

**THE  
INTERNATIONAL  
ELECTROMAGNETIC  
FIELD  
PROJECT**





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**Regional Workshop  
on Radio Frequency Fields:**

**Health Effects & Policy Options for  
Protection**

Thursday 17 & Friday 18 November 2005  
Swinburne University of Technology  
Melbourne, Australia

## CO-SPONSORS

 <p><b>ACRBR</b> Australian Centre for RF Bioeffects Research</p>	<p>The Australian Centre for RF Bioeffects Research</p>
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# INTERNATIONAL ELECTROMAGNETIC FIELD (EMF) PROJECT

## Regional Workshop on Radio frequency fields: Health Effects & Policy Options for Protection

17-18 November 2005 – Melbourne, Australia

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Dr Mike Repacholi World Health Organization, Switzerland

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### WHO ADMINISTRATION

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Dr David Black University of Auckland, New Zealand

Professor Lawrie Challis UK Mobile Telecommunications and Health  
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Dr Emilie Van Deventer Perkins World Health Organization (WHO), Switzerland

Dr Bernard Veyret Bordeaux University, France

Mr Mike Wood Telstra Corporation, Australia

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# INTERNATIONAL ELECTROMAGNETIC FIELD (EMF) PROJECT

## Regional Workshop on Radio frequency fields: Health Effects & Policy Options for Protection

17-18 NOVEMBER 2005 – MELBOURNE, AUSTRALIA

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Abstracts

Invited Speakers

Student Poster Presentations

# AGENDA

**WHO Workshop on Health Effects and Management of RF Fields  
Scientific Program  
Melbourne, Australia, 17-18 November 2005**

**Scope and purpose:** To provide an overview of WHO EMF activities, current knowledge on biological health effects of exposure to RF fields, what research is being conducted and how the RF issues are being handled by SE Asian countries and communicating with the public and workers on RF.

**Thursday 17 November 2005**

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07:30 Registration  
08:30 Welcome – Swinburne University Vice Chancellor: Prof Ian Young

**WHO ACTIVITIES** **CHAIR: R. Croft**

08:40 WHO's EMF Project results on RF health effects  
*Dr Mike Repacholi, WHO, Switzerland*  
09:30 Are there Sensitive Subpopulations to RF exposure?  
*Dr Emilie van Deventer, WHO, Switzerland*  
10:00 WHO Workshop on Base Stations and Wireless Networks: A summary  
*Dr Colin Roy, ARPANSA, Melbourne*  
10:30 **Morning Tea**

**RESEARCH** **CHAIR: I. Cosic**

11:00 Overview of the Research Program at the Australian Centre for Radio  
Frequency Bioeffects Research (ACRBR)  
*Dr Rodney Croft, ACRBR, Melbourne*  
11:30 Key RF Laboratory Research Programs in Europe  
*Dr Bernard Veyret, Bordeaux University, France*  
12:00 Panel Discussion on Research  
12:30 **Lunch**

**BIOLOGICAL AND HEALTH EFFECTS** **CHAIR: A. Wood**

14:00 Comparison of Measured and Calculated RF Fields Around Mobile Base  
Stations  
*Mr Mike Wood, Telstra Australia*  
14:15 RF Field Levels Around Base Stations – Measurements, Predictions and  
Public Concern  
*Mr Lindsay Martin, ARPANSA*  
14:30 Are Mobile Phones or their Base Stations Dangerous?  
*Dr Bernard Veyret, Bordeaux University, France*  
15:00 Mobile Telephony and Tumor Risk  
*Dr Anders Ahlbom, Karolinska Institute, Sweden*  
15:30 Does Modulation of RF Fields Matter?  
*Prof. Lawrie Challis, University of Nottingham, UK*  
16:00 **Afternoon Tea**  
16:30 Panel Discussion on RF Health Effects from Mobile Telecommunications  
*Moderator: J. Loy*  
17:30 **Close**

Friday 18 November 2005

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**STANDARDS AND PRECAUTION**

**CHAIR: C. Roy**

- 08:30 Scientific Basis for ICNIRP Standards  
*To be advised*
- 09:00 WHO/EURO Booklet on Wireless Communication  
*Dr Colin Roy, ARPANSA, Melbourne*
- 09:30 Harmonizing Standards and Precaution  
*Dr Emilie van Deventer, WHO, Switzerland*
- 10:00 Panel Discussion on Standards and Precaution
- 11:00 **Morning Tea**

