MOBILE & WIRELESS FORUM

20 YEARS 1998-2018

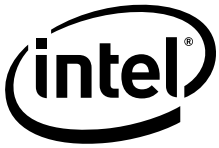
MWF

Mobile & Wireless Forum

Members












The MWF also acknowledges the significant contributions of former members who help shape and fund the research in this book, including Alcatel, Microsoft, Mitsubishi Electric, Nokia, Panasonic, Philips, Sagem and Siemens.

Contents

Introduction

Mobile phone usage around the world and over time

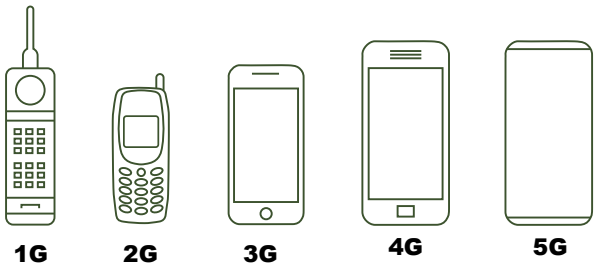
While there were commercial mobile telephony systems in operation in the USA and Sweden as far back as the 1950s, the first ever call from a handheld mobile phone was made in 1973 when Motorola employee Martin Cooper stood in New York City and placed a call to the headquarters of Bell Labs in New Jersey using a prototype Motorola DynaTAC 8000x.

Ten years later the world's first commercial handheld mobile phone, was released to the public. It was big, had a 35 minute battery life, 10 hour charge time and cost the equivalent of $10,000 today. The world's first text message came in 1992.

Flash forward to today. The total number of mobile subscriptions in the world is around 7.8 billion, according to data from Ericsson[1]. That's about one subscription for every person in the entire world and a penetration rate of over 100 percent, up from just 34 million subscriptions in 1993.

People around the world have adopted mobile phones like few other products in human history. When mobile phones were first introduced to the market in 1983 no one could have predicted the profound and far-reaching impacts the communication technology would have on the world.

The technological leaps forward with each generation of mobile networks have delivered improved user experiences. We have gone from analogue voice calls in first generation (1G), digital voice and basic data in second (2G), mobile broadband in third (3G), and more capacity and speed in fourth (4G).



Now we are anticipating the arrival of the fifth generation (5G) which will push wireless boundaries and enable the Internet of Things (IoT) – the interconnection of everyday objects and appliances through built-in computing devices enabling them to send and receive data which will bring greater connectivity and the integration of artificial intelligence into our daily lives.

Wireless communication devices have become highly accessible products available to people from all walks of life in developed and developing nations in all corners of the world. The role these devices have played in contributing to our globalized and interconnected world has had unforeseen impacts on our very way of life.

[1] Ericsson Mobility Report Interim Update, February 2018, p. 2.

Mobile phones have provided for the first time, basic communication services to billions. Perhaps the most profound impacts have been in the world's developing countries. Compared with traditional fixed-line networks rolled out in the West in the early 20th century, mobile communication networks are easier and faster to build. As a result those networks have been built as primary communication infrastructure in many countries.

We are now seeing mobile devices become the primary communication means in many countries around the world. For the first time, more than half of all households in the U.S. contain a mobile phone but not a landline telephone.

The advent of smartphones has ushered in a new era of mobile connectivity and possibility. Smartphone subscriptions have outnumbered standard mobile phone subscriptions and are expected to more than double by 2020, reaching 6.1 billion[2]. Almost 80% of these new subscriptions will come from Asia Pacific, the Middle East and Africa.

The internet browsing capabilities of smartphones have seen worldwide mobile data traffic continue to grow. Increased viewing of video content at higher resolutions has been a primary driver of the huge growth in data usage and it is expected that video will account for around 75% of mobile data traffic by 2023.[3]

Smartphones are changing the way we use mobile devices. Mobile phone users, particularly young people, are spending more time looking at their devices in their hand rather than talking on them. The ability to browse the internet, send text messages, film video and interact with various applications has seen the phone call function become one of the lesser used features on the modern mobile phone.

This has been the trend of the last few years but the future of mobile and wireless devices is hard to forecast. Between 2018 and 2021, for example, the number of IoT connected devices is expected to grow 23 percent annually, of which cellular IoT is forecast to have the highest growth rate. Of the 28 billion total devices that will be connected by 2021, close to 16 billion will be IoT devices.

With mobile and wireless technology constantly evolving at such a rapid pace, it is important to acknowledge that not everyone has been entirely happy about these developments. For example, public concern has existed about whether the radio signals from mobile phones and other wireless devices have any impact on our health.

For those living near base stations, there are many who have welcomed the greater connectivity and speed that such developments allow, although there are some who have also been concerned about the constant exposure of yet another radiofrequency source in their environment.

2 Ericsson Mobility Report, June 2015, p. 6.
3 Ericsson Mobility Report, November 2017, p. 11.

The mobile phone industry takes these concerns seriously, and while the benefits of the technology are clear, industry must ensure that any concerns are addressed through open and transparent information, as well as independent quality scientific research that paves the way for health authorities and governments around the world to provide the best available advice to the public.

The Mobile & Wireless Forum's role in this area, which this booklet details, is to support such research and help contribute to the development of standards for the industry to use to ensure compliance of the various products and services, thus allowing people to enjoy the full benefits of the technology.

Introduction to the MWF

The Mobile & Wireless Forum is an international not-for-profit member association of companies with an interest in mobile and wireless communication. The association exists to support the highest quality research for use in the development of public policy, standards and regulation.

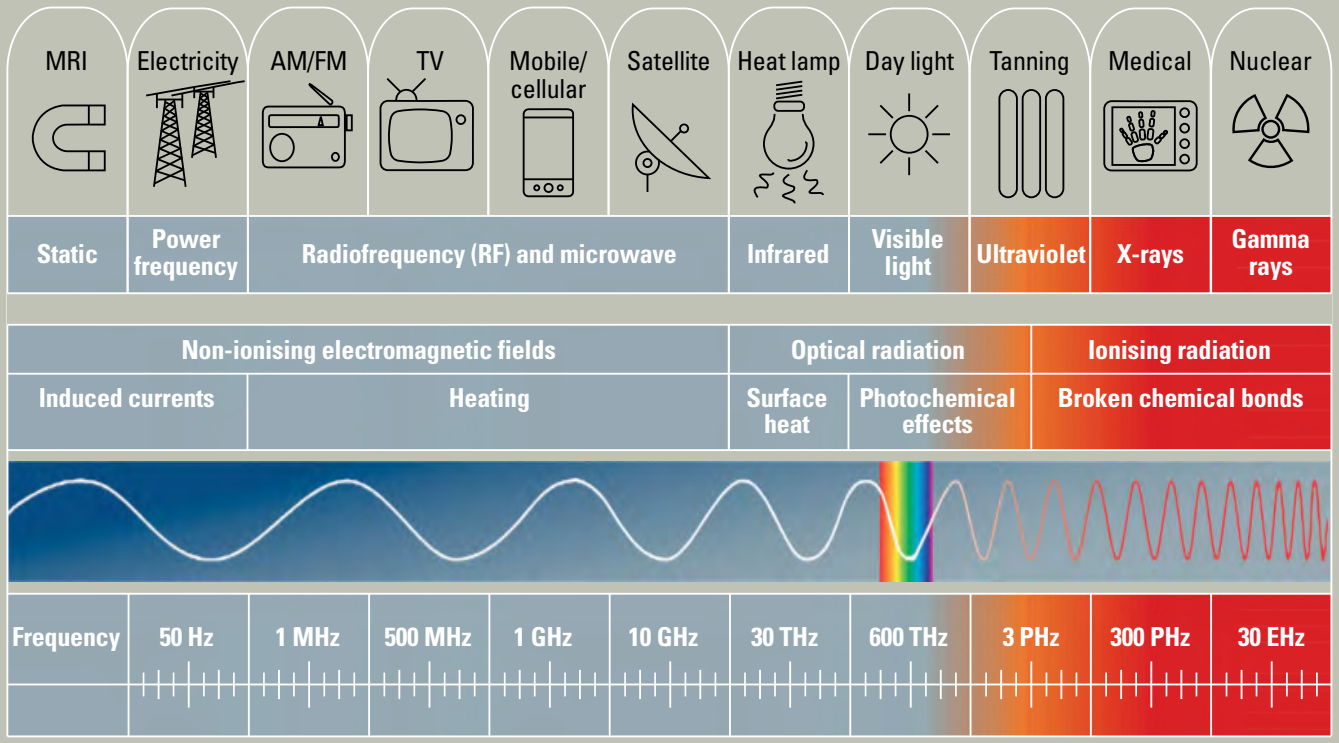
Technological innovations since the MWF's inception 20 years ago[4] have seen the world's use of wireless devices develop in new and unexpected ways. These exciting developments have seen the association's scope broaden, now giving strong focus to the introduction of 5G and the Internet of Things (IoT) – two innovations central to the new era of technological change we are entering known as the Fourth Industrial Revolution.

While the MWF's scope has evolved, its overall mission remains the same: to facilitate joint funding, between governments, industry and international health organizations, on key research projects investigating issues concerning the safety of wireless technology, product integrity and accessibility.

Since 1998, one of the core objectives of the MWF has been to respond to the concerns about the safety of mobile and wireless devices through the support of research, standards and communication. The need for governments and the mobile industry to actively communicate and maintain an open dialogue with the community about their concerns remains as true today as it was 20 years ago.

[4] In January 2017, the Mobile Manufacturers Forum (MMF) changed its name to the Mobile & Wireless Forum (MWF).

THE ELECTROMAGNETIC SPECTRUM



The international research effort into the effects of radio waves has been immense and over the years this research has been used to develop safety standards for all wireless products. The MWF has operated in this research space with an ethos of transparency providing high quality public information and analysis on the safety of wireless technology.

Introduction to EMF Research

In the world around us there are naturally occurring and human-made electromagnetic fields (EMF). The most recognisable form of EMF is sunlight and it is the only form visible to the naked eye. Another natural source of EMF is the Earth's magnetic fields.

Human-made EMF around us are created by electrical appliances such as microwave ovens and refrigerators, as well as radio communications devices such as radio and TV broadcasts and mobile phones.

All EMF exist through a combination of electric fields, created by differences in voltage, and magnetic fields, created by electric currents. The oscillating electric and magnetic field components of EMF are existing simultaneously and at sufficient distances from the source they are generally perpendicular to each other. EMF carry energy and travel through space at the speed of light.

The frequencies that EMF may have are described by the electromagnetic spectrum, and ranges from static fields like the Earth's magnetic field, to radio frequency (RF) used in mobile and other wireless communications through to X-rays used in medicine to diagnose, among other things, broken bones and high energy radiation for treating cancer.

Mobile and wireless devices, TV and radio broadcast, microwave oven and satellite technologies operate using the non-ionizing part of the electromagnetic spectrum (between 0 and 3000 THz). Unlike the ionizing radiation part of the spectrum occupied by X-rays and gamma rays (from radioactive sources) which have enough energy to break molecular bonds and are known to increase the risk of cancer at high doses, the radio frequency electromagnetic fields transmitted by mobile communication equipment cannot cause molecular bonds to break.

Extensive research has been conducted into possible health effects of exposure to EMF of many parts of the electromagnetic spectrum. The World Health Organization (WHO) notes that in the area of biological effects and medical applications of non-ionizing radiation approximately 25,000 articles have been published over the past 30 years. Scientific knowledge in this area is now more extensive than for most chemicals.

Currently mobile phones, tablets and wireless devices operate in 0.3 – 6 GHz spectrum and with the advent of 5G more devices will occupy new spectrum in the range from 6 GHz to 100 GHz. As concluded by WHO and other health organizations, there is no conclusive evidence that devices operating within the limits established by ICNIRP in the range from 0 to 300 GHz poses a hazard to humans and no public health risks have emerged from several decades of EMF research.

It is important to understand that in science it is easy to prove effects but not the absence of an effect (i.e whether something is safe). The distinction between established and possible effects is often unclear in scientific reports. Expert judgements are therefore critical in the understanding of RF safety.

Biological effects and health effects

Biological effects are a response to stimulus or to a change in the environment around you and are not necessarily bad for your health. Health effects are changes in health resulting from exposure to an agent or source.

Eating a freezing cold ice cream can give you brain-freeze (ice-cream headache), a sensation which goes away a short time after you stop eating it. Going for a run or sitting in a sauna will cause your body temperature to rise. These biological effects are not considered health effects because the result is temporary and not detrimental to your health.

Filling the research gap

The role of the WHO International EMF Project

The scientific knowledge about EMF and health is substantial and continues to grow. New findings are released on a regular basis, presented at scientific meetings and published in open scientific journals. Sometimes, media accounts make these findings seem confusing or contradictory, causing people to wonder what to believe about mobile phones and health.

A look at the media headlines from the past and present continue to provide valuable insights into areas of public concern.

Back in 1996, in response to growing public concern and in line with its charter to protect public health, the WHO established the International EMF Project to identify knowledge gaps where further research could improve health risk assessments.

The International EMF Project brings together available resources from international and national agencies and scientific institutions to investigate health effects of EMF and advises national health authorities on appropriate responses.

The Project's objectives are to develop a solid base of evidence regarding potential health risks, facilitate dialogue between stakeholders providing clear and unbiased information about current scientific knowledge and to help countries to set their national EMF legislation and regulations.

What is the International EMF Project?

The International EMF Project is located at the WHO headquarters in Geneva, Switzerland and is funded by contributions from WHO member states. The project is overseen by an advisory committee known as the International Advisory Committee (IAC) consisting of representatives of eight international organizations, eight independent scientific institutions and more than 50 national governments.

The scientific work is conducted in collaboration with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and all activities are coordinated and facilitated by the WHO Secretariat.

The Research Agenda and its recommendations

In the year following its formation, the International EMF Project initiative developed the WHO's first Research Agenda in order to facilitate and coordinate research worldwide on the possible adverse health effects of EMF. At the time, high-intensity RF fields had been shown to cause adverse health effects through heating tissues. But questions still remained about the effects of extended exposure to low-level RF fields, i.e., those emitted from mobile phones or basestations. Ongoing research was compared with research still required for the WHO to better assess health risk.

The first Research Agenda recommended further research into the 900 – 2000 MHz (0.9 – 2 GHz) frequency range, extremely low frequency (ELF) electric and magnetic fields emitted from powerlines and possible long-term effects on health from exposure to static magnetic fields.

Over the last two decades, as research needs have been addressed and new evidence published, the agenda has undergone multiple periodic reviews and refinement. A 2006 update of the Research Agenda called for more epidemiology and human studies focused on children, especially regarding brain cancer and cognitive function. Further research was also needed to further characterize the phenomenon of electromagnetic hypersensitivity (EHS).

A 2010 update of the Research Agenda called for more studies on assessing parental, child and teenage exposure to address the open question of whether their development is susceptible to RF EMF. Research assessing the exposure characteristics of new and emerging technologies using RF energy were also identified as a high priority.

As a result, more than $200 million have been spent on research to fulfil these research priorities over the years.

Environmental Health Criteria

Environmental Health Criteria (EHC) reviews or monographs are international, critical reviews conducted through independent, scientific peer-review groups on the effects of chemical, physical and biological agents on human health and the environment.

They provide an internationally agreed risk assessment and recommendations for scientists and administrators responsible for the establishment of safety standards and regulations around the world.

In late November 2014 the WHO released a draft of the scientific content of its overall risk assessment of all health outcomes from exposures to RF EMF for expert comments.

Currently the WHO is reviewing all the scientific evidence and research progress with the intention of publishing an Environmental Health Criteria Monograph and updated Research Agenda.

The EHC is the most comprehensive and detailed review the WHO undertakes on any agent or substance. In the case of RF EMF, the monograph will build upon the classification of RF fields by the International Agency for Research on Cancer (IARC) with all the non-cancer related endpoints that have been studied to date.

The final monograph will be the WHO's formal risk assessment of all studied health outcomes from RF EMF exposure to provide governments with policy recommendations and guidance on regulations setting.

Who is IARC?

The International Agency for Research on Cancer (IARC) coordinates and conducts research on the causes of human cancer, the mechanisms that cause cancer, and develops scientific strategies for prevention and control.

The IARC Monographs identify environmental factors that may be carcinogenic to humans. National health agencies can use this information as scientific support for their actions to prevent exposure to potential carcinogens.

The IARC process evaluates the strength of evidence from human and animal data that an agent may cause cancer in humans. The classification refers to the strength of the evidence and not the likelihood that in normal use they do cause harm.

An agent therefore may be classed as a cancer hazard by IARC even though the cancer risk is low at current human exposures. IARC's classification scheme is as follows:

Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Not classifiable as to its carcinogenicity to humans
Group 4	Probably not carcinogenic to humans

In 2011, IARC classified RF Fields as a possible human carcinogen (2B). According to IARC, 'this category is used for agents for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals. It may also be used when there is inadequate evidence of carcinogenicity in humans but there is sufficient evidence of carcinogenicity in experimental animals.'

The next stage of review is an overall EHC risk assessment which will be undertaken by the World Health Organization (WHO) covering all health outcomes – not just cancer.

The WHO updated its fact sheet on mobile phones to reflect the IARC classification. The 2011 fact sheet says: 'A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use.'

