinical Audiology, Russia

Project Reference: QLK4-CT-2001-00150

Duration: 01-01-2002 to 31-12-2004

The Interphone project:

Does exposure to radio-frequency electromagnetic fields from mobile phones increase the risk of cancer?

Epidemiologists study the occurrence of health effects in human populations. Without large samples, sound methods and accurate exposure estimates, their results can be ambiguous – a common problem for research on the possible link between mobile phones and cancer because frequent users of long standing are not yet numerous. As one of the largest epidemiological studies in this field so far, Interphone is expected to break new ground.

Estimates from market-research companies in 2005 place the number of mobile-phone users worldwide at 1.8 billion, equal to the entire world population in 1920. To extend our limited knowledge of the possible link between cancer and exposure to radio-frequency (RF) electromagnetic fields (EMFs) in this massive user population, the multinational Interphone study was launched in 2000. The results are eagerly anticipated because of the number of long-term users in Interphone's study population. Observers are hoping it will bring a decisive clarity denied to previous epidemiological research on this question.

The Interphone consortium

Coordinated by the World Health Organisation's International Agency for Research on Cancer (IARC), Interphone is a suite of three conjoint multinational studies, each concerned with a different class of tumour. Research teams gathered the data, working in parallel in 13 countries using the same common methods and research instruments. Validated centrally by IARC, the data were then entered into a master database at IARC's headquarters in Lyon, France, where analysis is now proceeding.

The EU funded the international coordination effort and the work of the national research teams in nine countries – Denmark, Finland, France, Germany, Italy, Norway, Sweden, the UK and Israel. Additional funds were donated by national and local bodies in participating countries, and by two trade associations – the Mobile Manufacturers' Forum and the GSM Association. Their contributions, channelled through the International Union against Cancer (UICC) as intermediary, was given and accepted on terms that insulated the research from conflicts of interest. Non-EU partners – Australia, Canada, Japan and New Zealand – funded their own studies.

The Interphone investigations

All of the studies were case-control studies and as such had two essential features[1]. The first is a study population – for Interphone this covered all subjects aged 30–50 resident during the study period in one of the regions selected, where mobile-phone use was greatest and longest established. The 'cases' were patients in the study population who had recently had a confirmed diagnosis of one of the three classes of cancer that Interphone is investigating. These are tumours arising in those tissues that absorb the highest proportion of the RF energy from hand-held mobile phones – the parotid gland, a salivary gland situated just in front of the ear; glial and meningeal brain tissues; and the vestibular part of the eighth cranial nerve near the ear, where tumours called acoustic neuromas can occur. For comparison, the researchers also enrolled for each case one or more non-sufferers randomly drawn from the study population and matching the case in age group, gender and residential area. These were the 'controls'.

The second essential feature is to determine how much each case and control has been exposed to EMFs from mobile phones. Interphone's approach was to calculate this from information gleaned in computer-aided interviews with the users themselves conducted by trained interviewers. They took account of the user's history of mobile-phone use, any occupational exposure to EMF and other forms of radiation (such as medical X-rays), and medical history. The formula used received validation in ancillary research using software-modified phones to collect data on the distribution of emitted power in different countries, regions and depending on pattern of use.

1. Links to web pages giving further details about Interphone is available under the heading 'Residential and occupational exposures to non-ionizing radiation' at http://www.iarc.fr/ENG/Units/RCA4.php

The Interphone results

EU funding of the project ended in April 2005 and analyses of the international dataset are in progress. Meanwhile, Interphone researchers have published analyses of two national data subsets and a combined analysis of data on acoustic neuromas in the five northern European countries. Of the Danish analyses on brain tumours and acoustic neuromas, neither found increased tumour incidence due to mobile-phone use[2]. The number of cases who were long-term users was, however, very small. On the other hand, acoustic neuromas among regular users were significantly larger on average than among non-users.

The Swedish neuroma analysis did find an increased incidence linked to phone use – a 90% increase in subjects who started phone use ten or more years before enrolment in the study, rising to 290% (based on 12 cases) when restricting analysis to tumours on the same side of the head as the user's normal phone use (where expected exposure is highest)[3]. By contrast, the Swedish brain-tumour results showed no increase in risk[4].

The Nordic combined analyses[5] also found no increased risk of neuromas globally among regular mobile-phone users although the possibility of an increased risk among long-term users could not be ruled out.

To date, few studies have included enough cases among long-term users to conclude confidently whether or not there is a link between mobile-phone use and brain cancer or acoustic neuroma. The Nordic analysis is the largest study to date. Only through further studies can firm conclusions emerge. With single-country studies generally limited in their statistical power, Interphone's ongoing analyses of its enormous multinational dataset could be decisive. IARC now estimates that it includes approximately 1 100 acoustic-neuroma cases, 2 600 glioma, 2 300 meningioma and their matched controls – enough to detect confidently a 50% risk increase linked to mobile-phone use beginning five years or more before enrolment. So the eager anticipation of Interphone's results is not over yet.