**RISK MANAGEMENT AND COMMUNICATION**

**CHAIR: B. Hocking**

- 11:30 How to Manage the RF Issue at the Local Level  
*Dr Colin Roy, ARPANSA, Melbourne*  
Occupational Safety and Health in Australasia  
*Dr David Black, Auckland University, NZ*
- 12:30 **Lunch**
- 14:00 Communicating with Stakeholders on the RF Issues  
*Dr Ray Kemp, Galson Consulting, London, UK*
- 14:30 Communicating with Children about EMF via the Web  
*Dr K Ng, University of Malaya, Kuala Lumpur*
- 15:00 Panel on Risk Management and Communication
- 16:00 **Afternoon Tea**

**WRAP-UP**

**CHAIR: M. Repacholi**

- 16:30 WHO's Recommendations on RF  
*Dr Mike Repacholi, WHO, Switzerland*
- 17:00 General discussion
- 17:30 **Close**

# Workshop Participants List

# INTERNATIONAL ELECTROMAGNETIC FIELD (EMF) PROJECT

## Regional Workshop on Radio frequency fields: Health Effects & Policy Options for Protection

17-18 NOVEMBER 2005 – MELBOURNE, AUSTRALIA

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# **ABSTRACTS**

## **Invited Speakers**

## **WHO'S EMF Project Results on RF Health Effects**

**Dr Mike Repacholi**  
**Coordinator, Radiation and Environmental Health**  
**World Health Organization, Geneva, Switzerland**

Because of growing concern that exposure to electromagnetic fields (EMF) may cause various health effects and everyone in the world, both in developed and developing countries are subjected to EMF from manmade sources, the World Health Organization (WHO) established the International EMF Project in 1996. The EMF Project has placed particular emphasis on promoting research to determine whether radiofrequency (RF) fields emitted from mobile telecommunications devices, especially at levels below those known to cause adverse health consequences by heating. So-called "non-thermal" effects have been investigated for many years.

Briefly the International EMF Project provides: a co-ordinated international response to the concerns about possible health effects of exposure to EMF; assesses the scientific literature and makes status reports on health effects; identifies gaps in knowledge needing further research to make better health risk assessments; encourages high quality, focused research to fill important gaps in knowledge; incorporates research results into its reviews, including the final reviews that will be published as WHO Environmental Health Criteria monographs, in which formal health risk assessments of exposure to EMF will be made. The Project also provides information on risk perception, risk communication and risk management as they apply to EMF; provides advice and publications to national authorities on EMF issues; and facilitates the development of internationally acceptable standards for EMF exposure.

Since the public are genuinely concerned about RF-induced health effects, the science and the technology need to be better communicated to them. WHO has produced a booklet entitled "Dialogue on risks to electromagnetic fields", which has been translated into many languages including Russian. The booklet can be downloaded from the WHO web site at: [www.who.int/emf](http://www.who.int/emf).

This paper gives a brief overview of WHO's EMF Project, the current state of knowledge regarding health effects from exposure to RF fields, and WHO recommendations to Member States to protect the health of their citizens from EMF fields. The ultimate objective of the Project is to provide sound advice to national authorities on how best to manage the EMF issues. Details on the EMF Project are available on the home page at: <http://www.who.int/emf/>.

## Are there Sensitive Subpopulations to RF Exposure?

Dr Emilie van Deventer,  
World Health Organization, Geneva, Switzerland

Different groups in a population may have variations in their ability to tolerate exposure to a particular environmental physical or biological agent. If the scientific database suggests it, consideration should be given to the normal spectrum of sensitivities to environmental stresses that would exist in any population, to the possibility that certain drugs may produce adverse reactions in patients exposed to the agent, and to people who are sick to the extent that they may be particularly sensitive to additional stress.

Exposure to radiofrequency (RF) electromagnetic (EMF) fields has been increasing greatly with the use of personal telecommunications devices over the last decade. The question whether there are sensitive subpopulations to RF exposure has been raised. Of particular concern are children and people suffering from symptoms attributed to electrical hypersensitivity. To review the evidence on these issues and to identify research needs, WHO convened two expert workshops in 2004, which will be summarized in this presentation.