WEIGHT OF SCIENTIFIC EVIDENCE

The 'weight of scientific evidence' approach means that no single study can answer any scientific question, and must not be viewed in isolation but against the backdrop of previous research. Factors such as the quality of the data, consistency of results, nature and severity of effects and relevance of the information are all important considerations for experts to determine appropriate weighting to be given to the evidence.

This approach is important to consider in research on radiofrequency (RF) electromagnetic field (EMF) health effects when individual studies provide different or conflicting results. Individual studies need to be seen in the light of the total research effort into mobile phone health and safety.

Scientific investigation is subject to potential errors, personal opinions and uncertainties. This applies as much to research on RF EMF health effects as it does to all other areas of science.

A coordinated approach

Governments and industry funding agencies like the MWF are encouraged to address the WHO Research Agenda in a coordinated and collaborative manner to maximize the effectiveness of research efforts to close the identified knowledge gaps.

This multi-stakeholder coordination reduces unnecessary duplication of effort and ensures the timeliest completion of studies identified as being of high priority for a health risk assessment.

The MWF has responded to the Research Agenda of the WHO's International EMF Project and has coordinated its global activities to correspond with these recommendations.

The MWF and its members acknowledge that enhancing the existing scientific database relating to RF EMF is of vital importance to ensure that independent health risk assessments recognized by the scientific community, governments and statutory bodies can be undertaken.

Consistent with its constitution, the MWF maintains an active research program to promote high quality bioelectromagnetic, dosimetric or related social research, which is designed to enhance the scientific database and the development of sound public policy.

The research

Research and publication

Scientific research plays an integral role in risk assessment to protect the public from harmful health effects.

Presenting the results of scientific research and making it widely available are just as important as performing the research in the first place. For international and national health authorities to make accurate risk assessments and set regulations in the name of protecting public health, scientific research must be presented in a clear and effective format.

The most common presentation form is the research paper which presents an original thesis about a topic and builds on the original thesis with information from multiple sources.

The value (and limitations) of peer review

Every year over one million papers of scientific research are published in scientific journals worldwide.

To get a paper published, scientists submit their research to a scientific journal which sends the paper to a small number of recognized experts in the relevant field. These qualified peers assess the competence, significance and originality of the study and provide analysis, judgement and evaluation.

This process is known as 'peer-review' and it is an important step in ensuring research papers are sufficiently detailed and that the conclusions are supported by the evidence prior to publication. When the process works as it should, the published paper is inevitably all the better for it.

When studies find results which are novel, the next stage is the well-established scientific process of replication and validation.

Replication refers to a process by which other scientists attempt to repeat the experiment and when scientists get the same, or very similar, results every time - a cause and effect relationship can be established. This is one of the reasons why the description of the research methodology is so important – it ensures that replication by others is possible. If an experiment cannot be replicated, the original authors conclusions must be viewed with doubt.

The process of peer-review and replication can be a complicated and painstaking process for researchers. Unfortunately peer review can be subject to scientific error and human oversight. Much depends on the credibility of the journal and the expertise of the reviewers.

While the process is not perfect, peer review is important for the public because it gives them a better guide to assess what scientific research they can trust and what research should be interpreted with caution.

Unfortunately, small studies are often released to the media in an attempt to gain publicity prior to the rigors of peer review and proper scientific assessment by expert bodies.

The MWF continues to endorse the importance of sound, peer-reviewed and replicated research so that people can make informed choices about wireless technologies.

The possibility of health effects from mobile devices will continue to be the subject of media speculation and public interest, however weight must be given to the expert judgements of international authorities considering the results of published, peer-reviewed and replicated scientific research.

Three types of research

Expert health agencies throughout the world rely on a hierarchy of evidence to evaluate potential human health effects. They are ranked in the following order of importance:

1. **Population studies** *(epidemiological studies)*: These studies are of primary importance in health risk assessment as they directly address the exposure and disease occurrence in the population.
2. **Laboratory studies** *(In vivo - animal or human)*: Laboratory studies are often used to understand how 'cause and effect' relationships change in animals or humans.

DIFFERENT TYPES OF STUDY DESIGNS

Systematic Review: a researcher reviews published papers about a particular issue or question. The researcher organizes and explains how papers were chosen, then evaluates the results of the papers to find either consistent or inconsistent results.

Meta-analysis: similar to a systematic review, a meta-analysis uses strict selection criteria and statistically combines results to confirm or reject a consensus. A meta-analysis is considered one of the strongest forms of evidence.

Randomized Controlled Trial: randomly separates a population into two groups, and then exposes them to a possible cause, or different treatments, and then results are observed. This kind of study is sometimes not possible or not ethical to do in humans.

Cohort Studies: observing two populations over time; one group is the 'experiment group' who has a particular condition or treatment over time; the other group is the 'control group' who does not have this condition or treatment. Cohort studies reduce the risks of selection bias that can affect case-control epidemiological studies where people who already have some illness and healthy controls are asked about past exposures.

Case Control Studies: observing a population at a single point in time, these studies identify factors that may contribute to medical conditions by comparing a selection of cases (people who have a disease) and controls (people without the disease). Participants are interviewed about their history to find what might be the cause. Researchers compare the odds of people who have the effect after exposure to a potential cause against the odds of people not showing the effect after exposure to the potential cause.

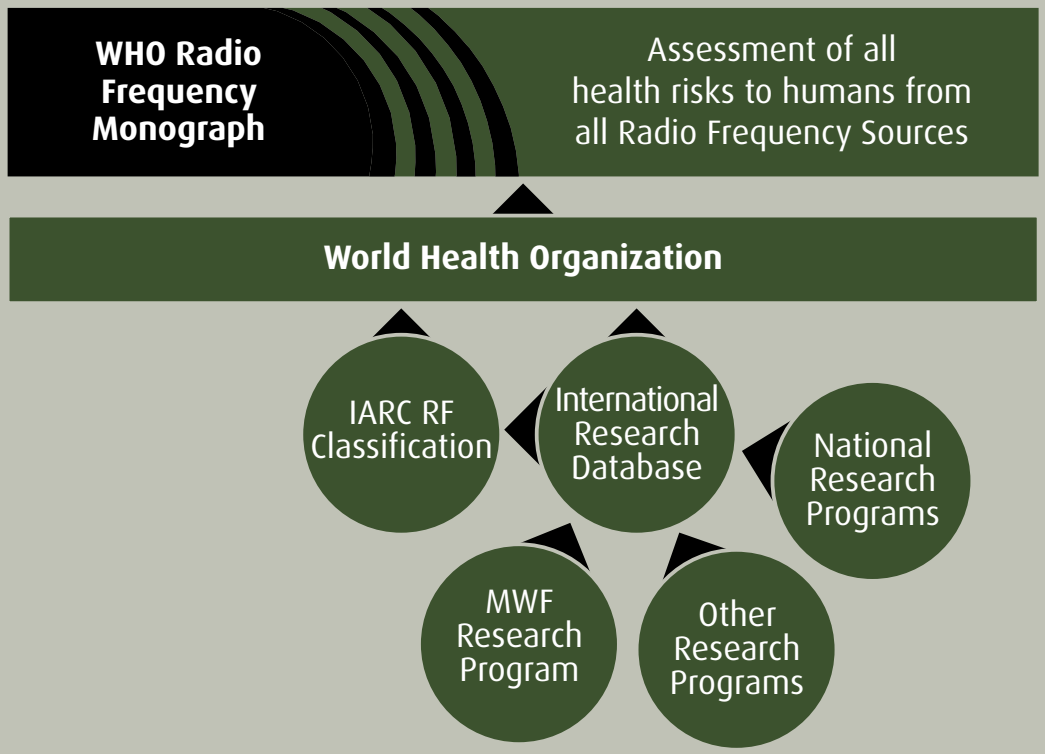
Cross-sectional Studies: observing a defined population at a single point in time. Researchers look for a cause and effect relationship at the same time.

Case Series/Case Reports: a pattern is noticed in a series of patients that invites further research.

3. **Test tube studies**
   (In vitro - mechanistic studies):
   In vitro studies are used to explore 'cause and effect' relationships independent of the modifying effects of the whole organism or human body. They are important for testing possible mechanisms of action and in understanding how something might react without the complexity of an entire living organism. While informative, they are given less weight because an effect might be negated within the complexity of an entire organism, so anything found in these types of studies needs to also be established in animal and/or human studies as well.

KNOWLEDGE RELATIONSHIPS

Overview of Radio Frequency Research Coordination



The MWF's Research Program

Research principles

The MWF is committed to ensuring that its support for research is undertaken with openness, transparency and independence. To this end it has adopted a number of established principles that it applies to the sponsorship of research, which for biological or human-health related research, include:

- Utilising the WHO Research Agenda as the framework for what research should be supported
- Funding of projects in conjunction with government or other third parties, wherever possible
- Limiting industry funding to 50% of the project costs if feasible
- Implementing independent project and/or financial management to provide a 'firewall' between researchers and industry sponsors
- Ensuring government research quality standards such as good laboratory practice are used
- Publishing all results, irrespective of outcome, in peer-reviewed journals

The MWF's nine research programs

The MWF has nine different research programs which have produced a diverse catalogue of scientific material. The programs can be divided into two key types of research – technical and health related research.

Technical research is all about making sure the research is done correctly. This may sound simple but it's far from it, especially in RF EMF research. Technical research involves developing the tools, equipment and procedures to accurately measure the RF EMF exposure, both within experiments as well as when testing products.

Program 2, which is made up of dosimetry studies, falls under the technical banner and it involves accurately measuring the ways RF energy is absorbed and creating realistic models and tools to conduct those measurements. Dosimetry is very important in the design and interpretation of health-related research, since without it, researchers cannot be sure what they are attempting to test is actually being tested. The body of work in EMF research is full of earlier studies where the dosimetry was missing or incomplete which means those experiments cannot be fully assessed or replicated by others – a key part of the scientific process.

Program 9, regarding Emerging and Future Technologies, includes work related to fifth generation (5G) networks and devices, and related technical dosimetry research. In this case, these studies provide a better understanding of how higher frequencies

QUICK GUIDE TO THE DIFFERENT TYPES OF RESEARCH SUPPORTED

(6 to 100 GHz) are absorbed within the skin, the temperature increases that are associated with such absorption and ultimately, how this can be used to design better compliance testing frameworks for devices operating at these higher frequencies.

All other MWF research programs fall under health research which assesses biological effects in cells, animals and humans. This includes the epidemiology, human, animal, cellular, mechanisms and social MWF research programs.

How the MWF projects fit into the WHO EMF Program

The first World Health Organization (WHO) EMF Research Agenda was released in 1997 and the MWF was founded the following year to coordinate contributions from member companies to direct towards its fulfilment.

The Agenda is used as the essential framework to determine which projects should be supported, and over the years it has been reviewed and updated to take into account those projects already undertaken and any new research needs that have arisen. With each new version of the WHO Research Agenda, its recommendations are reviewed by the MWF's EMF Standards and Research Working Group to determine which specific recommendations and gaps they think that the MWF supports research to address.

The MWF then consults with scientists and researchers at universities about the possibility and feasibility of undertaking the particular research projects. This may be undertaken directly or through open Request For Proposals (RFP) processes. Universities or other independent organizations may be utilized to act as project and financial managers while national health agencies or other organizations may also be approached to act as co-sponsors.

These collaborative measures help to ensure there is a separation between researchers and industry ('firewall principle') when it comes to undertaking the actual research.

FIREWALL PRINCIPLE

When a company or industry funds scientific research, there is often a perceived conflict of interest and the credibility of that research may suffer as a result. When government funding for research and development lags, often it is industry which collaboratively provides support for critical additional research.

This has been the case for the Mobile & Wireless Forum, whose principal purpose is to jointly support research projects that address the research agenda of the World Health Organization, filling the gaps in knowledge and much needed funding.

In supporting research into the health and safety of mobile communications, the MWF is acutely aware of the sensitivities involved. To this end, the MWF upholds a 'firewall principle', ensuring all health related research projects are managed independently from the industry under strict protocols to ensure there is no industry influence.

For a firewall to be successful, a third party, often a university or even a government agency, receives the funding from industry and then deals exclusively with the researchers with regards to payments, progress and reporting.

Most of the MWF's health research is funded in conjunction with government health agencies and the MWF actively encourages all results, whatever they are, to be published in peer-reviewed scientific journals.

The mobile communication industry is in a difficult situation when it comes to funding research. If it did not fund any research it would be accused of not caring about the public's concerns. However, when it does fund legitimate research it may be accused of a conflict of interest. Setting up these strict firewall protocols helps to address these concerns and ensures the scientific independence of the researchers involved.

One of MWF's core projects, the INTERPHONE project, the largest study ever conducted on mobile phone use and brain cancer, published in May 2010, was partially funded by industry (MMF and the GSMA) through the International Union for Cancer Control (UICC) which acted as the firewall. Researchers received funds under strict agreements that guaranteed complete scientific independence. Industry funding only complemented funds received from national and local health research funding organizations.

At the time, the lead researcher in the Australian arm of the project, Professor Bruce Armstrong, responded to allegations that industry had influenced the Interphone results when he said:

'Basically from the level of investigators at INTERPHONE, we never received, never saw, never felt and never smelt anything from industry that suggested that we should do anything other than what we as investigators thought we should be doing in relation to design, conduct, analysis and reporting.'

'I'm personally satisfied that there was no influence, and if there had been, then I think I would have known.'

Programs

PROGRAM 1
EPIDEMIOLOGY STUDIES

Epidemiology studies are the most important studies in health risk assessments on RF EMF because they directly address questions about occurrence and prevalence of exposure and disease in populations of humans. In a nutshell, epidemiology studies try to work out who is getting ill, and when and where illness is occurring.

In the MWF supported epidemiological studies researchers base their assessment on the Bradford Hill criteria for causation established in 1965 by the English epidemiologist Austin Bradford Hill. The criteria set out nine rules including strength, consistency, and plausibility to find out if a relationship between two things is 'cause and effect', or merely a correlation.

Studies undertaken

INTERPHONE: International Case-Control Studies of Cancer in Relation to Mobile Telephone Use
Principal Investigator: E. Cardis
Institution: International Agency for Research on Cancer (IARC)

COSMOS: Cohort Study of Mobile Phone Use and Health
Currently underway
Principal Investigator: Various
Institution: Various

INTERPHONE

The INTERPHONE study was the biggest study undertaken into health impacts of mobile phones consisting of a set of multi-national case-control studies coordinated by the WHO's specialized cancer research agency, the International Agency for Research on Cancer (IARC).

The study involved 13 participating nations including Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the UK. The overall project involved separate national studies in each of the participating countries as well as a final overall assessment of all the combined data publish by IARC in 2010.

The enormous research effort began in 1998 and 1999 when IARC coordinated a feasibility study which concluded that an international study on the relationship between mobile phone use and brain tumor risk would be not only informative but also achievable.

The feasibility study concluded that the participating regions had sufficient history of mainstream mobile phone use to give researchers nearly 100 percent power to detect (with a 95 percent confidence interval) an increased risk of tumors associated with mobile phone use up to five years.

The overall aim was to determine whether or not mobile phone use increased the risk of certain head and neck cancers and was achieved through the examination and comparison of data on entire lifetime

history of phone use among cancer cases (participants with brain tumors) and control groups (healthy participants).

Following 12 years of studies investigating risks related to mobile phone use and other potential risk factors for tumors no link was found between mobile phone use up to a decade.

Of the thousands of tumor cases investigated (including 2,765 glioma, 2,425 meningioma, 1,121 acoustic neurinoma, 109 malignant parotid gland tumor cases and 7,658 controls), IARC reported no increased risk of brain and neck tumors from mobile phone use.

In some instances, the results indicated an increased risk for the highest cumulative call times but these unexpected findings were thought to be caused by biases in the procedure used to collect data which require researchers to interview cases and controls.

It is widely recognized that the design of INTERPHONE was the best available when it was started in 2000. However, the ability of participants to accurately recall how much they used their mobile phone 10 years ago, and on which side of their head they used it, has been a weakness of the project.

Health authorities around the world have reviewed INTERPHONE's results and have confirmed the appropriateness of current mobile phone exposure limits.

COSMOS

This ongoing cohort study is investigating the possible health effects of long term mobile phone use. It is an international study being conducted in six European countries – UK, Denmark, Sweden, Finland, France and the Netherlands, and aims to follow approximately 300,000 Europeans over a period of up to 25 years.

The study includes a number of questionnaires at regular intervals to collect data to address the question of mobile phone use and health, and the data will also be linked to health registry records. The study is attempting to enhance our knowledge on the relationship with tumors, various neurological diseases, vascular diseases and other self-reported symptoms. So far researchers have obtained extensive data on a range of other issues including wider environmental exposures, lifestyle and demographics.

The self-reported mobile phone use data is cross-referenced with data from mobile network operators unlike previous studies where data were solely based on estimates provided by people themselves.

Recent papers from the study have provided the first evidence of differences in the validity of self-reported mobile phone use between those who do and do not experience symptoms while using a mobile phone.

The study from the Imperial College of London, the UK arm of the international study, has found that those who experience related health symptoms are more likely to overestimate call duration.

COSMOS has tried to improve upon the methods for collection and analysis of self-reported data seen in the INTERPHONE study, as a means to address some of the limitations experienced in that study.