2. Further details about these results are available at http://www.iarc.fr/ENG/Units/RCAg.html and http://www.iarc.fr/ENG/Units/RCAd1.html respectively
3. Further details about these results are available at http://www.iarc.fr/ENG/Units/InterphoneSwedish.html
4. Further details about these results are available at http://www.iarc.fr/ENG/Units/RCAh.html
5. Further information about these results can be found at http://www.iarc.fr/ENG/Units/RCAi.html

Project title:

International case-control studies of cancer risk in relation to mobile telephone use (Interphone)

Project partners:

- International Agency for Research on Cancer, France
- Danish Cancer Society, Institute of Cancer Epidemiology, Denmark
- Radiation and Nuclear Safety Authority (STUK), Finland
- Université Claude Bernard Lyon I, France
- Johannes Gutenberg-Universität Mainz, Institut für Medizinische Statistik und Dokumentation, Germany
- The Gertner Institute for Epidemiology & Health Policy, Chaim Sheba Medical Centre, Israel
- Istituto Superiore di Sanità, Italy
- Norwegian Radiation Protection Authority, Norway
- Karolinska Institutet, Sweden
- Institute of Cancer Research, Section of Epidemiology, United Kingdom
- University of Leeds, Paediatric Epidemiology Group, United Kingdom

Project Reference: QLK4-CT-1999-01563

Duration: 01-02-2000 to 30-04-2005

The Perform-A project:

What can systematic animal studies tell us about the possible link between mobile-phone radiation and cancer?

Since an early Australian animal study linked a significant increase in the risk of contracting cancer to the electromagnetic fields generated by mobile phones, no subsequent study has confirmed it. The Perform-A consortium attempted to replicate the Australian study and carried out a further set of animal studies to understand the possible link in more detail.

In 1997, Australian researchers led by Michael Repacholi published the results of a study that has become a landmark for research on the health effects of electromagnetic fields (EMFs)[1]. For one hour per day over an 18-month period, Repacholi and his team exposed a strain of transgenic[2] mice known as pim1 to electromagnetic fields of the kind generated by GSM mobile phones. What they found was not reassuring. The exposure regime multiplied the risk of lymphoma to 2.4 times the normal level. Lymphomas are cancers affecting the lymph nodes. Hodgkin's disease is one example.

Scientific interest in researching the possible link between long-term EMF exposure and cancer in animals soared and more than two dozen such studies have already been carried out since 1997. Among those that have published their results so far – and that is the majority – none has found a significant correlation between EMFs and cancer.

It is too early however to conclude that no such link exists. This is a new field of research that has not yet had time to develop a strong collective identity. Faced with common difficulties, different research groups have improvised their own individual solutions. Experimental design, methodology, laboratory apparatus, laboratory practice – some or all of these factors have varied from one study to the next.

The Perform-A consortium

In response to this dynamic state of affairs, the Perform-A project, led by the Fraunhofer Institute from Germany, combines two ambitious aims. It shares its scientific aim with many of its predecessors –to clarify whether radio-frequency EMFs cause or help cause cancer in animals like rats and mice. The other aim is more pragmatic but no less important – to set a new standard for research studies of this kind and make a start at embedding consistent, good practice across the field.

Although not a legal requirement, the consortium's life-science laboratories carried out the Perform-A experiments according to Good Laboratory Practice (GLP). This is a detailed set of principles established by the Organisation for Economic Co-operation and Development (OECD) for laboratory safety studies on pharmaceuticals, chemicals and biological substances. Companies in OECD member states who want to market any of these products are required by law to comply with GLP in the conduct of their safety studies. The principles are meant to guarantee that the data they have to submit to the regulatory authorities are a reliable basis for safety assessments.

Financial support for the Perform-A project came from a handful of sponsors. The European Commission controlled all project financing and contributed just over 25% of the project cost. Some of the remainder came from two mobile-phone industry bodies, the GSM Association and the Mobile Manufacturers Forum. The Swiss and Austrian governments also donated funds. In an agreement made before the experiments began, all sponsors accepted that their funding of the research did not entitle them to privileged access to the results. Not until all manuscripts disclosing the results were accepted by scientific journals would the sponsors see them.

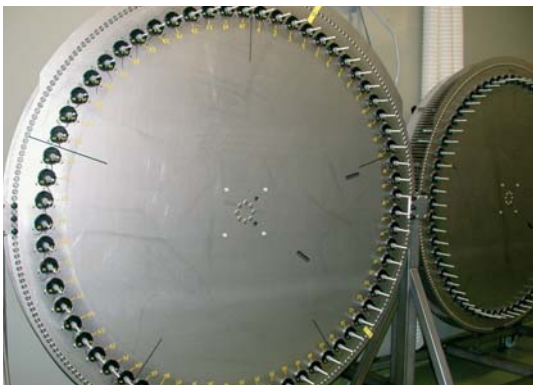
1. Repacholi et al, Radiation Research 147(5), pp631-640, 1997

2. Transgenic mice have externally introduced genes and are used to test the effects of genes on health

The Perform-A experiments

There were four sets of experiments, each delegated to its own specialist life-science laboratory, one each in Germany, Switzerland, Austria and Italy. Another partner, the Swiss IT'IS foundation, designed an exposure system for all four experimental sites that is capable of delivering a homogeneous whole-body dose of radio-frequency electromagnetic radiation to all exposed animals. The company also constructed, installed and operated identical copies of the apparatus at each laboratory.