The WHO workshop on children sensitivity to EMF was held in Istanbul, Turkey, in June 2004. Use of mobile telephones by young children has been a concern expressed by the Stewart Committee report in the United Kingdom and others. There have been suggestions that exposure of young children to electromagnetic fields (EMF) may be detrimental to their health, especially during the development and maturation of the central nervous system, immune system and other critical organs. Also, children are exposed to EMF for a much greater part of their lifespan than adults. In addition to reviewing the available evidence, a research agenda was developed that identifies high-priority studies needed to fully assess the potential vulnerability of children ([http://www.who.int/peh-emf/meetings/children\\_turkey\\_june2004/en/index.html](http://www.who.int/peh-emf/meetings/children_turkey_june2004/en/index.html)).

The workshop on EMF Hypersensitivity took place in Prague, Czech Republic, in October 2004. Sensitivity to EMF, or electrical hypersensitivity (EHS), comprises nervous system symptoms, including like headache, fatigue, stress, sleep disturbances, skin symptoms, pain and ache in muscles. The prevalence of EHS sufferers has not been extensively evaluated, but their exposure is generally several orders of magnitude under the limits in internationally accepted standards. The workshop concluded that there is no proven scientific link between EMF exposure and symptoms. However, EHS is a real and sometimes a disabling problem for the affected persons. The conference reviewed current state of knowledge and opinions and proposed ways forward on this issue ([http://www.who.int/peh-emf/meetings/hypersensitivity\\_prague2004/en/index.html](http://www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html)).

## **WHO Workshop on Base Stations and Wireless Networks: A Summary**

**WHO International EMF Project  
15-16 June 2005, Geneva, Switzerland**

**Mr Colin Roy  
Director NIR Branch  
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)**

The Workshop set out as its scope and objectives to answer the following questions:

- what are the current and future wireless technologies?
- what RF exposures do people receive from these technologies?
- is there evidence of health effects from long-term, low-level RF exposures?
- what further research is needed, if any?
- what international standards exist or are being developed?
- what have national authorities done in response to this issue?
- how can we provide effective communication to all stakeholders on this issue?
- what policy options can be recommended for national authorities?

The expected outputs from the workshop were:

- compilation of presentations on the WHO EMF WebPage,
- a Rapporteur's report summarising the conclusions and recommendations,
- proceedings of key papers,
- a peer-reviewed journal publication,
- a fact or information sheet for the general public and
- a brochure for local authorities with practical advice related to mobile phone base stations and wireless networks.

The presentation will summarise the key findings from the workshop and will discuss the implications for base station deployment in Australia and elsewhere.

## **Overview of the Research Program at the Australian Centre for Radio Frequency Bioeffects Research (ACRBR)**

**Rodney Croft\***

**Michael Abramson, Irena Cosic, John Finnie, Ray McKenzie, Andrew Wood**

**\*Australian Centre for RF Bioeffects Research, Swinburne University of Technology,  
Australia**

As part of a National Health and Medical Research Council (Australia) initiative, the Australian Centre for Radio Frequency Bioeffects Research (ACRBR) was established in 2004. A principal function of the ACRBR is to conduct research to help determine whether there are health-related consequences of using low-level radio frequency (RF) emitting devices. To this end the ACRBR is currently engaged in a number of research programs assessing the effects of second and third generation radio technologies (and related electromagnetic fields; EMF) on endpoints ranging from molecules to human populations.

This research includes a program of molecular modeling, with its principle focus on exploring RF interactions with proteins in order to investigate bioactivity changes of selected protein groups (e.g. dehydrogenases and heat shock proteins) exposed to EMF, as well as investigating the influence of inter and intra-cellular water as a medium for electromagnetic radiation and the supply of energy for molecular activation.