DOSIMETRY

- Radiofrequency energy, like medicines prescribed by doctors, does not have an effect on humans unless it is absorbed by the body. Dosimetry is the general term used to describe the measurement or numerical assessment of the energy absorbed in the body due to ionizing or non-ionizing electromagnetic exposure.
- Ever since the invention of X-rays it has been understood that ionizing radiation is absorbed by the human body and high intensity ionizing radiation has enough energy to break molecular bonds which may cause harmful biological effects through damaging cells.
- Electromagnetic fields occur naturally in the environment around us and those in the radiofrequency range of the spectrum are used for radio, television and communications. However, for RF EMF to have a biological effect on humans the RF energy has to penetrate the body. For a long time we have been able to measure environmental RF fields, however measuring the exact amount of energy deposited in the human body is trickier.
- Dosimetry studies specifically attempt to address this by determining how much EMF energy is absorbed in the body and it is calculated and measured using the specific absorption rate (see SAR pull out).
- Dosimetric evaluations remain critical for exposure assessment in epidemiological studies and are important for ongoing assessment of product safety and compliance with RF exposure standards.
- Dosimetry is considered differently to other types of scientific research as outlined by the WHO Research Agenda, however dosimetry is very important in the design and interpretation of experimental studies involving humans, animals and cells.

SPECIFIC ABSORPTION RATE

- The specific absorption rate (SAR) is a measure of the rate of RF energy absorbed by the body, e.g., from a wireless or mobile device. Researchers use dosimetric evaluations to assess the SARs and to understand how and where energy is deposited in the body.
- The international SAR limit for mobile phone handsets is 2W/kg averaged over 10 grams of tissue. The exposure limit for the general public includes a significant 50 fold safety margin below known risk levels, such as acute exposure to sensitive organs like the eye, and for workers the safety factor is 10 times.
- The RF exposure standards have been established to specify the maximum allowed exposure for wireless communication devices such as mobile phones and incorporate additional safety factors to ensure that all users, including children, pregnant women and the elderly, can all safely use these devices.
- To ensure mobile phones are safe, exposure standards take a conservative scenario – a phone operating at maximum power output – whereas in real life everyday use phones rarely work at maximum power output.
- In normal use, phones operate at lower power levels, adapting constantly to use the minimum power required to make a call in order to maximize battery life and available call time. This is known as 'adaptive power control' and it ensures the many mobile phones present in a crowd of people don't interfere with each other and that the network runs efficiently so it can handle large number of connections at once.

PROGRAM 2
DOSIMETRY STUDIES

The MWF's dosimetry research program has been designed to support health research programs through improved exposure controls and suitable exposure systems. The aim of this program has also been to resolve questions and uncertainties about standards setting through the use of highly detailed modeling, enhanced testing methods and measurement technology which are used in compliance testing of wireless equipment.

As such, the dosimetry studies can be separated into three groups: Exposure system development and control; Standards setting support; and Testing Methodology.

Studies undertaken

Exposure system development and control

IT'IS Foundation (General Support)
Principal Investigator: N. Kuster
Institution: IT'IS, Switzerland

Standards setting support

Development of Simulated Tissue Equivalent Dielectric Materials
Principal Investigator: V. Vigneras-Lefebvre
Institution: University of Bordeaux, France

Thermal and RF Modeling of Cellular Phone Exposure
Principal Investigator: J.J.W. Lagendijk
Institution: University of Utrecht, Netherlands

Evaluation of Electromagnetic Field and SAR Distributions from EEG Electrode Cap
Principal Investigator: L. Angelone
Institution: Massachusetts General Hospital, United States

Virtual Family
Principal Investigator: A. Christ
Institution: IT'IS Foundation, Switzerland

Low Power Exemption Rationale for Wireless Transmitters at Distances of 25 mm or Greater from the User
Principal Investigator: M. Ali and G. Schmid
Institution: University of South Carolina, USA and ARC Seibersdorf, Austria

RF Thermal Response: Parameters Sensitivity and SAR vs Temperature Distributions
Principal Investigator: R. Croft
Institution: Swinburne University of Technology, Australia

Thermal Effects Review (2 Projects)
Principal Investigator: M. Dewhirst and M. Zisken
Institution: Duke Medical Center and Temple Medical School, USA

Principal Investigator: J. Morrissey
Institution: Nova Southeastern University, United States

Dielectric Parameters for Tissue Simulating Liquids - 30MHz to 6GHz
Principal Investigator: J Hyttinen
Institution: Tampere University of Technology, Finland

RF Safety Compliance Testing of Multiple Input Multiple Output (MIMO) Antennas
Principal Investigator: R Croft
Institution: Swinburne University of Technology, Australia

Determining Maximum Allowable Emitted Power Level from Low-Power Transmitters for SAR Compliance
Principal Investigator: M. Ali
Institution: University of South Carolina, USA

Exposure patterns caused by RF emissions of low power transmitters
Principal Investigator: G. Schmid
Institution: ARC Seibersdorf, Austria

Local SAR Versus Power Density between 1 and 10 GHz
Principal Investigator: R. Croft
Institution: Swinburne University of Technology, Australia

Low Power Exemption for Wireless Transmitters Based on Temperature
Principal Investigator: M Ali and R Zaridze
Institution: University of South Carolina, USA and Tbilisi State University, Georgia

Testing Methodology

International Inter-laboratory SAR comparison program
Principal Investigator: C. Davis
Institution: University of Maryland, United States

Procedures, Validation, System Verifications and Uncertainty Analysis for the reliable use of fast SAR Methods
Principal Investigator: N. Kuster
Institution: IT'IS Foundation, Switzerland

Scientific Basis for Base Station Exposure Compliance Standards (2 Projects)
Principal Investigator: G. Neubauer
Institution: ARC Seibersdorf, Austria

Principal Investigator: N. Kuster
Institution: IT'IS Foundation, Switzerland and 7 other institutes

An Assessment of Passenger Exposure to the Radiation of Trunk Mounted Antennas
Principal Investigator: A. Christ
Institution: IT'IS Foundation, Switzerland

Program highlights

Foundation for research on information technologies in society

The MWF supported the work of the Foundation for Research on Information Technologies in Society (IT'IS) in Switzerland for many years and helped it to become one of the world's premier RF dosimetry and measurement research centres.

The Foundation conducted a wide variety of dosimetry and measurement projects using state-of-the-art exposure systems developed for use in the biological research projects supported by MWF, including the Perform A projects and the DMBA replication study in China.

In addition, they have undertaken many specific dosimetry and measurement projects for the MWF such as the Virtual Family, Children's RF absorption, 5G and Fast SAR detailed in this and other programs areas.

CHILDREN'S EXPOSURE TO EMF

Over the years concerns have been raised about the possibility of greater vulnerability for children exposed to RF EMF because of an increased susceptibility to health risks during developmental stages.

The view that children absorb more energy than adults from mobile phones because of their smaller heads and thinner skulls was proposed in a paper in 1996. At the time computer modelling images were widely distributed on the internet supporting this incorrect claim.

The use of realistic children models, developed in the MWF research program as well as others, found no significant differences in the amount of absorption and highlights the importance of accurate dosimetry in exposure assessments.

Without the development of accurate and realistic human models such as the Virtual Family (see below) used in dosimetric evaluations, questions about children's exposure would have remained unanswered.

Development of simulated tissue equivalent dielectric materials

Human tissues (skin, bone, muscle, etc.) have different dielectric properties which change with different electromagnetic frequencies. For SAR testing, phantoms need to be filled with materials that accurately represents these tissues, but at the same time they have to allow a measuring device, known as a probe, to move freely within to undertake an assessment.

This program therefore developed materials that represented the electrical properties of tissues in the human body. Subsequent work by other researchers has added to this over the years which has increased the frequency range that the materials can be used with.

Thermal and RF modeling of cellular phone exposure

This was a four-year research project carried out by the Department of Radiotherapy at University Medical Centre Utrecht in the Netherlands.

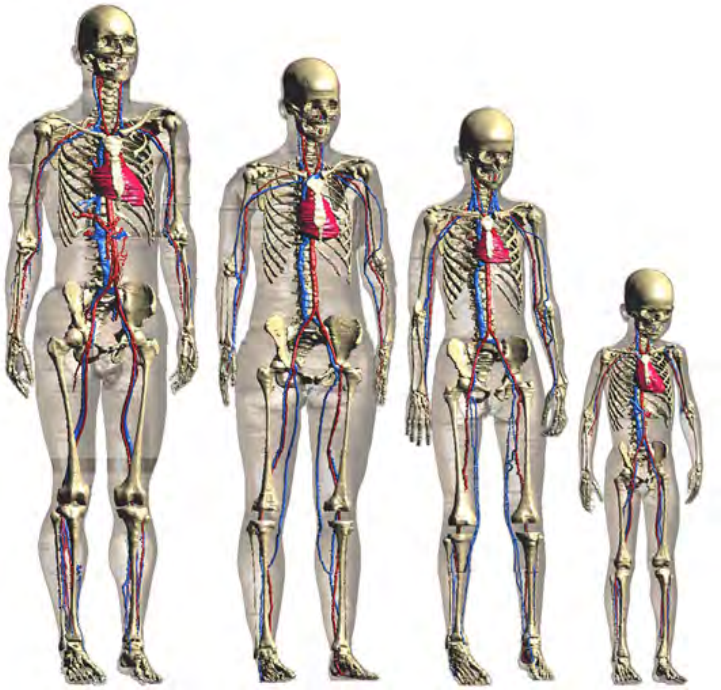
The principal objective of the project was to further investigate the temperature rise induced by mobile phone exposure using newly developed 3D high resolution imaging techniques comparing human and rabbit eyes. The studies looked at the movement of oxygen, blood flow and temperatures within the eye under different electromagnetic exposures such as infrared and radiofrequency.

The study found that blood diffusion in the eye is very slow compared to other parts of the body making it the most sensitive organ to RF exposure, as any temperature increase resulting from RF exposure is diffused via the blood at a slower rate than in other parts of the body. The results of these studies reaffirmed the basis of the 10 gram averaging mass used in the SAR standards, since the 10 gram mass is the approximate size of the average human eye.

Virtual Family

With the development of MRI technology, it was possible to obtain highly detailed scans of the human body and to model these in 3D format to create incredibly detailed and accurate anatomical models.

As a result, we can say hello to Duke, Ella, Billie and Thelonious. As a family, they have contributed significantly to the wealth of scientific knowledge on EMF health effects through their involvement with several dosimetry studies.



The Virtual Family from left to right: Duke (34 years), Ella (26 years), Billie (11 years) and Thelonious (6 years).

These models have allowed scientists to use high powered computers to better predict possible exposures to RF energy across the frequency range. Using these models they are able to create theoretical simulated exposures for a range of ages, body types and body positions to better understand the RF exposure in different scenarios.

As the name of this project suggests, the family members are not actual humans, although they are realistic whole body models based on high resolution MRI scans of healthy human volunteers.

The family offered unprecedented detail of human tissues and organs for electromagnetic exposure and compliance testing.

The IT'IS Foundation in Switzerland carried out the project in conjunction with the US Food and Drug Administration and supported by the MWF and the GSM Association.

The results of the project were made available to the scientific community to assist in dosimetry research.

This project has now expanded beyond the original family and is now known as Virtual Population, a widely-referenced set of human anatomical models used for dosimetry and biomedical purposes.

Dielectric parameters for tissue simulating liquids - 30MHz to 6GHz

Exposure limits for wireless devices are set out in international standards and are assessed for compliance through the use of a phantom filled with a liquid that simulates the dielectric properties of the human body. One of the problems with existing SAR testing methodologies is that regulators have required the use of different liquids which lead to increased testing time and effort.

This study compared both worst case and realistic exposure scenarios and compared the results obtained using the tissue simulant liquids established by the International Electrotechnical Commission (IEC) standards with those required by the United States Federal Communications Commission (FCC).

The study demonstrated that both tissue liquids resulted in very conservative outcomes meaning that the liquids overestimated SAR in anatomical models, and in some cases, by more than 50%.

Determining maximum allowable emitted power level from low-power transmitters for SAR compliance

This project examined low-powered devices and aimed to explore and develop a relationship between antenna performance metrics with specific absorption rate, so that it was possible to determine the levels at which a device would always comply with RF exposure limits.

The project provided key inputs that have formed the basis of a low power exclusion formula in the international standard IEC 62479, ensuring that certain low-power devices are inherently compliant with the RF exposure limits, and that additional SAR compliance testing is not necessary.

PROGRAM 3
ANIMAL STUDIES

At the turn of the century there was an insufficient amount of published data from long-term animal studies investigating the effects of mobile phone use and base station exposure.

Shortcomings in existing studies such as inaccurate dosimetry, insufficient group sizes, and one exposure level only, along with different signal characteristics applied in each such as carrier frequency, pulsation, near and far fields, and transfer rates, made it problematic to make a joint risk assessment.

In response, the MWF, the GSM Association and the European Commission jointly funded PERFORM-A which consisted of six 2-year (or life-time) studies conducted in both sexes of two different rodent species to test for possible cancer effects of RF from mobile phones.

Two subprojects were conducted using rats and mice prone to mammary tumor or lymphoma to test if low-level RF exposure caused tumor growth.

The program simulated mobile phone exposure from the main mobile communications systems in Europe at the time, namely the Global System for Mobile Communications (GSM, 900 MHz) and Digital Personal Communications System (DCS, 1800 MHz).

The nature of these studies was equivalent to the type of studies regularly performed to evaluate the health risks of chemicals, pharmaceuticals or environmental agents.

In the years leading up to this study, major improvements had been achieved in the design and characterization of exposure systems, in particular to ensure a consistent exposure. This study had two new set ups to ensure uniform whole-body exposure over the entire exposure period.

Rodents were exposed to three whole-body exposure levels or were sham exposed during the entire exposure period.

As an overall conclusion, three out of four studies produced no evidence that exposure had any adverse health effect or any influence on the incidence, severity or time of appearance of any tumor. The only effect observed was a borderline one related to the animals response to long term repeated exposures to GSM signals.

The results of PERFORM-A played an important role in the health risk assessment of the use of mobile phones and base stations undertaken by the European Union (EU), IARC and WHO.

Studies undertaken

PERFORMA A1: Two combined toxicity/carcinogenicity studies of 900 MHz GSM and 1800 MHz DCS wireless communication signals in B6C3F1 mice
Principal Investigator: C. Dasenbrock
Institution: Fraunhofer Institute, Germany

PERFORMA A2: Two combined toxicity/carcinogenicity studies of 900 MHz GSM and 1800 MHz DCS wireless communication signals in WISTAR rats
Principal Investigator: E. Ruedin
Institution: RCC, Switzerland

PERFORMA A3: Evaluation of 900 MHz GSM wireless communication signals on DMBA-induced mammary tumors in Sprague Dawley rats
Principal Investigator: R. Hruby
Institution: ARCS, Austria

PERFORMA A4: Evaluation of 900 MHz GSM wireless communication signals on Lymphoma induction in Eμ-PIM 1 transgenic mice
Principal Investigator: G. Oberto
Institution: RBM, Italy

DMBA Replication
Principal Investigator: H. Jiang
Institution: Zhejiang University, China

France-Russia Study
French Part of Study
Principal Investigator: B. Veyret
Institution: PIOM Laboratory, ENSCPB, France

Russian Part of Study
Principal Investigator: O. Grigoriev
Institution: Institute of Biophysics, State Research Centre, Moscow, Russia

Program highlights

Understanding the data used to set Russian exposure limits

The purpose of this project was to verify Soviet-era research which reported RF effects on the immune systems and psychological development of rats. These reports were influential in setting exposure limits and remain the basis of modern Russia's RF standards.

None of these studies had been published in major international journals in part because Russia used a completely different metric to measure RF energy compared with the Western world which used SAR.

This caused confusion and uncertainties which the WHO International EMF Project considered important to replicate with modern laboratory methods.

BLOOD BRAIN BARRIER

In the early 20th century scientists investigating interfaces between blood, brain and spinal fluid injected adult animals with blue dye. The dye stained almost all body tissues, except much of the brain which retained its original colour.

These scientists had discovered the existence of the blood-brain barrier (BBB), a semi-permeable gate between the brain and bloodstream.

The barrier plays a very important role in maintaining the optimal fluid environment of the brain acting like a very fine sieve allowing only very small molecules to pass through. Toxins in the blood, along with large and highly charged molecules are filtered to maintain a constant environment for the brain.

High blood pressure, infection and trauma can disrupt the normal functioning of the BBB. Exposure to ionizing radiation is also known to increase leakage of this natural barrier that protects the brain from toxic substances.

The possible effects of radio frequency (RF) exposure from mobile phones (even though it is non-ionizing in nature) on the BBB and the potential for resulting disease of the nervous system tissue has long been an issue of scientific interest in RF research, with the early studies yielding a variety of results.

In response to these early results, the World Health Organization's 2003 Research Agenda for Radio Frequency Fields identified the urgent need to assess the accuracy and reproducibility of the studies and other neuropathologies (e.g., dura mater inflammation, dark neurones), which resulted in additional research of which the MWF also played a part (see 4.4 below).

On top of this, some critics claimed that the Soviet-era ethos saw scientists receive more funding and freedom to focus their studies on radiation effects on the worker, free from corporate interference. They claimed the Russian understanding of health effects was advanced, evidenced by tighter exposure limits than in Western countries.