Animal room at Fraunhofer ITEM with the exposure system for mice



Each wheel exposes up to 65 mice, radially arranged around the antenna

In the Italian laboratory, researchers attempted to replicate the experiment by Repacholi and his team on pim1 mice, but under more carefully controlled conditions so as to increase the statistical power of the results. The Austrian group looked at the effect of EMF exposure on female rats in which breast cancers had already been induced by a known carcinogen. They were subjected to a daily four-hour exposure for six months. The aim was to advance understanding of how EMF exposure might influence the incidence, growth, latency and the malignancy or non-malignancy of the tumours.

The research groups at the German and Swiss laboratories investigated the occurrence and growth of cancers in mice and rats respectively. At both sites, the animals underwent exposure to EMFs at GSM frequencies for two hours per day and five days per week over the course of two years. The German and Swiss researchers chose different strains of mice and rats to complement the Italian study.

The Perform-A results

The results will remain confidential until the conclusion of the project at the end of September 2005, by virtue of the confidentiality agreement between the Perform-A consortium and its sponsors. The date is a timely one. The World Health Organisation's International Agency for Research on Cancer has plans to begin an evaluation of research on the link between mobile-phone EMFs and cancer in October.

Project title:

***In vivo* research on possible health effects of mobile telephones and base stations (carcinogenicity studies in rodents) (Perform-A)**

Project partners:

- Fraunhofer-Gesellschaft zur Föderung der angewandten Forschung e V., Germany (Coordinator)
- Swiss Federal Institute of Technology, Laboratory for EMF and Microwave, Switzerland
- Österreichisches Forschungszentrum Seibersdorf GmbH, Department of Life Sciences, Austria
- RCC Ltd, Switzerland
- Aristotle University of Thessaloniki, Radiocommunications Laboratory, Department of Physics, Greece
- Istituto di Ricerche Biomediche "A. Marxer" – RBM S.p.a, Italy

Project Reference: QLK4-CT-1999-01476

Duration: 01-03-2000 to 30-09-2005

The Ramp2001 project:

Can long-term use of mobile phones cause adverse non-thermal effects in brain or nerve cells?

There is no scientific consensus on the biological effects of prolonged exposure to radio-frequency electromagnetic fields (RF-EMFs). One question that remains unanswered is whether exposure to RF-EMFs within current safety limits can nevertheless cause cellular or molecular changes in the brain or nervous system that are not due to heating of the tissues. The Ramp2001 team is seeking answers to this question.

Mobile-phone calls are carried by radio waves. While a call is in progress, they transport signals in both directions between the handset and the nearest base station in the operator's network. They also have a side effect, though. The user's body inevitably absorbs some of the waves, where they cause heating in the body tissue. It is not a large effect. Manufacturers design phones to operate with a low radio-frequency output power to maximise battery life. However, a user typically holds the phone right up against his or her head during calls. Since the EMF is most intense near the handset antenna, the power absorbed by the head could be non-trivial were it not for safety regulations. Too large a rise in the temperature of brain tissue would be harmful if sustained for long enough.

Advisory and regulatory bodies, both national and international, have set safety standards. They express them in terms of the specific absorption rate (SAR) index. That is the rate at which one kilogram of body mass absorbs radio-frequency energy. Fixed at one tenth of the SAR value that causes a 1°C temperature rise in the body, the safety limits are binding on all mobile-phone manufacturers.

Virtually all mobile phones have remained well within the prevailing safety limits, even after reductions in the limits were introduced, as has happened on occasion. But a growing number of research studies are beginning to undermine faith in them. The research suggests that low-frequency RF fields may have biological effects unrelated to heating. Although many in the scientific community and industry dispute the relevance of the research, some groups argue that non-thermal effects warrant further investigation.

Moreover, the long latency period of many illnesses that could be linked to RF exposure means that experts cannot be certain that long-term use of mobile phones does not harm the development and functioning of the nervous system.

Picture from INERIS

Microphotograph of an astrocyte: astrocytes (cells of the nervous system) from rat brains are used to test for effects of RF-EMF

Picture from INERIS

A Rota-rod, used for testing the differences in rat behaviour with or without exposure to RF irradiation

Picture from ICEmB

An electromagnetic cell used for exposure of nervous cells to RF-EMF. Nervous system cells are cultivated in dishes positioned at the bottom of the structure

The Ramp2001 consortium

The Ramp2001 project is a contribution to the concerted effort that is needed to answer today's uncertainties about non-thermal effects. The partners also foresee the project's results feeding into future revisions of safety standards. Through experiments on animals and artificial cell cultures, they are studying the biological effects of short- and long-term RF-EMF exposure of brain and nerve cells (neurons), especially any non-thermal effects.