In vitro and in vivo neurobiology features prominently in the ACRBR research program. In a murine model, the acute genomic response (c-fos expression) has been employed to detect any subtle neuronal changes after mobile telephony exposure. Any alterations in BBB permeability after 'whole of gestation' exposure of foetal mouse brains, and exposure of the neonatal brain for the first postnatal week, have also been examined immunohistochemically. Further to this, investigations are being conducted into possible effects of 915-MHz modulated RF on a synthetic Blood-Brain Barrier model in the rat, on long-term potentiation in rat hippocampus, and lectinocytochemical detection of these effects on rat hippocampal cells

Extending this research to humans the ACRBR is exploring issues related to individual differences in possible RF effects, employing both experimental and epidemiological methodologies. In terms of the former, these include whether there are differential effects of mobile phones on 13-15, 20-35 and 50-75 year olds on measures of cognitive performance and neurophysiological activity, whether changes in these parameters are consistent within individuals, and via a provocation design whether these measures are reliably changed in self-reported EMF-hypersensitives. In terms of the latter, we are engaged in a cohort study of young adolescents that will determine whether there are any relationships between their phone usage patterns and measures of cognition, hearing and blood pressure, over a 3-year period.

Further to the strong dosimetry support that the ACRBR provides for each of these studies, it is independently engaged in dosimetry research. This research addresses a number of issues, including the effectiveness of current RF exposure compliance techniques to account for the detail variation of tissue properties and morphologies over the range of the human population, including age, gender and race, and in particular, the identification of the most significant factors to include in such models to provide adequate accuracy in prediction of human exposure over a range of exposure scenarios. For the new generations of wireless consumer devices, the

ACRBR's dosimetry research program also includes exploration and specification of localized SAR and power flux density (S) as RF safety exposure metrics in the 1–10 GHz frequency range, by comparing their ability to best predict peak tissue temperature rise in the affected tissues. This presentation will describe the above ACRBR work in more detail.

## Key RF Laboratory Research Programmes in Europe

Dr Bernard Veyret

Laboratoire PIOM, ENSCPB, Université de Bordeaux, France and  
Dipartimento Elettronica, Università La Sapienza, Roma, Italy.

Research in "bioelectromagnetics" has been very active in recent years, for a large part motivated by health concerns related to mobile telephony. Most of the research activity has been performed in Europe, with Japan, Korea and Australia being also active. In Europe, many of the programmes have been at the international level (e.g. EC 5<sup>th</sup> FP<sup>1</sup>) but also at the national level (e.g. Comobio in France, "La Vita" in Finland, MTHR in the UK). This is bound to continue in view of the need for further international cooperation, large research budgets and coordination at the international level by WHO.

The overall quality of the research on RF and health has steadily risen: exposure systems are now of sufficient quality and modelling of the EMF levels inside the tissues and organs or the culture media has greatly improved. More and more replication or conformation studies have been performed with the help of the authors.

In conclusion this field of science, led by health concerns, has matured and the fact that non- specialized scientific journals now publish negative as well as positive findings is a sign of that evolution. Another trend is that of the creation of national (e.g. MTHR in the UK, "Santé et Radiofréquences" in France) or trans-national foundations (FGF<sup>2</sup>) with the purpose of funding the research with contributions from governments and industry and setting up of scientific boards and firewalls. This is helping increase the independence of the research and its visibility as such by the public.

Several national reports have been published over the years that describe and analyse the results coming from the laboratories (e.g. AFSSET in France<sup>3</sup>, NRPB in the UK<sup>4</sup>, SSI<sup>5</sup> in Sweden). There are major programmes that are now completed within the 5th FP such as Reflex<sup>6</sup>, Perform B<sup>7</sup>, but some are still ongoing such as Guard<sup>8</sup>, Perform A, and Perform C. Other have started (EMFnEAR<sup>9</sup>). Several other projects are dealing with collecting and analysing published papers on RF and health in collaboration with WHO (e.g. EMF portal<sup>10</sup>).

The strength of European research in part can be attributed to the actions which aim at improving the collaboration between scientists (COST 281<sup>11</sup>) or informing the EC

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<sup>1</sup> Framework Programme

<sup>2</sup> [www.fgf.de](http://www.fgf.de)

<sup>3</sup> [www.afsset.fr](http://www.afsset.fr)

<sup>4</sup> [www.hpa.org.uk/radiation/publications/documents\\_of\\_nrpbf/pdfs/doc\\_15\\_5.pdf](http://www.hpa.org.uk/radiation/publications/documents_of_nrpbf/pdfs/doc_15_5.pdf)

<sup>5</sup> [www.ssi.se](http://www.ssi.se)

<sup>6</sup> full report available at [www.verum.foundation.de/www2004/html/pdf/euprojekte01/REFLEX\\_Final%20Report\\_Part%201.pdf](http://www.verum.foundation.de/www2004/html/pdf/euprojekte01/REFLEX_Final%20Report_Part%201.pdf)