The original researchers didn't detail how the results were obtained so the designers of the new study agreed on a protocol which was followed in two separate laboratories, in Moscow and Bordeaux, both attempting to verify the USSR reports. Unfortunately the results were mixed with both labs getting different results, limiting its overall value in assessing the earlier Soviet-era research. However, the project was a good example of the MWF's efforts to promote international collaboration between scientists and the project was supported by the French Health and Radiofrequency Foundation, CNRS, the MWF and the GSM Association.

PROGRAM 4
IN VIVO STUDIES

In Latin the term *in-vivo* means 'within the living' and refers to testing in living organisms or cells. The term *in-vitro* translates to 'in the glass' and refers to test tube studies where cells and molecules are tested outside their normal biological context.

Studies in tissues and living cells play a supporting role in health risk assessments. They allow researchers to test the plausibility of a theory by testing biological mechanisms which help identify cause and effect relationships.

Test tube studies are useful to explore possible mechanisms and biological processes but it is often difficult to see how such results can be applied to human health. Cellular studies have the potential to identify clear responses to RF EMF exposures and therefore can be used as a screen for possible effects of new RF signals.

All the studies in this MWF Program sought to replicate the findings of earlier studies.

Studies undertaken

Activity of the enzyme ODC in cell cultures following RF exposure

Laboratory 1
Principal Investigator: B. Billaudel
Institution: CNRS, France

Laboratory 2
Principal Investigator: J. Naarala
Institution: Univ Kuopio, Finland

Genotoxicity studies following RF exposure

Laboratory 1
Principal Investigator: C. Marino
Institution: ENEA, Italy

Laboratory 2
Principal Investigator: D. Lloyd
Institution: NRPB, United Kingdom

Spatial working memory in rodents

Laboratory 1
Principal Investigator: Z. Sienkiewicz
Institution: NRPB, United Kingdom

Laboratory 2
Principal Investigator: J.-C. Cassel
Institution: ULP, France

Investigation of 900 MHz Electromagnetic Radiation for Effects on Permeability of the Blood Brain Barrier
Principal Investigator: J. Morris
Institution: Battelle, United States

Heat Shock Protein (HSP27) Study
Principal Investigator: J. Roti Roti
Institution: Washington University, United States

Program highlights

Spatial working memory in rodents

There has been an ongoing concern that mobile phones cause headaches, sleep problems and other cognitive effects. In 1994 a group of researchers (Lai *et al.*) found that rodents exposed to 2.45 GHz microwaves for 45 minutes performed worse in a maze designed to test their orientation and ability to remember their surroundings.

Despite the significance of the findings there had only been one attempt to replicate this study and the experiment was a failure.

These two MWF supported studies replicated the Lai *et al.* study but found exposed rats performed at a comparable level in the maze to non-exposed rats. The results suggest that exposure to RF EMF under the conditions of the replication did not affect cognitive function.

Investigation of 900 MHz electromagnetic radiation for effects on permeability of the Blood Brain Barrier

At the time of this study, radiofrequency effects had been reported in the blood brain barrier of animals exposed to RF signals. However, considerable controversy existed regarding these effects, and a comparable number of studies had similarly reported no observable effects.

This study attempted to replicate earlier work on the integrity of the Blood Brain Barrier (BBB) in animals exposed to Global System for Mobile Communications (GSM) RF signals, while also incorporating improvements in the study design including multiple exposure levels along with positive controls and a blind experimental design.

The results of this study suggested GSM RF signals have no influence on the BBB in rodents however inconsistencies in the study hampered the ability to interpret the data.

Heat Shock Protein (HSP27) Study

A heat shock protein (HSP) is a protein which is activated in a living cell in response to a rise in temperature above normal level.

HSPs have two key roles – they keep other cellular proteins in order, stopping them from misassembling, and they activate immune responses by sounding the alarm on cancerous or infected cells.

It is well documented that HSPs can be induced by environmental stresses such as heat, inflammation, tissue damage and infection. Some of these conditions may also cause cancer, although many of these conditions normally do not.

This study looked at the potential effects of RF energy on the wide range of molecular changes that cells undergo in response to environmental stresses in animal cells and attempted to replicate earlier findings.

The results showed no significant change in the levels of HSP following exposure to the same types of RF fields that standard wireless networks use.

PROGRAM 5
HUMAN STUDIES

With the rapid uptake of mobile phones there have been concerns that they may cause a number of personal symptoms including headache, skin irritation and fatigue.

Some individuals who experience these symptoms believe they are caused by an increased sensitivity to electromagnetic fields as a result of daily mobile phone use.

There have been several previous studies looking at whether exposure to RF energy can be associated with headaches, high blood pressure and has any impact on the quality of our sleep.

The previous studies looking at possible health and physiological effects from mobile phone use had been inconsistent, short in length and participant's personal characteristics had been poorly defined which meant results were difficult to interpret.

Studies undertaken

The effects of 900MHz GSM wireless communication signals on subjective symptoms, physiological reactions, alertness, performance and sleep
Principal Investigator: B. Arnetz
Institution: Uppsala University, Sweden

Further research was needed to understand this phenomenon known as 'electro hypersensitivity'. This project was not designed to be a specific replication of earlier studies in this area, but it looked at the same questions using an improved study design and exposure systems.

The objective was to establish whether exposure to RF caused by mobile phone use during the day had any effect on a large range of self-reported symptoms including:

- Headache
- Stress hormones
- Vertigo
- Skin irritation
- Sensation of heat
- Blood pressure
- Heart rate and heart rate variability
- Sleepiness and performance

The experiment involved a total of 75 people aged 18 – 45, with a mixture of people experiencing symptoms and healthy controls. Some subjects were exposed to three hour long mobile phone exposure and others were not exposed (also known as a 'sham' exposure). The study was double-blinded meaning both the participants and the scientists didn't know who was and who wasn't exposed.

The study found no significant link between RF exposure and specific symptoms experienced by the group who associated them with everyday phone use. Participants, regardless of whether they reported mobile phone related symptoms or not, were not able to correctly define the true RF exposure status to a larger degree than would be expected by chance. The results showed that headache was more commonly reported after RF exposure than sham and surprisingly, that there was higher occurrence of headache in the non-symptom group.

PROGRAM 6
MECHANISM PROGRAM

It is widely accepted that if you apply excessive heat to the human body there will be a biological effect, otherwise known as a thermal effect. If a person comes into contact with fire, the energy from the flames is strong enough to damage tissue and a burn occurs.

Concerns have been raised about whether RF EMF emitted from wireless devices can cause biological effects in the absence of measurable thermal effects. Such effects are referred to as non-thermal effects and for them to occur there must be a mechanism within the body that allows the energy to have an impact without a thermal response.

We know that extremely high frequency radiation (ionizing) such as gamma rays have enough energy to break molecular bonds. However, RF EMF do not have sufficiently high frequency, or intrinsic energy, to have a comparable molecular effect.

Some people have been concerned that potential non-thermal mechanisms were ignored by the RF exposure standards. To clarify uncertainties, this program saw five prominent physical scientists examine whether biological mechanisms existed which would allow RF EMF to effect cells and molecules in the human body without any thermal impact.

Studies undertaken

Effects of RF fields on ion transport and on DNA
Principal Investigator: D. Astumian
Institution: University of Maine, United States

Modeling and simulating RF energy absorption in cellular systems
Principal Investigator: J.C. Weaver
Institution: Massachusetts Institute of Technology, United States

Energy accumulation in biologically active models due to RF absorption and possible biological effects
Principal Investigator: E. W. Prohofsky
Institution: Purdue University, United States

A theoretical investigation of the effects of low-level RF fields on molecular transport, chemical reaction rates and rectification
Principal Investigator: F. Barnes
Institution: University of Colorado, United States

Micro and macroscopic study of RF absorption
Principal Investigator: K. Foster
Institution: University of Pennsylvania, United States

A variety of models for RF interactions with biological molecules, cells, and tissues were evaluated to set limits based on established physical principles. These models include but are not limited to, effects on ion transport, reaction rates and chromosome breakages.

As an example of the relevance and findings of this program, the project by Prof. Earl Prohofsky looked at issues arising from claims that the RF energy from mobile phones could be absorbed by molecules in the body and affect their normal functions as a result.

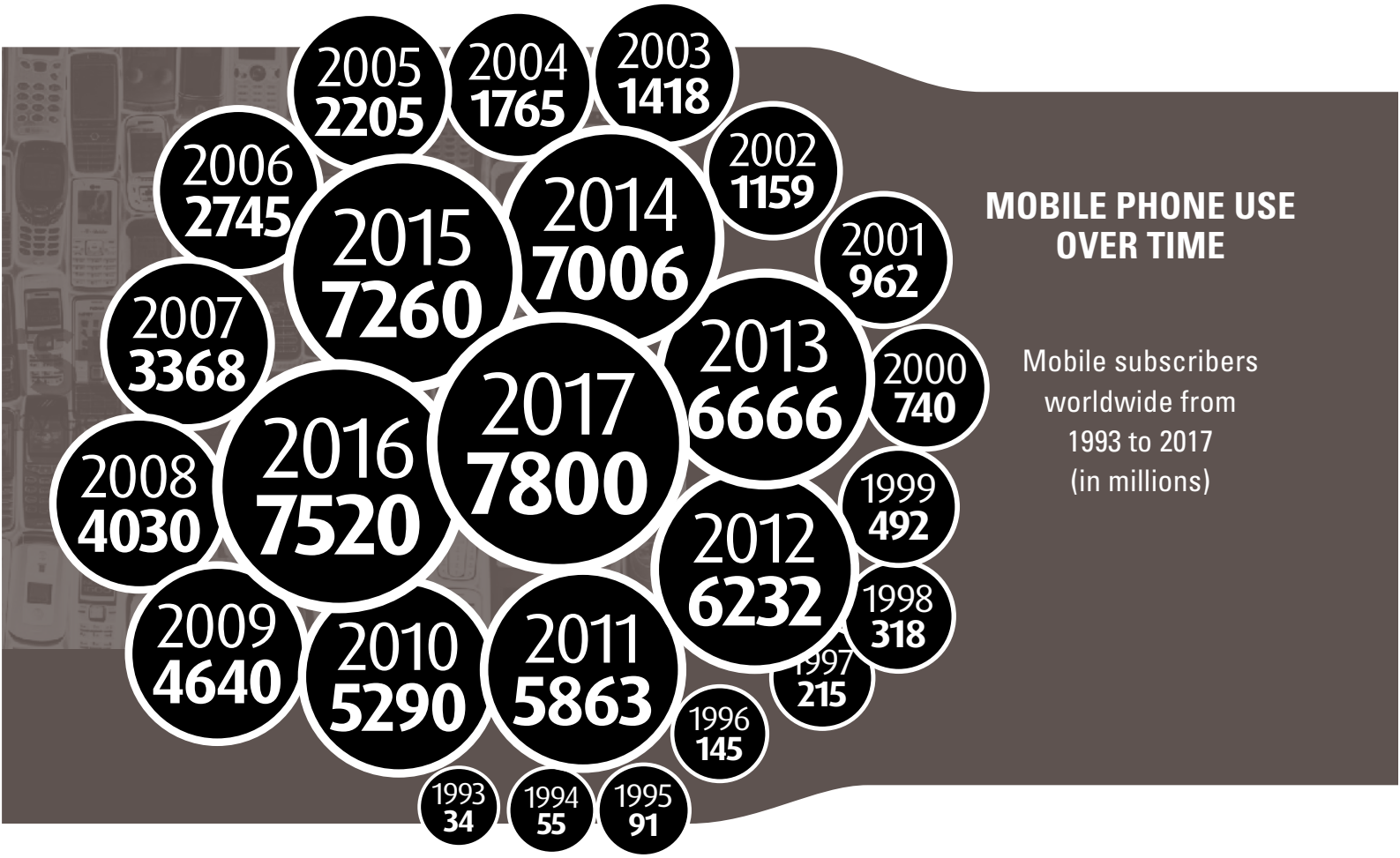
The project found to the contrary, that at the frequencies used for wireless communications, there does not appear to be any mechanism for resonant RF energy absorption that could deliver energy to a localized molecular site.

All the studies in this program revealed that human exposure to RF fields such as those emitted by wireless devices on a daily basis were too weak, and at frequencies too low, to have any chemical or structural effect on molecules.

PROGRAM 7
NATIONAL RESEARCH PROGRAMS

The MWF's Program areas tend to focus in on specific types of scientific research investigating defined aspects about mobile phones, health and safety. In this regard, Program 7 is unique from the other program areas because of the great diversity in research methods and subjects investigated in the 28 individual projects that made up the United Kingdom's Mobile Telecommunications and Health Research Program (MTHR).

MTHR was one of the largest national research programs when it was first established in 2001 and was jointly funded by the UK government and the mobile phone industry including the MWF. The



MOBILE PHONE USE OVER TIME

Mobile subscribers worldwide from 1993 to 2017 (in millions)

UK Department of Health coordinated the £13.6 million program and an Independent Programme Committee provided a firewall to ensure scientific independence.

The overall theme of the program was to investigate possible health impacts of mobile telecommunications (including mobile phones and base stations) on people. The diverse program of 31 studies included epidemiological, human, cellular, and dosimetric studies investigating a wide range of possible human health effects in areas including brain cancers, nervous system, brain function, electrical hypersensitivity, and biological mechanisms.

The program included social studies on risk communication to assess public understanding of scientific uncertainty and reactions to government advice on mobile phones and base stations and also studies on mobile phones and driving.

Studies undertaken

- A Case-Control Study of Brain Tumors and Acoustic Neuromas in Relation to Use of Mobile Phones
- UK Case-Control Study of Adult Brain Tumors
- Cohort Study of Mobile Phone Users (Pilot Study)
- A Case Study of Leukaemia in Relation to Use of Mobile Phones
- Case-Control Study of Cancer Incidence in Early Childhood and Proximity to Mobile Phone Base Stations
- Mobile Cellular Communication and Cognitive Functioning
- The Effects of Mobile Phone Radiation on Blood Pressure
- Study to Evaluate the Effects of Mobile Telephone Usage on Labyrinthine Function
- The Effect of Mobile Phone Use on Symptoms and Neuroendocrine Function in 'Normal' and 'Hypersensitive' Users
- Conversations in Cars: The Relative Hazards of Mobile Phones
- The Effects of Radiofrequency Radiation on Brain Physiology and Function
- Cellular and Sub-Cellular Effects of Microwave Radiation in Simple Model Organisms
- The Effect of Pulsed Radiofrequency Electromagnetic Fields on Redox Signalling and Calcium Homeostasis
- Measurement of the Dielectric Properties of Biological Tissue in Vivo at Microwave Frequencies
- Interaction of Emerging Mobile Telecommunications Systems with the Human Body
- Assessment of the SAR in the Head from TETRA Handsets
- Personal Dosimetry of RF Radiation

Program highlights

The precautionary approach - Assessing the impact of precautionary advice

In the early 2000s there was a growing imperative on policy makers and regulators to be transparent in public health communication about the uncertainties and risks of base stations and mobile phone use.

At the time there was widespread academic and policy debate about the true impact of precautionary advice. Some believed it actually increased public perception of risk which was the opposite of the intended effect. Barnett *et al.* conducted two studies examining public responses to precautionary information to try and clarify some of the uncertainties.

The first study conducted a national survey to explore whether two leaflets produced by the Department of Health about health uncertainties related to mobile phones and base stations were associated with increased concern or reassurance.

The second study was a questionnaire which explored the way in which people conceptualize precaution and the way in which they react to precautionary advice.

While the precautionary principle adopted in the two leaflets (of which around nine million copies were distributed) aimed to reduce concern, the research suggested precautionary advice generally caused concern instead of providing reassurance.

The results suggested that UK government's precautionary approach may be considered valuable, but against a backdrop of low trust in government, the public didn't necessarily view the approach as good governance and it failed to reduce their concerns.

In light of the increasing imperative for transparent communication of uncertainty, Barnett *et al.* identified the precautionary approach was likely to prove an ongoing policy challenge for government.

Hypersensitivity - Psychological factors associated with self-reported sensitivity to mobile phones

Ever since the rapid uptake of mobile phones in the mid-1990s there has been a perceived association between usage and the onset of nonspecific symptoms such as headaches, fatigue, and concentration problems.

The phenomenon is commonly referred to as 'electromagnetic hypersensitivity' although the WHO now refers to by the more general term Idiopathic Environmental Intolerance (IEI) and describes the subjective symptoms felt by a small percentage of the population who report being uniquely 'sensitive' to electromagnetic fields.

This study assessed the health of 52 people who reported sensitivity to mobile phones, 19 who reported hypersensitivity, and 60 non-sensitive controls. The participants completed a questionnaire assessing phone use, psychological health, symptoms of depression, modern health worries, general health status, symptom severity, and the presence of other medically unexplained syndromes. At the time, it was one of the largest and most rigorous studies of its kind and it found no support for the notion that exposure to mobile phone signals caused the aversive symptoms reported.

A second study supported through the MTHR program saw separate researchers look at whether symptoms might be caused by the minimal and continuous exposure to base stations one might experience in everyday life. Participants were asked whether a nearby base station was turned on or off but neither the hypersensitive or control groups were better at identifying the correct state.