The team combines diverse scientific and technical expertise, uniting expertise in biophysics, cell biology, computer modelling, neurophysiology and pharmacology. The researchers are drawn from Italy, France, Sweden and the United Kingdom and are coordinated by the Italian Interuniversity Centre ICEmB, a consortium composed of various research groups, administratively sited at the University of Genoa.

The Ramp2001 experiments

To ensure comparability of results, all RF exposure experiments were carried out with the same frequency and modulation parameters – those used in second- and third-generation mobile telephony systems – and at four reference SAR values: one above, one close to, and two below current safety standards.

One team experimented on live rats, first exposing them to RF-EMF for varying durations and then performing behavioural and memory tests on them. The rats' brains were subsequently removed for a range of biochemical tests and for imaging by electron microscopy. For the latter, they chose a novel imaging technique which measures brain energy consumption, to identify regions in the brain most sensitive to the GSM frequencies. Mapping the brain like this also helped the team select appropriate activities for the behavioural tests that would serve in further experiments to recognise abnormal brain function resulting from RF-EMF exposure.

Other Ramp2001 partners developed an innovative exposure set-up for exposure tests on slices of brain tissue removed from unexposed rats. The results served as a yardstick against which the consortium later compared results from the memory and behaviour tests on live rats to give a fuller picture of electrophysiological changes in the brain. The regions of the brain of most interest were those normally closest in humans to hand-held mobile phones.

One aim the Ramp2001 project pursued keenly was an exploration of the effects RF-EMF exposure might have on cell proliferation and cell differentiation – the process by which immature, unspecialised cells give rise to cells with specialised characteristics. For this, the teams worked with cultured neuronal cells, including tumour cells derived from embryonic nerve cells. To complement these studies, two teams developed theoretical models and computer simulations to improve understanding of how RF-EMF interacts with nerve cells at a cellular level. They paid close attention to early stages of these interactions, where the EMF signal interacts with the cell membrane.

The Ramp2001 results

Originally a three-year initiative scheduled to end in December 2004, the project's life was extended to the end of September 2005. Results are not yet complete but preliminary findings do not show any particular effect of RF-EMF exposure on the biological systems examined.

Project title:

Risk assessment for exposure of nervous system cells to mobile telephone EMF: from* in vitro *to* in vivo *studies (Acronym: Ramp2001)

Project partners:

- University of Genoa – Interuniversity Centre ICEmB, Italy (Project coordinator)
- Institut National de l'Environment Industriel et des Risques, Verneuil en Halatte, France
- Chalmers University of Technology, Department of Electromagnetics, Gothenburg, Sweden
- University of Bradford, School of Informatics, United Kingdom

Project Reference: QLK4-CT-2001-00463

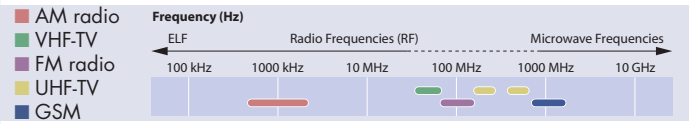
Duration: 01-01-2002 to 30-09-2005

The Reflex project:

Do extremely low-frequency and radio-frequency electromagnetic fields cause biological changes in cells?

The question of whether extremely low frequency electromagnetic fields influence human health has stubbornly resisted resolution for some time now, and the same can be said of radio-frequency electromagnetic fields. The Reflex consortium sought to clarify the issue through an in vitro study at the level of individual cells. This involved exposing a wide range of human and animal cell lines to electromagnetic fields at intensities within current safety limits and analysing the outcomes.

The range of frequencies classified as extremely low frequency (ELF) is not large, stretching from zero only as far as 300 Hz. Their significance, though, is hard to minimise. Electricity supply grids over the entire world operate within this range and give rise to ELF electromagnetic fields (ELF-EMFs). So, sources of ELF-EMFs are widespread inside and outside the home and workplace – power lines, electrical wiring and all manner of electrical appliances. EMFs classified as radio frequency (RF-EMF) cover a much broader range, extending from low to extremely high frequencies, 30 kHz to 300 GHz. They too are all around us, for instance in the transmission signals for radio and television broadcasts, mobile telecommunications networks, as well as in wireless networking of computers and other digital devices.



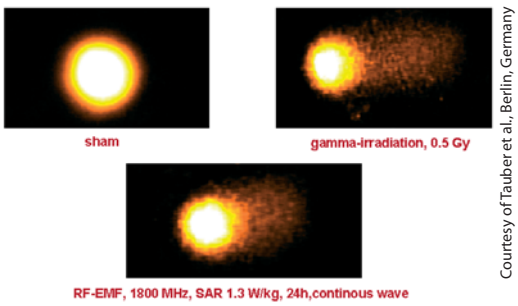
Many experimental and epidemiological studies have investigated the biological effects of these fields on humans. A large number have found no detrimental influence, but controversy still clings to the issue. On the one hand, some experiments have pointed to the potential for ELF-EMFs to alter genes. On the other hand, it remains unclear whether this in turn can cause diseases such as cancers and neurological illnesses. Also in question are the biological mechanisms by which EMFs may trigger pathological conditions at the cellular level. Possibilities include: uncontrolled increase in cell numbers; the suppression of, or increase in, cell death; and changes in the mechanisms and structures involved in the coding of genetic information.

The Reflex consortium

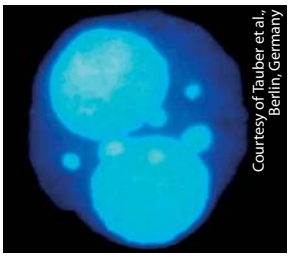
It is this latter problem that the Reflex team addressed. Through rigorously controlled and replicated experiments the partners looked for detrimental cellular changes in EMF-exposed cells that in the long term may create conditions suitable for the development of diseases such as cancer. Coordinated by VERUM – The Foundation for Behaviour and Environment in Germany, the team assembled to carry out the 52-month research project consisted of 12 research groups drawn from seven European countries. Replication of the experiments and their results formed a vital part of the project as much earlier research is doubted because the results had not been independently replicated and verified.

The Reflex experiments

To enable experiments to be accurately replicated and to ensure comparability of their results, it was vital for the experimental set-ups at different sites to be as similar as possible and their operation strictly controlled. The team supplemented pre-existing exposure systems with a novel apparatus, custom built for the Reflex project, for generating ELF-EMFs and RF-EMFs. They installed four copies of each unit in multiple laboratories. Each copy comprised an incubator with two chambers for the cells. A computer decided randomly which one was to be irradiated by EMFs and which one was not.



DNA strand breaks in HL-60 cells after exposure to γ-irradiation and to high-frequency electromagnetic fields. The longer and brighter the tail, the higher the DNA-strand break frequency.



A dividing HL-60 cell with several micronulei detected with the micronucleus test under the microscope. The occurrence of one or more micronuclei is evidence of a genotoxic effect sustained by the cell

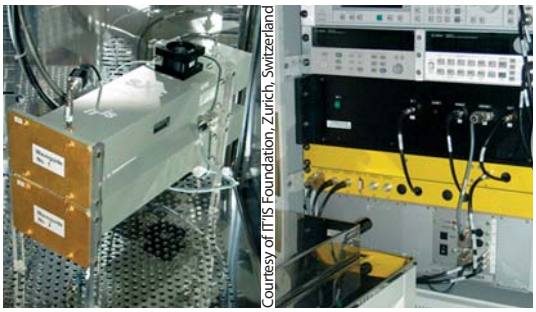
In the ELF-EMF exposure systems, selected human cell lines were irradiated. Among these were lymphocytes, the white blood cells that help the body fight infection; fibroblasts, the cells that make the connective tissue that forms the supporting framework of organs in the body; muscle cells; and animal cell lines like granulosa cells from rats. Similar experiments were performed in the RF-EMF exposure systems on cell lines that included HL-60, a human cell line used as a model of early bone-marrow precursor cells; granulosa cells from rats; human lymphocytes; fibroblasts and brain cells.

After exposure, the Reflex researchers analysed the cells for cellular changes indicative of genotoxicity – for example, aberrations in chromosomes or the presence of DNA damage, or of micronuclei, fragments of chromosomes left outside the nucleus during cell division. They also monitored changes in expression of genes and proteins in the exposed cells – expression is the process where the genetic information encoded in a gene is converted into the structure and function of a cell.

The Reflex results

A mixed but intriguing pattern emerged from their analyses. Intermittent exposure to ELF-EMF at 50Hz, a common electrical mains frequency, had genotoxic effects on human fibroblasts, human melanocytes and some animal cells. Lymphocytes and other cell lines, meanwhile, remained unaffected. In fibroblasts, they discovered a direct correspondence between the intensity and duration of ELF-EMF exposure and the number of DNA breakages or micronuclei, both markers of genotoxicity. Obtained by two of the Reflex laboratories, these results were validated by two laboratories outside the project.

Two chambers within an incubator in which one set of cells are exposed to extremely low-frequency electromagnetic fields and the other set, the control group, is not



Two high-frequency-EMF exposure chambers within an incubator

In cells exposed to RF-EMF the researchers also identified genotoxic effects – marked by, among other things, DNA breakages, chromosomal aberrations and the formation of micronuclei – in human fibroblasts, HL-60 cells and granulosa cells in rats, but not in lymphocytes. Once more, the degree of damage depended on the duration of exposure and on the type of signal used.

The Reflex team also obtained evidence that in some cell cultures both ELF-EMFs and RF-EMFs may affect the expression of genes and proteins involved in such activities as cell division, proliferation and differentiation.

These findings are a valuable addition to our understanding of the effects ELF-EMFs and RF-EMFs can cause in human and animal cells cultured in the laboratory. However, before any conclusions can be drawn regarding the risks to human health, the results will have to be complemented by whole-animal studies.