While no accepted bioelectromagnetic mechanisms exist to explain this correlation, health experts accept that the symptoms felt by suffers are real. This report recommended clinicians and researchers should pay greater attention to electromagnetic hypersensitivity sufferers.

Child exposure - Mobile phone base stations and early childhood cancers: case-control study

In the United Kingdom, the number of mobile connections had risen from just under nine million in 1997 to almost 74 million in 2007. Public concern existed about the exposures of young children to mobile telephony, as the developing

brain and other tissues might be more susceptible than in adults to potential effects of low level exposures to RF EMF.

In response to public concern, the researchers carried out a case-control study of early childhood cancer sufferers and estimated maternal exposures to radiofrequency during pregnancy from macro cell base stations in Great Britain.

Researchers examined 1,397 cases of cancer in children aged 0-4 from the National Cancer Registry from 1999 - 2001 and 5,588 birth controls from National Birth Register, individually matched by sex and date of birth with four controls per case.

The results found there was no association between risk of early childhood cancers and estimates of the mother's exposure to mobile phone base stations during pregnancy.

PROGRAM 8
SOCIAL AND SOCIETAL IMPACTS PROGRAM

Mobile phones have provided basic communications services to billions of people worldwide for the first time in human history. With rapid uptake of any technology there will be wide-ranging impacts on society.

When the first handheld mobile phone was put on the market in 1983, no one could have predicted the profound impact modern day smartphones would have on our lives. This is particularly true for people in the developing world where mobile networks are the primary communications infrastructure allowing instant communications in countries where before there was virtually none.

Mobile phones have allowed for faster responses in emergency situations, provided means for families to stay in contact and helped people access new opportunities.

On the other hand, the uptake of mobile phones among some user groups has created hotbeds for cyberbullying and the phenomenon of 'nomophobia'; the fear of being without your mobile phone.

Regardless of whether the impacts are positive or negative, many of the ways mobile phones affect society have in the past been assumed and not well documented.

As part of the MWF's ongoing commitment to support research, a number of research projects investigating the social implications of the use of mobile phones have been supported over the years.

Unlike the other program areas, Program 8 boasts a greater diversity in its subject material ranging from research into the impact of mobile phones on emergency response times, health, wellbeing and family relationships to risk communication and public awareness of precautionary advice.

The potential health impacts of increased mobile phone use for contacting emergency services in life threatening situations
Principal Investigator: A. Briggs
Institution: Kadoorie Centre for Critical Care Research and Education, UK

Mobile communication technology: An international study of the impacts of precautionary measures on risk perception and trust
Principal Investigator: P. Wiedemann
Institution: Research Centre Juelich, INB-MUT, Germany

An Assessment of the Social Impact of Mobile Telephony in Brazil
Principal Investigator: R. Sabbatini
Institution: The Edumed Institute, Brazil

Mobile Telephony and Health: Public Perceptions in Great Britain
Institution: IpsosMORI, United Kingdom

Handsets: Impact of Knowledge and Voluntary Precautionary Recommendations on Risk Perception
Principal Investigator: M. Siegrist
Institution: ETH Zurich, Switzerland

The Role of Mobile Phones in Family Relationships
Principal Investigator: D. Roker
Institution: Trust for the Study of Adolesence (now Young People in Focus), UK

Improving Mobile Phone Speech Recognition by Personalized Amplification: Application in People with Normal Hearing and Mild-to-Moderate Hearing Loss
Principal Investigator: A. van Hasselt
Institution: The Chinese University of Hong Kong, Hong Kong.

An Evaluation of Public Understanding of Safety Compliance Information for Mobile Phones
Circle Research, United Kingdom

The potential health impacts of increased mobile phone use for contacting emergency services in life threatening situations

Many health service professionals refer to the 'golden hour' following an emergency and the health benefits of receiving treatment during that period.

This large epidemiological study investigated whether the growing use of mobile phones is associated with shorter emergency services response times in the case of a life threatening situations, and the degree to which it leads to better health outcomes.

The researchers analysed patient records from two county hospitals in the UK from 1995-2006 for all emergency dispatches to immediately life-threatening (Code Red) events and compared the patients outcomes based on whether a mobile phone or landline was used to call for help.

They found around 137 more lives are saved per 100,000 patients when emergency services are called from a mobile phone in the critical moments after the onset of an acute illness or injury compared to a landline phone.

The study found that patients are more likely to survive when emergency services were called from a mobile phone rather than a landline and the likelihood of being admitted to the emergency department was also reduced.

Mobile telephony and health: Public perceptions in Great Britain

Questions about the safety of mobile phones have been covered extensively in the UK media coinciding with increasing public use. While majority of media reports are accurate and balanced, some reports have unfortunately been misleading and incorrect.

This project involved the MWF, the GSM Association and the UK Mobile Operators Association (MOA) who commissioned Ipsos MORI, a leading market research company in the UK, to analyze trends in the British public's awareness and perceptions of the alleged health risks and assess the effect of media coverage up to 2004. The MOA has continued publishing updates since then.

Among its detailed findings, the study found that people were more

concerned about base stations than handsets. However, concerns regarding mobile phones and base stations are also not a 'top of mind' issue for most people and concerns regarding handsets were trending downwards.

The role of mobile phones in family relationships

Mobile phones have undeniably become a big part of the way family members communicate with one another in the 21st century but what are the benefits and disadvantages of use and how do they impact safety, surveillance and privacy? The Trust for the Study of Adolescence (TSA) examined 60 families containing young people aged 11-16 on how mobile phones (including texting) are used in communications between teenagers and their parents.

The study found that young people and parents see mobiles as a key way for families to keep in touch. Mobile phones were also seen as tools to monitor and ensure young people's safety, while some participants said it gave a false feeling of security.

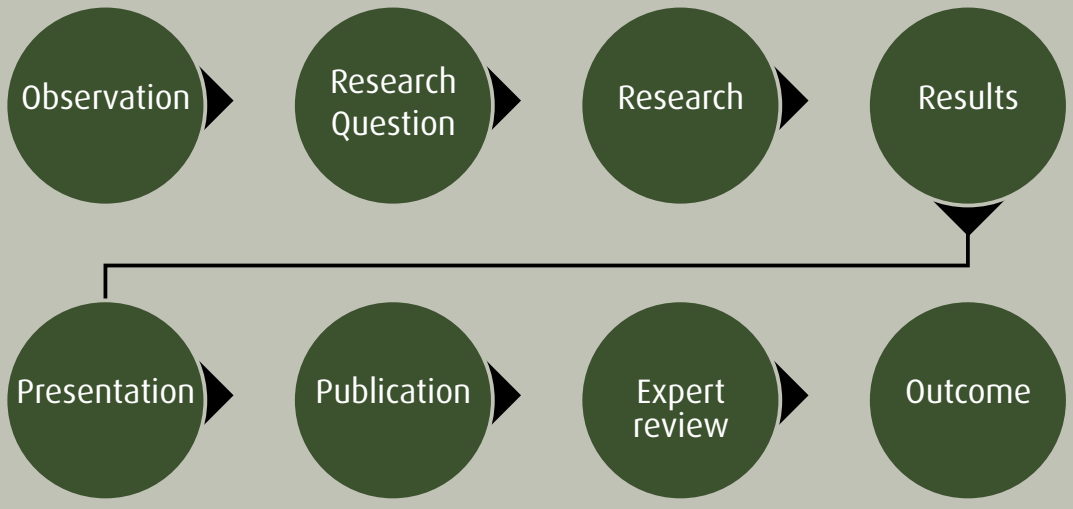
Some participants felt there was a downside in relation to some young people withdrawing from family activity and into their own social worlds.

Improving mobile phone speech recognition by personalized amplification: Application in people with normal hearing and mild-to-moderate hearing loss

With around 38 percent of the world's population experiencing hearing problems, this project looked at the impact of mobile phone assisted hearing devices, particularly with regards to speech recognition.

Listening and comprehension during a mobile phone call can be more difficult because there is an absence of visual and some acoustic cues.

OVERVIEW OF THE SCIENTIFIC RESEARCH PROCESS



(These might include: Incorporation into Research database, Subjected to confirmation/replication studies, or incorporated into Standards, etc)

Background noise at either end of the conversation doesn't help either.

For those with hearing loss, these various factors can make the conversation difficult to hear and understand. Assisted hearing technology within devices allows the user to adjust the sound output to suit their own hearing profile.

The results of the study found that assisted hearing technology provided better speech recognition via the mobile phone both in quiet and in noisy environments for people with hearing impairment between 8 to 10 percent, as well as for people with normal hearing. The improvement in speech recognition was significantly better for people with hearing impairment.

PROGRAM 9 – Emerging and future technologies program

As smartphones and wireless devices are becoming increasingly sophisticated, global mobile data demands are increasing exponentially. With increased demand, radiofrequency spectrum is becoming a scarce resource because so many wireless devices are now occupying the 3 kHz – 6 GHz band which limits future growth.

Carriers urgently need to increase network capacity and improve spectrum efficiency. Ways they can do this is by deploying the new and even more efficient 5G networks, utilizing frequency bands above 6 GHz, and use small cell infrastructure to supplement existing base stations, particularly in urban areas.

The use of higher frequency bands sees new challenges arise in terms of electromagnetic field (EMF) exposure assessments because the fundamental exposure metrics are changing from SAR to power density (PD).

In recent years the MWF has broadened its scope to give stronger focus to the introduction of 5G and the Internet of Things (IoT) which has seen increased research in this area aiming to enhance the understanding of dosimetric aspects of 5G and small cells, and develop efficient and accurate procedures for compliance testing at frequencies above 6 GHz.

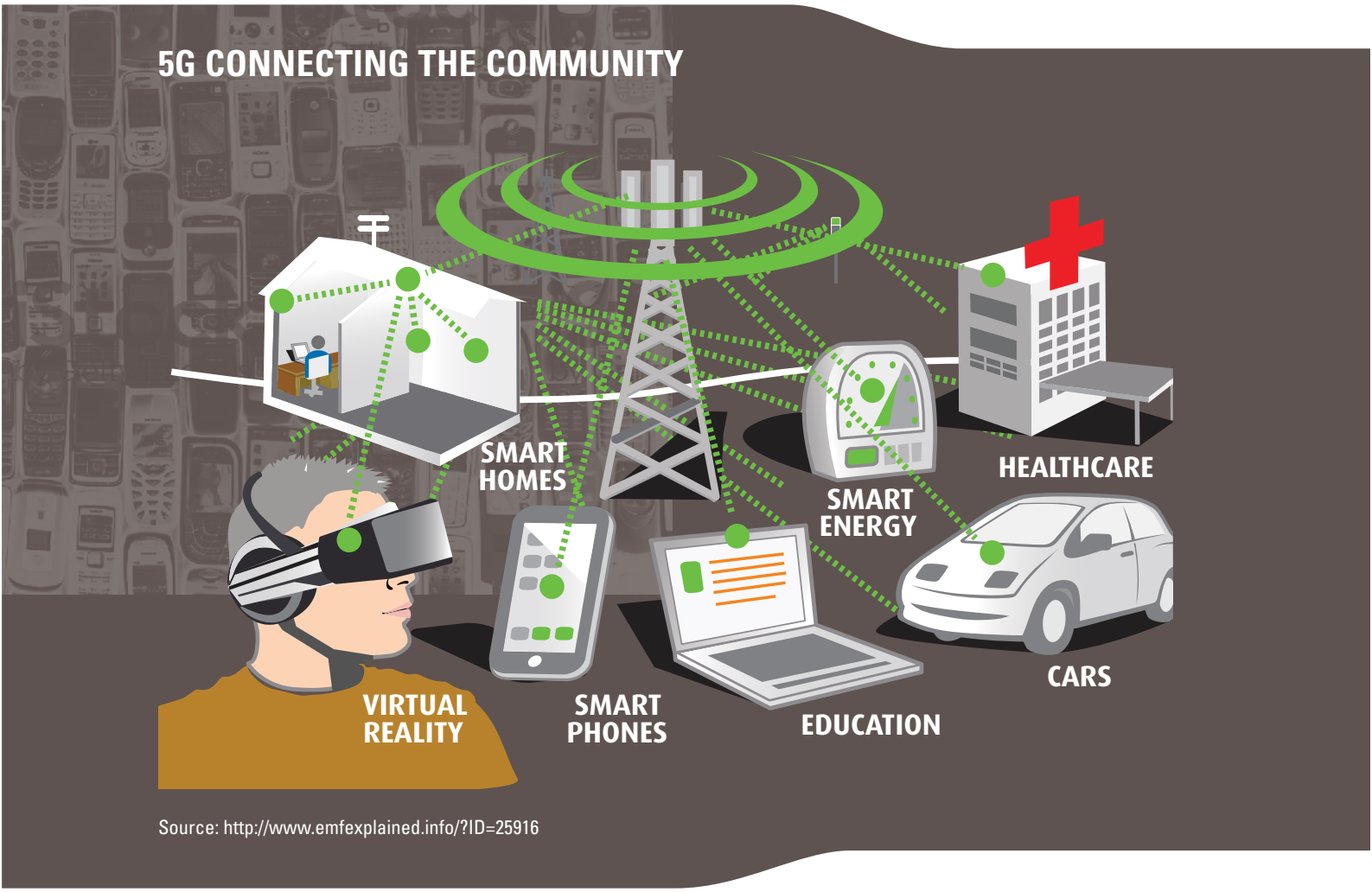
Studies undertaken

Wi-Fi and Health: Review of Current Status of Research
Principle investigator: K. Foster
Institution: University of Pennsylvania, USA

Small Cell RF Exposure Measurement Program
Principle investigator: Marnus Van Wyk
Institution: EMSS/Alphawave, South Africa

The transition from SAR to power density

As you move up in the electromagnetic spectrum, the frequency gets higher and the wave lengths get smaller. With shorter wavelength, the depth of penetration of the radio waves in biological tissue decreases. This means frequencies above 6 GHz, which will be used by 5G devices, only penetrate and deposit energy in the skin unlike lower frequencies seen in 3G and 4G, which have a larger depth of penetration. This shallow absorption above 6 GHz explains why standards bodies define limits in terms of power density at higher frequencies rather than SAR.



Exposure Limits and Compliance Assessment Methods for Wireless Devices Operating at Frequencies above 6 GHz
Principle investigator: N. Kuster
Institution: IT'IS, Switzerland

Thermal modelling of near-field exposure from 5G devices'.
Principal investigator: A. Christ
Institution: IT'IS, Switzerland

Millimetre-wave near field measurements for EMF
Principal investigator: M. Gustafsson
Institution: Lund University, Sweden

Study of the correlation between power density and temperature increase
Prinicipal investigator: L. Alon
Institution: New York University, USA

Study highlights

Understanding Wi-Fi

Within the past two decades Wi-Fi has become ever-present in modern society, as it rapidly emerged as the preferred service for supporting local wireless networks.

At the time of this paper, a series of high quality studies had provided a good, but not complete, understanding of the levels of radiofrequency (RF) exposure to individuals from Wi-Fi. The available data confirmed that RF exposures from Wi-Fi and wireless networks are far below international RF EMF exposure limits for RF energy. However the limited number of technology-specific health effects studies were very mixed in terms of quality and outcome.

The review made suggestions on future research on the topic and concluded that a full-scale research program in search of

biological effects of Wi-Fi exposures, similar to the research undertaken with mobile telephones, was considered unnecessary.

Measuring small cell exposures

With an increasing number of mobile subscribers and devices using the available frequency bands, the capacity needs will be addressed by introducing new bands at higher frequencies above 6 GHz, so called millimetre waves.

The drawback of millimetre is the shorter transmission range, which is partly due to the fact that they are easily obscured by buildings or obstacles in urban environments. To overcome this challenge small cells will be deployed to create direct connections over shorter distances. Small cells are also already used in current networks using frequency bands below 6 GHz to increase the capacity.

There have been a number of studies undertaken to date that have largely focused on emissions from mobile phones and macro base stations. While most of this information is applicable to small cells in a general sense, what was missing was an actual practical study of RF EMF exposure from small cell access points in real world settings.

This project performed measurements at 98 sites in South Africa, the Netherlands and in Italy in 2017.

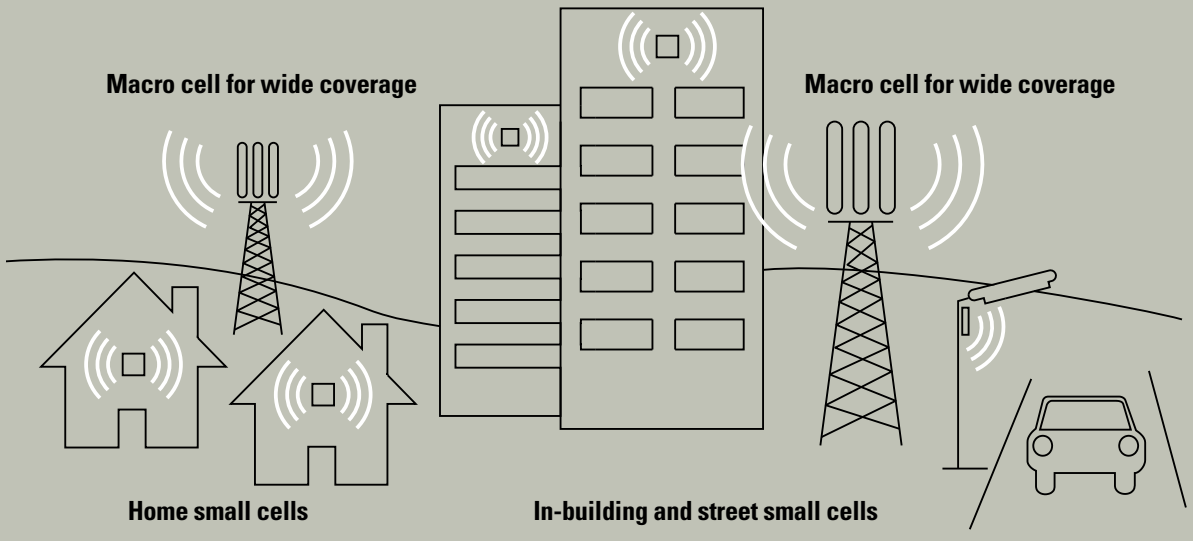
The measurements undertaken covered a broad range of typical installations including antennas mounted inside buildings, outdoor antennas mounted on low rise structures such as bus stops, and outdoor antennas mounted on structures above four metres such as lamp posts and buildings. The results highlighted that all the sites operate well below international exposure limits.