Project title:

Risk evaluation of potential environmental hazards from low energy electromagnetic field exposure using sensitive *in vitro* methods (Reflex)

Project partners:

- VERUM – Foundation for Behaviour and Environment, Germany (Coordinator)
- Free University of Berlin, Clinical Chemistry, Germany
- University of Vienna, Occupational Health, Austria
- Institute for Plant Genetics, Germany
- Ramon y Cajal Hospital, INSALUD, Spain
- STUK – Radiation and Nuclear Safety Authority, Finland
- University of Hannover, Institute of Biophysics, Germany
- University of Bologna, Department of Physics, Italy
- Ecole National Supérieure de Chimie et de Physique, PIOM, France
- Swiss Federal Institute of Technology, Switzerland
- University of Milan, Department of Medical Pharmacology, Italy
- Resource Centre/Primary Database (RZPD), Germany

Project Reference: QLK4-CT-1999-01574

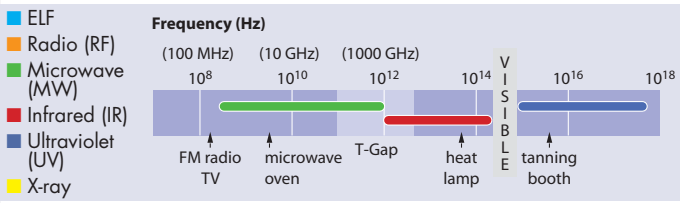
Duration: 01-02-2000 to 31-05-2004

The THz-Bridge project:

Is terahertz radiation safe for biomedical and biological applications?

Medical applications of terahertz radiation are currently the focus of a good deal of research. Anticipating an imminent growth in its use in laboratories and hospitals, the THz-Bridge team came together to address questions of safety that must be answered before standards can be established for THz radiation exposure.

Terahertz radiation spans the electromagnetic spectrum's so-called T-gap. As the figure below shows, the T-gap stretches from about 100 gigahertz to 20 terahertz; it is a region that has attracted far less attention than its neighbours – higher-frequency infrared and the lower-frequency microwaves. But this is now changing.

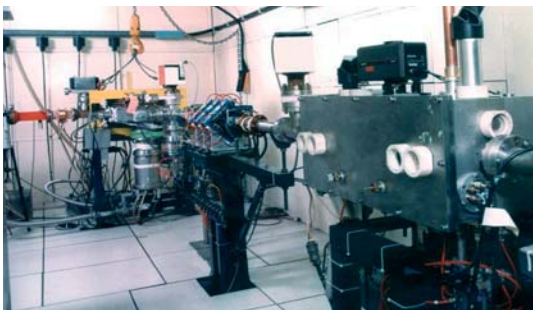


Improvements in semiconductor and laser technology have contributed to recent advances in the production of more powerful sources and detectors of THz radiation. This has opened up this once sedate expanse of the spectrum for exploration by a wider community of academic and industrial scientists and engineers. Already, researchers are developing applications in fields as diverse as astronomy, environmental science, quality assurance, medical imaging and safety. One team of researchers, recognising that current knowledge about the biological effects of THz radiation is limited, took the proactive step of launching the THz-Bridge project to assess the potential impacts of this technology on the health of users and patients.

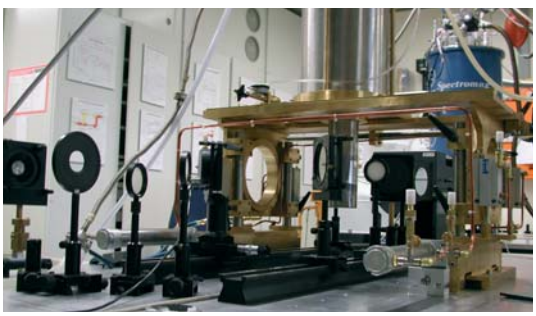
The THz-Bridge consortium

The ENEA Frascati research centre in Italy headed the THz-Bridge team and international co-operation was vital as THz radiation sources spanning the entire T-gap are not available in any single country. Partners included research centres and universities in Germany, Greece, the UK, Italy and Israel and a British company specialising in applications of terahertz radiation. Together they combined expertise and skills from a range of complementary disciplines including spectroscopy and biomedical imaging – all of them required for the team's diverse programme of biological experiments with a variety of THz-radiation sources.

The THz-Bridge experiments



The ENEA THz source based on a compact Free Electron Laser

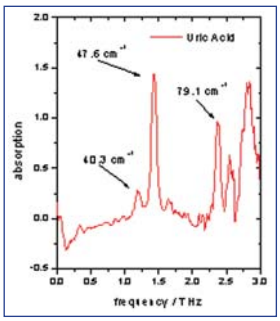


The THz spectrometer at the University of Stuttgart

In a major part of their work, the partners studied the interaction of THz radiation with biological samples of increasing complexity to assess their susceptibility to damage by the radiation. Irradiated samples were monitored for changes in morphology and biological function relevant to the biological system under study. These included: changes in the properties of cell membranes to certain molecules, alterations in the activity of cells found in the outer layer of skin, and assessment of photochemical damage to the building blocks of DNA molecules that encode genetic

information in cells. In white blood cells exposed to THz radiation, the team looked for signs of genotoxicity due to disturbances or damage to molecules or cellular structures involved in genetic inheritance.

Establishing a database of biological spectra was another important objective. These are graphical plots that convey information about the absorption and emission of radiation by irradiated samples over a specified range of wavelengths. For this, the team carried out spectroscopic analysis of biological samples over infrared and THz wavelengths to identify regions of the spectrum that could be used for THz imaging applications. A typical spectrum is shown in the figure left.



The THz spectrum of uric acid. The differences in absorption can form the basis for biomedical imaging applications.

The third strand of the team's work was the preparation of a questionnaire that was distributed at conferences and through the project website to groups around the globe that are using, or are planning to use THz sources. The primary objective was to collate information on the use of THz radiation from a safety point of view. What, it asked, are the safety precautions adopted? What are the exposure conditions of personnel? What is the perceived risk felt by users of THz sources? And what are the physical parameters of the sources used – such frequency and power levels?

The THz-Bridge results

In the irradiation studies, the team detected no biological effects under many exposure conditions. However, in some cases they discovered a change in the ability of certain chemical compounds to flow through artificially created membranes. They also observed genetic damage in lymphocytes (white blood cells) that were directly exposed to THz radiation without the shielding effect of blood serum. The main conclusion from the project is that THz radiation will probably not be harmful in biomedical imaging applications, at least when patients are limited to single exposures. However, setting exposure guidelines requires further studies to identify more clearly the relationships between dose and response.

The targets for their spectroscopic studies were the various constituents of human blood, such as red and white blood cells, haemoglobin, glucose, total protein and cholesterol, as well as a range of amino acids from which proteins are made. The biological spectra the team collected during the course of the project are now available to research groups worldwide on the project's website[1]. They also developed tests for analysing blood samples by infrared spectroscopy of substances such as cholesterol, total protein and glucose.

The THz-Bridge survey of THz-radiation users was the first global survey of its kind. Over a period of one year, approximately 20% of the user community returned completed questionnaires. From research groups in the EU, Japan, Russia and the US, these indicate a clear need for action. Not one set of standards for exposure of occupational workers exposed to THz radiation came to light.

1. http://www.frascati.enea/THz-BRIDGE

Project title:

Tera-Hertz radiation in biological research, investigation on diagnostics and study of potential genotoxic effects (THz-Bridge)

Project partners:

- ENEA, Frascati Research Centre, UTS Tecnologie Fisiche Avanzate, Italy (Coordinator)
- Forschungszentrum Rossendorf e. V., Institut für Kern- und Hadronenphysik, Germany
- Tel-Aviv University, Department of Physiology and Pharmacology – Sackler School of Medicine, Israel
- Universität Stuttgart, 1. Physikalisches Institut, Germany
- Johann Wolfgang-Goethe Universität Frankfurt am Main, Institut für Biophysik, Germany
- University of Genoa, Centro Interuniversitario sulle Interazioni tra Campi elettromagnetici e Biosistemi, Italy
- National Hellenic Research Foundation, Theoretical and Physical Chemistry Institute, Greece
- Teraview Limited, United Kingdom
- The University of Nottingham, School of Biomedical Sciences, Human Anatomy and Cell Biology, United Kingdom
- Universität Freiburg, Department of Molecular and Optical Physics, Germany

Project Reference: QLK4-CT-2000-00129

Duration: 01-02-2001 to 31-01-2004

The EMF-NET project:

What are the implications for policy-makers and the public of research into the health effects of electromagnetic fields?

The quest to understand if and how electromagnetic fields affect health is naturally a sensitive one. Working from the incomplete charts drawn up so far by scientists, is it possible for policy makers to steer a course that avoids undue conflict between the many stakeholders? The EMF-NET project is doing its best to make sure the answer is yes.

Scientists researching the health effects of non-ionising electromagnetic fields have to contend with an enormous stretch of the electromagnetic spectrum, reaching from static electric and magnetic fields to electromagnetic fields at frequencies in the terahertz range. They also have to contend with the complexity of the human organism. The number and nature of the ways in which these two systems interact can at present only be guessed at. So it is no surprise that the approaches and techniques so far mustered by this still youthful branch of science are heterogeneous.

Behind the scenes, there are the dynamic social and political forces at work among an enormous array of stakeholders with different interests in the field – the scientists and research groups themselves; policy makers, politicians, governments and regulatory bodies, at local, national and international levels. And we must not forget health professionals, industrialists, investors, trade associations, trade unions, marketing professionals, users of devices reliant on EMFs, patients, and so on. Nor should we overlook for a moment the modern media.