Enhancing compliance testing for 5G devices

When any new wireless technology is introduced to the public it is important to understand whether the new technology challenges the basis of the current exposure standards set by international and national organizations and if so, to revise them accordingly.

The first part of this study sought to provide an overview of the health effects and basis for the current limits for frequencies above 6 GHz. The project also sought to determine the safety margin for the current limits, identify which standards

EXAMPLES OF TYPICAL SMALL CELL INSTALLATIONS AND USES



provided the most accurate limits and suggest possible improvements to the power density limits applicable for 5G devices operating above 6 GHz.

Using a multilayered skin model the researchers found that the absorption of RF energy at frequencies greater than 6 GHz occurs in the skin which suggests that a skin temperature increase, rather than a core temperature increase, should be the focus of exposure standards.

IT'IS is one of the premier RF dosimetry and measurement research centres in the world producing state-of-the-art exposure systems. The transition from SAR to power density measurement of EMF has introduced difficulties in evaluating exposure with existing systems. Part two of this project sought to define appropriate power density equivalents in measuring human exposure to 5G devices operating at higher frequencies.

Testing 5G devices with smart antennas

Fifth generation devices operating in the millimetre wave range will have 'smart antennas' which will use efficient, directional connection to nearby base stations instead of the full 360 degree transmission seen in previous generations. A way to conceptualize this is to imagine the beam of light from a handheld torch moving in different directions through the darkness connecting to surrounding trees (base stations).

This study looked at the skin temperature increase caused by exposure to these fields of 5th generation wireless devices. The researchers were trying to establish the relationships between different types of antennas, interaction with the skin models and temperature increases.

The study found the deterioration of the reactive field within the first few millimetres from the antenna of devices is significant. Its impact on the energy absorption and temperature increase is very small and can be dismissed.

Measuring power density

In this project, a methodology to reconstruct the power density near an RF source based on measurements further away from the source was investigated for 28 and 60 GHz antennas. The applied methodology showed that back-projection can be used as a relevant technique to assess compliance with power density limits in close proximity of a 5G wireless device.

Power density and temperature increase

This study is looking at the correlation between power density and temperature increase by utilising MRI scans of participants immediately after exposure to determine the real temperature increase experienced. Exposures will be undertaken at 28, 40 and 60 GHz. Preliminary experiments on phantoms and a pilot in vivo study were conducted at 42.25 GHz.

Conclusion

Achievements over 20 years of MWF research program

When the MWF was founded in 1998 in response to the WHO EMF Research Agenda there was significant public concern about possible health effects from radio waves emitted from mobile phones and base stations.

Over the years there has been a significant shift in the scientific understanding about numerous aspects of EMF emitted from mobile phones and their effects on humans which has closed the knowledge gaps identified in the various updates of the Research Agenda.

As the WHO has stated:

'Scientific knowledge in this area is now more extensive than for most chemicals.'[7]

Through its nine Research Programs, the MWF has facilitated joint funding between governments, industry and international health organizations on key research projects which has contributed to closing the gaps and supporting the development of safety standards and regulations.

The INTERPHONE and COSMOS studies were conceived in response the WHO's call for more high-quality epidemiological studies. These projects are significant because they have addressed direct end points on whether mobile phones cause a range of health effects, including brain cancer.

The huge international collaborative effort of the multiple participating countries and institutions is an achievement in itself and it helps maximize the value of the research and reduce any unnecessary duplication of effort. Where INTERPHONE had limitations (primarily in only assessing risk up to 10 years) COSMOS seeks to improve by looking for any links for up to 25 years of mobile phone use.

Prior to the rodent studies in the MWF's animal research program, there were insufficient published data from long-term animal studies investigating the effects of RF exposure from mobile phone use. The four PERFORM-A and DMBA replication studies addressed direct end points in EMF effects, addressed inter-generational and lifetime exposure questions and played an important role in subsequent European Union health risk assessments.

The dosimetry program has seen the development of state-of-the-art exposure systems and realistic human and tissue models which has been instrumental in improving compliance testing and obtaining consensus around the relevance of the basis of the 10 gram averaging mass used in the SAR standards.

Other projects such as the Inter-laboratory SAR Comparison project which involved fifteen different SAR testing labs around the world, helped in the early days to demonstrate that reproducibility was possible with complex SAR exposure assessments. This project also helped to cement acceptance of the standards that compliance testing is based upon.

The spirit of collaboration has continued over the years with base station measurement and other dosimetry projects, even through to the most recent work on establishing compliance frameworks for 5G.

[7] *What are electromagnetic fields?*, Electromagnetic fields, World Health Organization

Where we are today vs 20 years ago

In health and safety research, there is a public expectation to prove something is safe. This is an impossible task in any field of science as no one can prove a negative. However, there is safety in the absence of any established health effects after such an extensive research effort over the years.

Scientific knowledge on the health effects of radiofrequency fields has come a long way since World War II, and particularly the formation of the WHO International EMF Project in 1996 and the release of its first research agenda the following year.

At the time there was anxiety and speculation that health effects such as cancer, changes in behaviour, memory loss, Parkinson's and Alzheimer's diseases, and many others, were resulting from exposure to mobile phones. The broad level of concern has compelled a lot of research which has been undertaken worldwide in the last 20 years.

Previous Research Agendas have been instrumental in assisting countries and institutions to develop funding priorities in RF EMF research. Numerous issues have now been researched and as the results have come in and the weight of science has been reviewed, many issues have been resolved or flagged as a lower priority.

The international research database on radiofrequency is now over 40 years old and has over 25,000 articles relating to the broader use and impacts of RF, with several thousand specifically relating to mobile communications. The scientific knowledge in this area is indeed extensive and covers a multitude of frequencies, modulations and power levels. Each new generation of technology inevitably invites the question – what do we know about this from a safety perspective? Based on the extensive research database that now exists there is a very sound basis upon which to enjoy wireless technologies today as well as to further develop them for tomorrow.

Lessons learnt from the process

The world has become increasingly reliant on mobile and wireless technologies over the years and this has been matched by an increasing demand for more accountability and transparency in the reporting of research findings and the sharing of research data.

Responding to public concern over the years has helped influenced risk management at national and local levels. Social research projects have provided valuable information on public perceptions of risk and provided insights on how to more effectively communicate about RF-related health issues. We now have a better understanding of the public interpretations of precautionary advice which has paved the way for the development of better risk communication practices which are already being deployed within the industry around the world.

We have also greatly advanced our understanding of dosimetry, improved our measurement methodology and compliance techniques and paved the way for the introduction of new technologies.

The MWF's commitments to continue to support research, develop and enhance relevant standards and compliance frameworks, and to ensure that research results are published wherever possible so the knowledge can be made widely available, remain the same today as they were when the association was established 20 years ago.

Appendix

The MMF's support of scientific research has resulted in the following peer-reviewed publications:

2018

Tissue Models for RF Exposure Evaluation at Frequencies above 6 GHz, Zisken *et al.*, Bioelectromagnetics. 39:173–189, 2018.

ACCEPTED PAPERS

Modeling Tissue Heating From Exposure to Radiofrequency Energy and Its Relevance to Exposure Limits: Commentary, Kenneth R. Health Physics, **Foster** *et al.*

SUBMITTED PAPERS

Total Field Reconstruction in the Near-Field Using Pseudo-Vector E-Field Measurements, Pfeifer *et al.*

RF-Induced Temperature Increase in Layered Skin Tissue for Frequencies from 6 to 100 GHz, Christ *et al.*

2017

Thermal Modelling for the Next generation of Radiofrequency Exposure Limits: Commentary, Foster, *et al.* Health Physics, vol.13, no.1, 2017

SUBMITTED PAPERS

Near-field Measurement Systems for Compliance Testing of Transmitters Operating between 10-110 GHz, Pokovic *et al.*

Novel Total Field Reconstruction in the Near-Field Using Psudo-Vector E-Field Measurements, Pokovic *et al.*

2016

The intracranial distribution of gliomas in relation to exposure from mobile phones: Analyses from the INTERPHONE study. Grell K., Frederiksen K., Schuz J., Cardis E., Feychting M., *et al.*, *Am J Epidemiol.*,Vol. 184, Pg. 818 - 828, 2016.

Investigation of bias related to differences between case and control interview dates in five INTERPHONE countries. Turner M., Sadetzki S., Langer C., Kewski D., Cardis E., *et al., Annals of Epidemiology.*, Vol. 26, Pg. 827 - 832, 2016.

Large Scale Study On The Variation of RF Energy Absorption in the Head & Brain Regions of Adults and Children and Evaluation of the Sam Phantom Conservativeness. J Keshvari1, M., *et al.,* Institute of Physics and Engineering in Medicine, January 2016.

Thermal Response of Human Skin to Microwave Energy: A Critical Review. Foster *et al., Health Phys.,* 2016.

Thermal Response to Tissue RF Exposure from Canonical Dipoles at Frequencies for Future Mobile Communication Systems. K. Foster, D. Colombi, *Electronic letters,* 2016.

Thermal Modeling for the Next Generation of Radiofrequency Exposure Limits: Commentary. K. Foster *et al.*, *Health Phys.,* 2016.

Improving Mobile Phone Speech Recognition by Personalized Amplification: Application in People with Normal Hearing and Mild-to-Moderate Hearing Loss. Kam *et al.*, Ear & Hearing, Vol. 38, N0. 2, e85–e92, 2016

Exposure Assessment of Portable Wireless Devices above 6GHz. Carrasco, *et al.,* 2016.

Evaluation of the Absorption in the Skin at Frequencies above 6GHz. Christ, A, *et al.,* 2016.

Skin Modelling at Millimetre Wave, Ziskin, *et al.,* Bioelectromagnetics, 2016.

2015

SAR Induced by Low and High Directivity Antenna Apertures at Distances Greater than 25 mm from the Body. Md. Anas B. *et al. Applied Computational Electromagnetic Society (ACES) Journal*, Vol. 30, No. 9, pp. 940-951, September 2015.

Pituitary tumor risk in relation to mobile phone use: A case-control study. Shrestha M., *et al., Acta Oncol.,* Vol. 54, Pg. 1159 - 1165, 2015.

Experimental study on the relationship between Specific Absorption Rate and RF conducted power for LTE wireless devices. B. Derat, *Microwave Conference (EuMC), 2015 European*, Paris, pp. 746-748, 2015.

2014

Are Children More Exposed to Radiofrequency Energy from Mobile Phones than Adults? Foster K. R. and Chou C-K., *IEEE Access*, vol. 2, no., pp. 1497-1509, 2014.

2013

Allergy and brain tumors in the INTERPHONE study: pooled results from Australia, Canada, France, Israel, and New Zealand. Turner M. C. *et al*. *Cancer Causes Control*, Vol. 24, Pg. 949 - 960, 2013.

Wi-Fi and Health: Review of Current Status of Research. Foster K. R. and Moulder J. E, Health Phys. 105(6):561-75, December 2013.

2012

Dielectric properties of porcine glands, gonads and body fluids. Peyman A., *et al.* (2012). Phys Med Biol, 57, N339-44.

Cognitive and physiological responses in humans exposed to a TETRA base station. Quinlan T., *et al.* (2012). Bioelectromagnetics, 33(1), 23-39.

Cognitive and physiological responses in humans exposed to a TETRA base station signal in relation to perceived electromagnetic hypersensitivity. Wallace D., *et al.* (2012) Bioelectromagnetics, 33(1), 23-39.

Mobile phone use and incidence of glioma in the Nordic countries 1979-2008: consistency check. Deltour I., *et al*., *Epidemiology*, Vol. 23, Pg. 301 - 307, 2012.

2011

Can exposure to a terrestrial trunked radio (TETRA)-like signal cause symptom? A randomised double-blind provocation study. Nieto-Hernandez R., *et al.* (2011). Occup Environ Med, 68(5). 339-44.

An international prospective cohort study of mobile phone users and health (Cosmos): design considerations and enrolment. Vermeulen R., *et al.* (2011) Cancer Epidemiol, 35(1), 37-43.

Location of gliomas in relation to mobile telephone use: a case-case and case-specular analysis. Larjavaara S., *et al*. *Am J Epidemiol.*, Vol. 174, Pg. 2 - 11, 2011.

Estimation of RF energy absorbed in the brain from mobile phones in the Interphone Study. Cardis E., *et al*. *Occup Environ Med.*, Vol. 68, Pg. 686 - 693, 2011.

Risk of brain tumours in relation to estimated RF dose from mobile phones: results from five Interphone countries. Cardis E. K., *et al*. Occup Environ Med., Vol. 68, Pg. 631 - 640, 2011.

Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Cardis *et al.*,Cancer Epidemiol, 35(5):453-64 2011 Oct.

Analysis of Three-Dimensional SAR Distributions Emitted by Mobile Phones in an Epidemiological Perspective. Deltour I., *et al*. Bioelectromagnetics, Vol. 32, Pg. 634 - 643, 2011.

Thermal aspects of exposure to radiofrequency energy: Report of a workshop, Foster *et al.,* International Journal of Hyperthermia 27(4): 307-319, 2011.

Thresholds for thermal damage to normal tissues: An update. Yarmolenko *et al.,* International Journal of Hyperthermia, 27(4): 320–343 , 2011.

Toward establishment of temperature thresholds for immunological impact of heat exposure in humans. Beachy *et al.,* International Journal of Hyperthermia 27(4): 344–352, 2011.

Hyperthermic effects on behavior. W. C. Wetsel, International Journal of Hyperthermia 27(4): 353–373, 2011.

Sleep after mobile phone exposure in subjects with mobile phone-related symptoms. Lowden *et al.,* Bioelectromagnetics 32(1):4-14. Jan 2011.

Thermal thresholds for teratogenicity, reproduction, and development. Zisken *et al.,* International Journal of Hyperthermia 27(4): 374–387. 2011.

Sensing hot and cold with TRP channels. W. C. Wetsel International Journal of Hyperthermia 27(4): 388–398, 2011.

No need to change from SAR to time-temperature relation in electromagnetic fields exposure limits van Rhoon *et al.,* International Journal of Hyperthermia 27(4): 399–404. 2011.

An International Project to Confirm Soviet-Era Results on Immunological and Teratological Effects of RF Field Exposure in Wistar Rats and Comments on Grigoriev *et al.*, Repacholi *et al.,* Bioelectromagnetics 32:325-330 2011.

An international prospective cohort study of mobile phone users and health (Cosmos): design considerations and enrolment. Schüz *et al.,* Cancer Epidemiol. 35(1):37-43, Feb 2011.

2010

Mobile phone base stations and early childhood cancers: case-control study. Elliott P, Toledano MB, Bennett J, Beale L, de Hoogh K, Best N and Briggs DJ (2010). BMJ, 340, c3077 doi: 10.1136/bmj.c3077

Absence of nonlinear responses in cells and tissues exposed to RF Energy at mobile phone frequencies using doubly resonant cavity. Kowalczuk C, Yarwood G, Blackwell R, Priestner M, Sienkiewicz Z, Bouffler S, Ahmed I, Abd-Alhameed R, Excell P, Hodzic V, Davis C, Gammon R and Balzano Q (2010). Bioelectromagnetics, 31(7), 556-65.

Exposure to GSM RF fields does not affect calcium homeostasis in human endothelial cells, rat pheochromocytoma cells or rat hippocampal neurons. O'Connor RP., *et al.* (2010) PLoS One, 5(7), e11828.

Cole-Cole parameters for the dielectric properties of porcine tissues as a function of age at microwave frequencies. Peyman A., *et al.* (2010) Phys Med Biol, 55, N413-19.

Idiopathic environmental intolerance attributed to electromagnetic fields (formerly "electromagnetic hypersensitivity"): an updated systematic review of provocation studies. Rubin GJ., *et al.* (2010) Bioelectromagnetics, 31(1), 1-11.

Do TETRA (Airwave) base station signals have a short-term impact on health and well-being? A randomized double-blind provocation study. Wallace D., *et al.* (2010) Environ Health Perspect, 118(6), 735-41.

Interaction Between 5 Genetic Variants and Allergy in Glioma Risk. Schoemaker *et al*., American Journal of Epidemiology, Online: May 12, 2010.