To bring order to this complex environment would be far too ambitious an aim for a single initiative but the participants in the EMF-NET coordination action do aspire to make a substantial contribution to this goal. They are looking to provide an 'interpretation interface' between science and policy making – a framework for the interpretation of research results through which European policy makers will be better able to take appropriate account of the best available science in their decision making.

The EMF-NET participants

EMF-NET draws on a distinguished line-up of participants. Among them are the coordinators of all EU-supported projects on the health effects of EMFs, as well as representatives of major national and international research programmes and projects in the field. But EMF-NET is much more than a talking shop where scientific experts will be content merely to swap notes. Other participants are bringing important additional perspectives to the table. They include industrialists from mobile-phone operators and the electrical and electronics industries, trade-union representatives and delegates from regulatory authorities. All told, 40 organisations are represented.

EMF-NET activities

The management team is putting its interpretation interface into place through a suite of interlocking activities, though none involves doing any laboratory-based or other primary research in the biological sciences. Underlying their approach is a constant process of identifying and bringing together the results of current research in the field, which is widely dispersed not only across scientific disciplines but also among researchers around the world. In another continuous background activity, participants are monitoring emerging technologies, such as third- and fourth-generation mobile telecoms systems, with

a view to helping identify the way ahead for future research. To help in both these tasks and others, the team is holding a series of public meetings, round tables, workshops and conferences.

Boards of experts will be making sense of new information as it emerges, each board consolidating all research findings relevant to salient issues that fall within its expertise and distilling them into EMF-NET interpretation reports. The management team will distribute the reports to several audiences. First and foremost are policy makers and health authorities, but they will also target other stakeholder groupings, not least fellow scientists, but also, and just as importantly, the public at large.

An investigation of risk perception and communication is a key element on the project's agenda. Here, the emphasis is on how to communicate information about risks – potential and actual – without on the one hand avoiding difficult questions or, on the other, provoking unjustified fears – a tall order in the incessantly shifting sands of any rapidly developing scientific domain. The project has also formed the European Fast Response Team on EMF and Health and charged it with providing prompt, concise answers to questions put by the European Commission services.

The EMF-NET results

Only one year into its four-year term, the project has already built up a high profile for itself in the scientific and policy-making communities, thanks in no small part to a project website rich in content[1]. It has made rapid progress in the cataloguing of relevant research results, organised and participated in dozens of events and is looking forward to future events it has set up for the coming year; including two activities dedicated to discussion of the implementation of EU directive 2004/40/EC on occupational exposure to EMF. In August 2005, it began publishing its first set of 13 interpretation reports. They cover subjects ranging from epidemiological and laboratory studies to emerging technologies. The Fast Response team has also published responses to questions on such matters as the recent advice from a UK regulatory body on the use of mobile phones by children, the health effects of telephone masts and the use of ferrite beads in hands-free kits for mobile phones.

1. See http://emf-net.isib.cnr.it/

Project title:

Effects of the exposure to electromagnetic fields: from science to public health and safer workplace (EMF-NET)

Steering Committee:

- Paolo Ravazzani, Istituto di Ingegneria Biomedica, Consiglio Nazionale delle Ricerche, Milan, Italy (Coordinator)
- Elisabeth Cardis, International Agency for Research on Cancer, Lyon, France
- Lawrence Challis, National Radiological Protection Board, Oxfordshire, United Kingdom
- Jochen Buschmann, Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., München, Germany
- Guglielmo D'Inzeo, Interuniversity Center «Interaction between Electromagnetic Fields and Biosystem» (ICEmB), Genoa, Italy
- Maria Feychting, Karolinska Institutet, Stockholm, Sweden
- Gerd Friedrich, Forschungsgemeinschaft Funk e. V., Bonn, Germany
- Kjell Hansson Mild, National Institute for Working Life, Umea, Sweden
- Jukka Juutilainen, University of Kuopio, Kuopio, Finland
- Jolanta Karpowicz, Centralny Instytut Ochrony Pracy-Panstwowy Instytut Badawczy, Warsaw, Poland
- Norbert Leitgeb, Institute of Clinical Engineering, Graz University of Technology, Graz, Austria
- Demosthenes Papamelethiou, Joint Research Centre, Ispra, Italy
- Theodoros Samaras, Aristotle University of Thessaloniki, Thessaloniki, Greece
- Gyorgy Thuroczy, "Frederic Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary
- Bernard Veyret, Ecole Nationale Superieure de Chimie et de Physique de Bordeaux, Bordeaux, France

Project Reference: SSPE-CT-2004-502173

Duration: 01-03-2004 to 29-02-2008

KI-70-05-528-EN-C

There is much public concern about the issues surrounding the effects of electromagnetic fields on health – in particular, the potential health effects of mobile telephones. This brochure describes what electromagnetic fields are, where they are found, and what is being done to investigate their potential for affecting our health. There are maximum exposure limits that are regularly reviewed in the light of new scientific research, much of it funded by the European Commission's Directorate-General for Research.

Publications Office
Publications.eu.int

ISBN 92-79-00187-6
9 789279 001871