Risk and Benefit Perceptions of Mobile Phone and Base Station Technology in Bangladesh. van Ellen *et al*., Risk Analysis, Published Online: 8 Apr 2010.

SAR versus Sinc: What is the appropriate RF exposure metric in the range 1-10 GHz? Part II: Using complex human body models. McIntosh *et al*., Bioelectromagnetics, Published Online: 30 Mar 2010.

Autoimmune Process after Long-Term Low-Level Exposure to Electromagnetic Field (Experimental Results). Part I. Mobile Communications and Changes in Electromagnetic Conditions for the Population. Need for Additional Substantiation of Existing Hygienic Standards. Grigoriev *et al.,* Biophysics, 2010, Vol. 55, No. 6, pp. 1041–1045 2010.

Autoimmune Processes after Long-Term Low-Level Exposure to Electromagnetic Fields (Experimental Results) Part 2. General Scheme and Conditions of the Experiment. Development of the RF Exposure Conditions Complying with the Experimental Tasks. Status of Animals during Long- Term Exposure. Grigoriev *et al.,* Biophysics, 2010, Vol. 55,No. 6, pp. 1046–1049 2010.

Autoimmune Processes after Long-Term Low-Level Exposure to Electromagnetic Fields (Experimental Results) Part 3. The Effect of Long- Term Nonthermal RF EMF Exposure on Complement-Fixation Antibodies against Homologenous Tissue. Ivanov *et al.,* Biophysics, 2010, Vol. 55, No. 6, pp. 1050–1053 2010.

Autoimmune Processes after Long-Term Low-Level Exposure to Electromagnetic Fields (Experimental Results) Part 4. Oxidative Intracellular Stress Response to the Long-Term Rat Exposure to Nonthermal RF EMF**,** Ivanov *et al.,* Biophysics, 2010, Vol. 55, No. 6, pp. 1054–1058 2010.

Autoimmune Processes after Long-Term Low-Level Exposure to Electromagnetic Fields (Experimental Results) Part 5. Study of the Influence of Blood Serum from Rats Exposed to Low-Level Electromagnetic Fields on Pregnancy and Fetal and Offspring Development. Lyaginskaja *et al.,* Biophysics, 2010, Vol. 55, No. 6, pp. 1059–1066 2010.

SAR variation study from 300 to 5000 MHz for 15 voxel models including different postures. Uusitupa *et al*., Physics in Medicine and Biology, 55(4):1157-1176, 21 February 2010.

The influence of the reflective environment on the absorption of a human male exposed to representative base station antennas from 300 MHz to 5 GHz. Vermeeren *et al*., Physics in Medicine and Biology, 55(18):5541, 21 September 2010.

SAR versus Sinc: What is the appropriate RF exposure metric in the range 1-10 GHz? Part I: Using planar body models. Anderson *et al*., Bioelectromagnetics, Published Online: 28 Apr 2010.

The Virtual Family - development of surface-based anatomical models of two adults and two children for dosimetric simulations. Christ *et al*., Physics in Medicine & Biology, 55(2):N23-N38 21 January 2010.

A case-control study of risk of leukaemia in relation to mobile phone use. Cooke *et al.,* Br J Cancer, 103(11), 1729-35. 2010.

Autoimmune Processes after Long-Term Low-Level Exposure to Electromagnetic Fields Part 4. Oxidative Intracellular Stress Response to the Long-Term Rat Exposure to Nonthermal RF EMF. Grigoriev *et al.,* Biophysics, 2010, Vol. 55, No. 6, pp. 1054–1058 2010.

Improved Numerical Modelling of Heat Transfer in Human Tissue Exposed to RF Energy. Prishvin *et al.,* Australasian Physical & Engineering Sciences in Medicine, vol.33, no.4, 307-17 Dec. 2010.

Computational electromagnetic analysis in a human head model with EEG electrodes and leads exposed to RF sources at 915 MHz and 1748 MHz. LM Angelone *et al.,* Radiation Research 174, 91-100, 2010.

Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Cardis *et al*., *Int J Epidemiol*, 39(3), 675-94. 2010.

A comprehensive study of the association between the EGFR and ERBB2 genes and glioma risk. Andersson *et al*., Acta Oncologica, 0(0):1-9, Posted online on 7 May 2010.

2009

Low-intensity microwave irradiation does not substantially alter gene expression in late larval and adult Caenorhabditis elegans. Dawe AS, Bodhicharla RK, Graham NS, May ST, Reader T, Loader B, Gregory A, Swicord M, Bit-Babik G and de Pomerai DU (2009). Bioelectromagnetics, 30(8), 602-12.

Risk factors for pituitary tumors: a case control study. Schoemaker MJ., *et al.* (2009) Cancer Epidemiol Biomarkers Prev, 18(5), 1492-500.

Factors influencing self-report of mobile phone use: the role of response prompt, time reference and mobile phone use in recall. Timotijevic L., *et al.* (2009) Appl Cog Psychol, 23(5), 664-83.

The Role of Mobile Phones in Family Communication. Devitt *et al*., Children & Society, 23(3):189-202, May 2009.

Variation of the dielectric properties of tissues with age: the effect on the values of SAR in children when exposed to walkie–talkie devices. Peyman *et al.,* Phys Med Biol, 54, 227–241. 2009.

Short-term exposure to mobile phone base station signals does not affect cognitive functioning or physiological measures in individuals who report sensitivity to electromagnetic fields and controls. Eltiti *et al.,* Bioelectromagnetics, 30(7), 556-63. 2009.

A confirmation study of Russian and Ukrainian data on effects of 2450 MHz micro-wave exposure on immunological processes and teratology in rats. Poulletier de Gannes *et al.,* Radiat Res 172:617–624. 2009.

Effects of exposure to DAMPS and GSM signals on Ornithine Decarboxylase (ODC) activity: I. L-929 mouse fibroblasts. Billaudel *et al.,* International Journal of Radiation Biology, 85(6): 1-9, June 2009.

Effects of exposure to DAMPS and GSM signals on Ornithine Decarboxylase (ODC) activity: II. SH-SY5Y human neuroblastoma cells. Billaudel *et al.,* International Journal of Radiation Biology, 85(6), June 2009.

Assessment of induced radio-frequency electromagnetic fields in various anatomical human body models. Kühn *et al*., Physics in Medicine & Biology, 55(4):875-890, 21 February 2009.

The relation between the specific absorption rate and electromagnetic field intensity for heterogeneous exposure conditions at mobile communications frequencies. Neubauer *et al*., Bioelectromagnetics, Published Online: 23 June 2009.

Correlating Threshold Power With Free-Space Bandwidth for Low-Directivity Antennas. Sayem *et al*., IEEE Transactions on Electromagnetic Compatibility, 51(1):25-37, February 2009.

Determinants of mobile phone output power in a multinational study: implications for exposure assessment. Vrijheid *et al. Occup Environ Med*, 66(10), 664-71. 2009.

Mobile phone exposure and spatial memory. Wiholm *et al.,* Bioelectromagnetics 30:59-65, 2009.

Exploring exposure to mobile-phone electromagnetic fields and psychophysiological and self-rated symptoms. Arnetz *et al.,* Psychosom Med. 71(1), 2009.

Risk of pituitary tumours in cellular phone users: a case-control study. Schoemaker *et al.,* Epidemiology, 20(3), 348-54. 2009.

Absence of genotoxic potential of 902 MHz (GSM) and 1747 MHz (DCS) wireless communication signals: In vivo two-year bioassay in B6C3F1 mice. Ziemann *et al*., International Journal of Radiation Biology, 85(5):454-464, May 2009.

Recall bias in the assessment of exposure to mobile phones. Vrijheid *et al*., Journal of Exposure Science and Environmental Epidemiology, 19(4):369–381, May 2009.

The estimation of 3D SAR distributions in the human head from mobile phone compliance testing data for epidemiological studies. Wake, *et al*., Physics in Medicine & Biology, 54(19):5695-5706, 1 September 2009.

History of allergic disease and epilepsy and risk of glioma and meningioma (INTERPHONE study group, Germany). Berg-Beckhoff *et al*., European Journal of Epidemiology, 24(8): 433-440, August 2009.

MNS16A minisatellite genotypes in relation to risk of glioma and meningioma and to glioblastoma outcome. Andersson *et al*., International Journal of Cancer, 125(4): 968-972, 2009.

Risk of pituitary tumors in cellular phone users: A case-control study. Schoemaker *et al*., Epidemiology, 20(3):348-354, May 2009.

Validity of self-reported occupational noise exposure. Schlaefer *et al*., European Journal of Epidemiology, 24(8):469-475, August 2009.

2008

Do the electromagnetic fields generated by mobile-phone base stations have short-term effects on health? A response to commentaries. Eltiti S, Wallace D, Zougkou K, Russo R, Joseph S, Russo R and Fox E (2008). Environ Health Perpect, 116, 64-5.

Can evidence change belief? Reported mobile phone sensitivity following individual feedback of an inability to discriminate active from sham signals. Nieto-Hernandez R., *et al.* (2008). J Psychosom Res, 65(5), 453-60.

Psychological factors associated with self-reported sensitivity to mobile phones. Rubin GJ., *et al.* (2008) J Psychosom Res, 64 (1), 1-9.

Mobile telephone use effects on peripheral audio vestibular function: a case-control study. Bamiou DE, Ceranic B, Cox R, Watt H, Chadwick P and Luxon LM (2008). Bioelectromagnetics, 29(2), 108-17.

Does the use of mobile phones affect human's short-term memory or attention? Cinel C, Boldini A, Fox E and Russo R (2008). Appl Cogn Psychol, 22(8), 1113-25.

Psychological factors associated with self-reported sensitivity to mobile phones. Rubin GJ., *et al.* (2008) J Psychosom Res, 64 (1), 1-9.

Meningioma and mobile phone use – a collaborative case-control study in five North European countries. Lahkola *et al.,* Int J Epidemiol, 37(6), 1304-13. 2008.

Comprehensive Analysis of DNA Repair Gene Variants and Risk of Meningioma. Bethke *et al*., Journal of the National Cancer Institute, 100(4):270-276, February 20, 2008.

Meningioma and mobile phone use – a collaborative case-control study in five North European countries. Lahkola *et al*., International Journal of Epidemiology, 37(6):1304-1313, December 2008.

Global Sense of Risk: Media Reporting on Scientific Studies and Potential Risks of Mobile Phones. Litmanen *et al.,* Journal of Research and Practice in Information Technology, 40(2), 2008.

Continuous wave and simulated GSM exposure at 1.8 W/kg and 1.8 GHz do not induce hsp16-1 heat-shock gene expression in Caenorhabditis elegans. Dawe *et al., Bioelectromagnetics*, 29, 92-99, 2008.

Precautionary Advice about Mobile Phones: Public Understandings and Intended Responses. Barnett *et al.,* Journal of Risk Research, 11(4), 525-540. 2008.

Exposure to mobile phone electromagnetic fields and subjective symptoms: a double-blind study. Cinel *et al.,* Psychosomatic Medicine, 70 (3), 345-348. 2008.

Quantitative Evaluations Of Mechanisms Of Radiofrequency Interactions With Biological Molecules And Processes. Sheppard *et al.,* Health Physics, 95(4):365–396 (2008).

Proliferation, oxidative stress and cell death in cells exposed to 872 MHz radiofrequency radiation and oxidants. Höytö A, Luukkonen J, Juutilainen J, Naarala J. Radiat Res. 2008 Aug;170(2):235-43.

The effects of 884 MHz GSM wireless communication signals on headache and other symptoms; an experimental provocation study, Hillert *et al.,* Bioelectromagnetics 29(3): 185-196. 2008.

Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: a case-control study. Takebayashi *et al*., British Journal of Cancer, 98(3):652-659, 5 February 2008.

SAR characterization inside intracranial tumors for case–control epidemiological studies on cellular phones and RF exposure. Varsier *et al*., Annals of Telecommunications, 63(1-2):65-78, February 2008.

Categorization of Mobile Phones for Exposure Assessment in Epidemiological Studies on Mobile Phone Use and Brain Cancer Risk. Varsier *et al*., IEEE Transactions on Microwave Theory and Techniques, 56(10):2377- 2384, October 2008.

Radiofrequency radiation does not significantly affect ornithine decarboxylase activity, proliferation, or caspase-3 activity of fibroblasts in different physiological conditions. Höytö A, Sokura M, Juutilainen J, Naarala J. Int J Radiat Biol. 2008 Sep;84(9):727-33.

Cellphone use and risk of benign and malignant parotid gland tumors – a nationwide case-control study. Sadetzki *et al*. American Journal of Epidemiology,167(4):457-467, 15 February 2008.

Epidemiology of Gliomas in Israel: A Nationwide Study. Sadetzki *et al*., Neuroepidemiology, 31(4):264-269, 2008.

Reproductive Factors and Risk of Meningioma and Glioma. Wigertz *et al*., Cancer Epidemiology Biomarkers & Prevention, 17(10):2663-2670, October 1, 2008.

Study on potential effects of '902-MHz GSM-type wireless communication signals' on DMBA-induced mammary tumours in Sprague-Dawley rats. Hruby *et al.,* Mutation Research/Genetic Toxicology and Environmental Mutagenesis, 649(1-2):34-44 8 January 2008.

Statistical Multipath Exposure Of A Human In A Realistic Electromagnetic Environment. Vermeeren, Health Physics, 94(4):345-354, April 2008.

Whole-body SAR in spheroidal adult and child phantoms in realistic exposure environment. Vermeeren *et al*., Electronics Letters, 44(13): 790-791, June 19 2008.

XRCC1 and XRCC3 variants and risk of glioma and meningioma. Kiuru *et al*., Journal of Neuro-Oncology, 88(2): 135-142, June 2008.

Mobile phones and brain tumours: a review of epidemiological research. Croft *et al.,* Australasian Physical & Engineering Sciences in Medicine, 31(4):255-267, December 2008.

Comprehensive analysis of the role of DNA repair gene polymorphisms on risk of glioma. Bethke *et al*., Human Molecular Genetics, 17(6):800-805, March 15, 2008.

Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Cardis *et al*., Physics in Medicine & Biology, 53(11):2771-2783, 7 June 2008.

2007

Complex permittivity of sodium chloride solutions at microwave frequencies. Peyman A., *et al.* (2007). Bioelectromagnetics, 28, 264-74.

Dielectric properties of porcine cerebrospinal tissues at microwave frequencies: in vivo, in vitro and systematic variations with age. Peyman A., (2007). Phys Med Biol, 52, 2229-45.

Dielectric properties of porcine cerebrospinal tissues at microwave frequencies: in vivo, in vitro and systematic variations with age. Peyman *et al.,* Phys Med Biol, 52, 2229-45. 2007.

Computation of Electromagnetic Fields in Assemblages of Biological Cells Using a Modified Finite-Difference Time-Domain Scheme. Abd-Alhameed *et al.,* IEEE Transactions on Microwave Theory and Techniques, 55(9), 1986-1994. 2007.

Development and evaluation of the electromagnetic hypersensitivity questionnaire. Eltiti *et al.,* Bioelectromagnetics, 28(2), 137-151. 2007.

Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomised provocation study. Eltiti *et al.,* Environ Health Perspect, 115(11), 1603-1608. 2007.

Public responses to precautionary information from the Department of Health (UK) about possible health risks from mobile phones. Barnett *et al.* Health Policy, 82(2), 240-205. 2007.

Effects of mobile phone electromagnetic fields on an auditory order threshold task. Cinel *et al.,* Bioelectromagnetics, 28(6), 493-6. 2007.

Ornithine decarboxylase activity of L929 cells after exposure to continuous wave or 50 Hz modulated radiofrequency radiation - a replication study. Höytö *et al.,* Bioelectromagnetics, 28(7):501-508, October 2007.

Ornithine decarboxylase activity is affected in primary astrocytes but not in secondary cell lines exposed to 872 MHz RF radiation. Höytö *et al.,* International Journal of Radiation Biology, 83(6):367-374, 2007.

The effect of GSM and TETRA mobile handset signals on blood pressure, catechol levels and heart rate variability. Barker *et al.,* Bioelectromagnetics, 28(6), 433-8. 2007.

Worst-case temperature rise in a one-dimensional tissue model exposed to radiofrequency radiation. T. Samaras *et al.,* IEEE Trans Biomed Eng. 54:3, 492-6, 2007.

Requirements for Reliable Worst-Case Assessment of Human Exposure to RF Electromagnetic Fields with Known Uncertainty. A Christ *et al.,* Health Physics, 92:6, 554-564 2007.

Carcinogenicity Study of 217 Hz Pulsed 900 MHz Electromagnetic Fields in Pim1 Transgenic Mice. Oberto *et al.,* Radiation Research, 168(3):316–326, September 2007.

GSM and DCS Wireless Communication Signals: Combined Chronic Toxicity/ Carcinogenicity Study in the Wistar Rat. Smith *et al.,* Radiation Research, 168(4):480-492, October 2007.

Carcinogenicity study of GSM and DCS wireless communication signals in B6C3F1 mice. Tillman *et al.,* Bioelectromagnetics, 28(3): 173-187, March 2007.

Mobile phone use and risk of glioma in five North European countries. Lahkola *et al.,* Int J Cancer, 120(8), 1769-1775. 2007.

Mobile telephone use effects on labyrinthine function: a case-control study. Bamiou *et al*., Bioelectromagnetics, 29(2), 108-17. 2007.

New Head Exposure System for Use in Human Provocation Studies with EEG Recording During GSM900- and UMTS-like Exposure. G Schmid *et al.,* Bioelectromagnetics, 28:8, 636–647, 2007.

Medical history, cigarette smoking and risk of acoustic neuroma: An international case-control study. Schoemaker *et al.,* International Journal of Cancer, 120(1):103-110, 1 January 2007.

History of Allergic Disease and Risk of Meningioma. Schoemaker *et al.,* American Journal of Epidemiology, 165(5):477-485, 1 March 2007.

Validation of the questionnaire used in the INTERPHONE Study: Measuring mobile telephone use in France. Hours *et al.,* Environnement, Risques & Santé, 6(2): 101-109, Mars-Avril 2007.

Dietary zinc intake and brain cancer in adults: a case-control study. Dimitropoulou *et al.,* British Journal of Nutrition, Published Online: 2 October 2007.

Cell Phones and Risk of brain and acoustic nerve tumours: the French INTERPHONE case-control study, Hours *et al.,* La Revue d'épidémiologie et de santé, 55(5):321-332, October 2007.

An International Case-Control Study of Interleukin-4Ra, Interleukin-13, and Cyclooxygenase-2 Polymorphisms and Glioblastoma Risk. Schwartzbaum *et al*., Cancer Epidemiology Biomarkers & Prevention, 16(11):2448-2454, November 1, 2007.

Allergic Conditions and Brain Tumor Risk. Wigertz *et al.,* American Journal of Epidemiology, 166(8):941-950, 15 October 2007.

EM Field Distribution Amd Propagation In Some Realistic Scenarios. Kakulia *et al*., Journal of Applied Electromagnetism, 9(2):39-53, December 2007.

An international case-control study of glutathione transferase and functionally related polymorphisms and risk of primary adult brain tumors. Schwartzbaum *et al.,* Cancer Epidemiology Biomarkers & Prevention, 16(3):559-656, 1 March 2007.

Medical exposure to ionising radiation and the risk of brain tumours: Interphone study group Germany. Blettner *et al.,* European Journal of Cancer, Published Online 8 August 2007.

The INTERPHONE study: design, epidemiological methods, and description of the study population. Cardis *et al.,* European Journal of Epidemiology, 22(9):647-664, September, 2007.

Use of mobile phones in Norway and risk of intracranial tumours. Klaeboe *et al.,* European Journal of Cancer Prevention, 16(2):158-164, April 2007.

Mobile phone use and risk of glioma in 5 North European countries. Lahkola *et al.,* International Journal of Cancer, 120(8): 1769-1775, 15 April 2007.

Genetic variation in p53 and ATM haplotypes and risk of glioma and meningioma. Malmer *et al.,* Journal of Neuro-Oncology, 82(3):229-237, May 2007.

Incidence of gliomas by anatomic location. Larjavaara *et al.,* Neuro-Oncology, 9(3): 319-325, 1 July 2007.

The INTERPHONE Study: Design, Epidemiological Methods, and Description of the Study Population. Cardis *et al., Eur J Epidemiol,* 22(9), 647-64. 2007

Environmental risk factors for sporadic acoustic neuroma (Interphone Study Group, Germany). Schlaehofer *et al.,* European Journal of Cancer, 43(11):1741-1747, July 2007.

2006

Development and evaluation of the electromagnetic hypersensitivity questionnaire. Bioelectromagnetics, 28(2), 137-51. Eltiti S, Wallace D, Zougkou K, Russo R, Joseph S, Russo R and Fox E (2006).

A systematic review of treatments for electromagnetic hypersensitivity. Rubin *et al.,* Psychotherapy and Psychosomatics, 75(1), 12-18. 2006.

Are some people sensitive to mobile phone signals? Within participants double blind randomised provocation study. Rubin *et al.,* British Medical Journal, 332(7526), 886-91. 2006.

Does acute exposure to mobile phones affect human attention?, Russso *et al.,* Bioelectromagnetics, 27(3), 215-220. 2006.

Managing the Possible Health Risks of Mobile Telecommunications: Public Understandings of Precautionary Action and Advice. Timotijevic *et al*., Health, Risk and Society, 8(2), 143-164. 2006.

Public exposure to radio waves near GSM microcell and picocell base stations. Cooper *et al.,* J Radiat Prot, 26(2), 199-211. 2006.

Dielectric measurement: error analysis and assessment of uncertainty. Gabriel *et al.,* Phys Med Biol, 51, 6033-6046. 2006.

A small temperature rise may contribute towards the apparent induction by microwaves of heat-shock gene expression in the nematode, Caenorhabditis elegans. Dawe *et al., Bioelectromagnetics*, 27(2), 88-97, 2006.

Mobile phone use and risk of glioma in adults: a UK case-control study. Hepworth *et al.,* British Medical Journal, 332, 883-886. 2006.

Call-related factors influencing output power from mobile phones. Hillert *et al.,* J Expo Sci Environ Epidemiol, 16(6), 507-514. 2006.

Development of novel whole-body exposure setups for rats providing high efficiency, national toxicity program (NTP) compatibility and well characterized exposure. W. Kainz, *et al.,* Physics in Medicine and Biology, 51:20, 5211–5229, 2006.

The Dependence of Electromagnetic Energy Absorption on the Properties of Layered Body Tissue in the Frequency Range from 236MHz to 6GHz. A. Christ, IEEE Transactions on Microwave Theory and Techniques, 54:5, 2188- 2195, 2006.

SAR approximation on the near-field of small antennas (30 MHz to 6 GHz) and deduction of an exclusionary clause for low power devices. M. Loeser *et al.,* IEEE Transactions on Antennas and Propagation, 2006.

Methodology of detailed dosimetry and treatment of uncertainty and variations for in vivo studies. Kuster *et al.,* Bioelectromagnetics, 27(5):378-39, July 2006.

Effects of 900 MHz GSM Wireless Communication Signals on DMBA-Induced Mammary Tumors in Rats. Yu *et al.,* Radiation Research, 165(2):174–180, February 2006.

Validation of short term recall of mobile phone use for the Interphone study. Vrijheid *et al., Occup Environ Med*, 63(4), 237-43. 2006.

Comparisons of Computed Mobile Phone Induced SAR in the SAM Phantom to That in Anatomically Correct Models of the Human Head. IEEE Trans. on Electromagnetic Compatibility, B. B. Beard *et al.,* 48:2, 397-407, 2006.

The Dependence of Electromagnetic Far-Field Absorption on Body Tissue Composition in the Frequency Range from 300MHz to 6GHz. A. Christ *et al.,* IEEE Trans. on Microwave Theory and Techniques, 54:5, 2188-2195, 2006.

Effects of geometry discretization aspects on the numerical solution of the bioheat transfer equation with the FDTD technique. T. Samaras *et al.,* Physics in Medicine and Biology, 51: 11, N221-N229, 2006.

Characterization of the electromagnetic near-field absorption in layered biological tissue in the frequency range from 30 MHz to 6000 MHz. A Christ *et al.,* Phys Med Biol. 51:19, 4951-65, 2006.

Analysis of the Accuracy of the Numerical Reflection Coefficient of the Finite- Difference Time-Domain Method at Planar Material Interfaces. A. Christ *et al.,* IEEE Trans. on Electromagnetic Compatibility, 48:2, 264-272, 2006.

International intercomparison of specific absorption rates in a flat absorbing phantom in the near-field of dipole antennas, Davis *et al.,* IEEE Transactions on Electromagnetic Capability, 48:579 – 588, Aug. 2006.

Assigning exposure to pesticides and solvents from self-reports collected by a computer assisted personal interview and expert assessment of job codes: the UK Adult Brain Tumour Study, Hepworth *et al.,* Occupational and Environmental Medicine, 63(4):267-272, 1 April 2006.

Mobile phone use and risk of glioma in adults: case-control study. Hepworth *et al.,* British Medical Journal, 332(7546):883-887, 15 April 2006.

Specific absorption rates in a flat phantom in the near-field of dipole antennas. Balzano *et al.,* IEEE Transactions on Electromagnetic Capability, 48:563 – 568, Aug. 2006.

Modest increase in temperature affects ODC activity in L929 cells: low- level radiofrequency radiation does not. Höytö *et al.,* Journal Radiation and Environmental Biophysics, 45(3):231-235, September 2006.

935 MHz cellular phone radiation. An in vitro study of genotoxicity in human lymphocytes. Stronati *et al.,* International Journal of Radiation Biology, 82(5):339-346, May 2006.

Mobile phone use and acoustic neuroma risk in Japan. Takebayashi *et al.,* Occupational and Environmental Medicine, 63(12): 802-807, 1 December 2006.

Validation of short term recall of mobile phone use for the Interphone study. Vrijheid *et al.,* Occupational and Environmental Medicine, 63(4):237-243, 1 April 2006.

Risk of Brain Tumors Associated with Exposure to Exogenous Female Sex Hormones. Wigertz *et al.,* American Journal of Epidemiology, 164(7): 629-636, 1 October 2006.

The effects of recall errors and of selection bias in epidemiologic studies of mobile phone use and cancer risk. Vrijheid *et al.,* Journal of Exposure Science and Environmental Epidemiology, 16(4):371–384, July 2006.

Cellular telephones and risk for brain tumors: A population-based, incident case-control study. Christensen *et al.,* Neurology, 64(7): 1189-1195, 12 April 2005. Erratum in: Neurology, 65(8):1324, 25 October 2005.

Mobile Phone Use and Risk of Parotid Gland Tumor. Lönn *et al.,* American Journal of Epidemiology, 164(7):637-643, 1 October 2006.

History of allergies and risk of glioma in adults. Schoemaker *et al.,* International Journal of Cancer, 119(9):2001-2246, 1 November 2006.

Cellular Phones, Cordless Phones, and the Risks of Glioma and Meningioma (Interphone Study Group, Germany). Schüz *et al.,* American Journal of Epidemiology, 163(6):512-520, 15 March 2006.

Radiofrequency Electromagnetic Fields Emitted from Base Stations of DECT Cordless Phones and the Risk of Glioma and Meningioma (Interphone Study Group. Germany), Schüz *et al.,* Radiation Research, 166(1):116-119, July 2006.

Exposure to Loud Noise and Risk of Acoustic Neuroma, Edwards *et al.,* American Journal of Epidemiology, 163(4):327-333, 15 February 2006. Erratum in: American Journal of Epidemiology, 163(12):1163, 15 June 2006.

Occupational Exposure to Radio Frequency/ Microwave Radiation and the Risk of Brain Tumors: Interphone Study Group, Germany. Berg *et al.,* American Journal of Epidemiology, 164(6):538-548, 15 September 2006.

2005

A systematic review of treatments for electromagnetic hypersensitivity. Rubin GJ., *et al.,* (2005) Psychother Psychosom, 75, 12-18.

Electromagnetic hypersensitivity: A systematic review of provocation studies. Rubin *et al.,* Psychosomatic Medicine, 67(2), 224-232. 2005.

Frequency and amplitude windows in the combined action of DC and low frequency AC magnetic fields on ion thermal motion in a macromolecule: Theoretical analysis. Zhadin *et al.,* Bioelectromagnetics 26(4) 323-330, 2005.

Whole-body exposure to 2.45 GHz electromagnetic fields does not alter anxiety responses in rats: a plus-maze study including test validation. Cosquer *et al.,* Behavioural Brain Research, 156(1):65-74, 6 January 2005.

Whole-body exposure to 2.45 GHz electromagnetic fields does not alter 12-arm radial-maze with reduced access to spatial cues in rats. Cosquer *et al.,* Behavioural Brain Research 161(2): 331-334, June 20 2005. Epub March 23 2005.

Letter to the editor concerning 'Radial arm maze performance of rats following repeated low-level microwave radiation exposure. Cobb *et al.,* [BEMS, 2004, 25:49-57] and 'letter to the editor' by Lai [BEMS, 2005, 26:81]. Cassel. Bioelectromagnetics. 26(7):526-7 Oct 2005; author reply 528.

Molecular Change Signal-to-Noise Criteria for Interpreting Experiments Involving Exposure of Biological Systems to Weakly Interacting Electromagnetic Fields. Vaughan *et al.,* Bioelectromagnetics 26:305-322 (2005).

Animal carcinogenicity studies on radiofrequency fields related to mobile phones and base stations. Dasenbrock, Toxicology and Applied Pharmacology, 207(2-S1):342-346, 1 September 2005.

Response, thermal regulatory threshold and thermal breakdown threshold of restrained RF-exposed mice at 905 MHz. Ebert *et al.,* Physics in Medicine and Biology, 50(21):5203-5215, 7 November 2005.

Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries. Schoemaker *et al.,* Br J Cancer, 93(7), 842-848. 2005.

Blood–brain barrier and electromagnetic fields: Effects of scopolamine methylbromide on working memory after whole-body exposure to 2.45 GHz microwaves in rats. Cosquer *et al.,* Behavioural Brain Research, 161(2):229-237, 20 June 2005.

Reevaluation and improved design of the TEM cell in vitro exposure unit for replication studies. Nikoloski *et al.,* Bioelectromagnetics, 26(3): 215-224, April 2005.

Cylindrical cell membranes in uniform applied electric fields: validation of a transport lattice method. Stewart *et al.,* IEEE Transactions on Biomedical Engineering, 52(10): 1643 – 1653, 2005.

Selection Bias Due to Differential Participation in a Case–Control Study of Mobile Phone Use and Brain Tumors. Lahkola *et al.,* Annals of Epidemiology, 15(5):321-325, May 2005.

Long-Term Mobile Phone Use and Brain Tumor Risk. Lönn *et al.,* American Journal of Epidemiology, 161(6):526-535, 15 March 2005.

p53 Genotypes and Risk of Glioma and Meningioma. Malmer *et al.,* Cancer Epidemiology Biomarkers & Prevention, 14(9):2220-2223, September 2005.

Polymorphisms Associated with Asthma Are Inversely Related to Glioblastoma Multiforme. Schwartzbaum *et al.,* Cancer Research, 65(14):6459- 6465, 15 July 2005.

Assessment of radiofrequency exposure from cellular telephone daily use in an epidemiological study: German Validation study of the international case– control study of cancers of the brain-INTERPHONE-Study. Berg *et al.,* Journal of Exposure Analysis and Environmental Epidemiology, 15(3):217-224, May 2005.

Mobile phone use and risk of acoustic neuroma: results of the Interphone case–control study in five North European countries. Schoemaker *et al.,* British Journal of Cancer, 93(7):842-848, 3 October 2005.

2004

Mobile Telephony and Health: Public Perceptions in Great Britain. MORI, February 2004.

AIterative Method for the Design of a Dual-Phase-Conjugation-Mirror Resonator with Multiple Apertures. Kwon *et al.,* Applied Optics, 43(4) 944-948 (2004).

RF Absorption Involving Biological Macromolecules. E.W. Prohofsky, Bioelectromagnetics 25:441-451 (2004).

Whole-body exposure to 2.45 GHz electromagnetic fields does not alter radial-maze performance in rats. Cassel *et al.,* Behavioural Brain Research, 155(1):37-43, 5 November 2004.

High Peak SAR Exposure Unit With Tight Exposure and Environmental Control for In Vitro Experiments at 1800 MHz. Schuderer *et al.,* IEEE Transactions on Microwave Theory and Techniques, 52(8), pp. 2057- 2066, August 2004.

In Vitro Exposure Systems for RF Exposures at 900 MHz. Schuderer *et al.,* IEEE Transactions on Microwave Theory and Techniques, 52(8), pp. 2067-2075, August 2004.

Cellular effects of electromagnetic fields. Naarala *et al.,* Alternatives to Laboratory Animals, 32(4):355-360, October 2004.

High Peak SAR Exposure Unit With Tight Exposure and Environmental Control for In Vitro Experiments at 1800 MHz. Schuderer *et al.,* IEEE Trans. Microwave Theory and Techniques 52:2057-2066, 2004.

Cellular Telephone Use and Risk of Acoustic Neuroma. Christensen *et al.,* American Journal of Epidemiology, 159(3):277-283, 1 February 2004.

Validation of self-reported cellular phone use. Samkangee-Zeeb *et al.,* Journal of Exposure Analysis and Environmental Epidemiology, 14(3):245–248, May 2004.

Mobile Phone Use and the Risk of Acoustic Neuroma. Lönn *et al.,* Epidemiology, 15(6): 653-659, November 2004.

2003

Assessment of specific energy absorption rate (SAR) in the head from a TETRA handset. Dimbylow *et al*., Phys Med Biol, 48, 3911-3926. 2003.

An approach to electrical modeling of single and multiple cells. Gowrishankar *et al.,* PNAS 100(6) 3203-3208, 2003.

Adiabatic pumping mechanism for ion motive ATPases. Astumian RD, Phys Rev Lett. 2003 Sep 12;91(11):118102. Epub Sept 2003.

Recall of past use of mobile phone handsets. Parslow *et al.,* Radiation Protection Dosimetry, 106(3):233-40, September 2003.

20 YEARS 1998-2018

MWF
Mobile & Wireless Forum

Bergostraat 115
Merelbeke 9829,
Belgium

15th Floor,
100 Queen's Road Central, Central,
Hong Kong

Av. Paulista, 2300 - Piso Pilotis
CEP 01310-300
São Paulo/SP Brazil

www.mwfai.org