<sup>7</sup> final report available from author

<sup>8</sup> [www.guard.polimi.it/](http://www.guard.polimi.it/)

<sup>9</sup> [www.emfnear.polimi.it/](http://www.emfnear.polimi.it/)

<sup>10</sup> [www.emf-portal.de](http://www.emf-portal.de)

<sup>11</sup> [www.cost281.org](http://www.cost281.org)

about research activities and results (EMF-NET<sup>12</sup>). The EC has published a short document explaining to the public the issues and the research activity: "Waves and research: Mobile phones and health".<sup>13</sup> Examples will be given in the talk of current research in Europe and of future activities in the light of coming health risk evaluations.

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<sup>12</sup> [www.jrc.cec.eu.int/emf-net](http://www.jrc.cec.eu.int/emf-net)

<sup>13</sup> RTD info No. 46 August 2005 at [europa.eu.int/comm/research/rtdinfo/index\\_en.html](http://europa.eu.int/comm/research/rtdinfo/index_en.html)

## Comparison of Measured & Calculated RF Fields Around Mobile Base Stations

**Mr Mike Wood**  
**National EME Manager, Telstra Corporation, Australia**

Public interest in the siting and operation of mobile phone base stations has highlighted the importance of having accessible and easy to understand information on electromagnetic energy (EME) levels within the community.

Detailed measurements by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), a Federal Government agency incorporated under the Health and Ageing portfolio, as well as other accredited laboratories have shown that environmental EME levels from mobile phone base stations are very low, often many thousands of times below the public safety limits. Typical EME levels are 0.0001% to 1% of the Australian safety limits.

In response to increasing demand for environmental EME assessments ARPANSA developed an EME prediction methodology based on well established scientific principles and an assumption of "worst case conditions" for a base station (maximum power and call traffic, and no impact of signal through the environment). Since 2003, Australia mobile carriers are required to publish an environmental EME report for all new or upgraded base stations.

To support the ARPANSA methodology and efficient generation of environmental reports, Telstra have developed an EME environmental RF calculation tool called RF-Map. Telstra uses RF-Map to plot the cumulative EME level from base stations in a local community.

Telstra has conducted detailed comparisons of measured and calculated EME levels at sample base stations to establish typical variations and provide guidance on achieving the most accurate results.

The comparison surveys show that with a clear view of a base station antenna and little environmental clutter like trees and buildings, measured and calculated levels are generally in very good agreement, typically within  $\pm 3$  to 6dB.

When there is significant environmental clutter and the base station antenna view is obstructed, the measured levels are usually significantly lower than the calculated levels, typically 10 to 20dB lower.

To achieve the most accurate results, it is important to have accurate base station configuration data - antenna pattern, mounting height, tilt, bearing and transmitter power and feeder losses. It is also important to establish any significant topographical differences and take multiple measurements or calculation points.

Using the ARPANSA methodology of maximum power and call traffic generally ensures that the calculations are conservative even when in clear view of the antennas.

By being able to provide EME information in a format that is easily understood by the community, local councils, government authorities and building owners, the uncertainty about EME levels is reduced.

## **RF Field Levels Around Mobile Base Stations – Measurements, Predictions and Public Concern**

**Mr Lindsay Martin, Manager  
Electromagnetic Radiation Section  
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)**

There remains a high degree of concern in parts of the community about possible health effects from radio frequency (RF) electromagnetic radiation (EMR) in the vicinity of mobile phone base station antennas. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has a role in protecting the Australian public and the environment from the harmful effects of radiation, and this includes responding to public anxiety through the provision of relevant and authoritative information.

The concerned public hold a wide range of views and includes those who are sure that RF EMR causes adverse health effects, even at levels below national standards. Others believe approved levels may be exceeded through equipment malfunction, inappropriate siting or the cumulative effect of many installations surrounding a particular location. Current information, from measurements and predictions, strongly indicates that exposure levels are very much lower than national standards. However, further survey data are needed for the public to be confident that environmental EMR levels remain low and are being independently monitored.

ARPANSA and the regulator, the Australian Communications and Media Authority (ACMA), has worked with industry bodies to ensure that communities living near proposed base station installations are provided with prediction reports, based on sound scientific methods, of the maximum levels of RF EMR that would be produced. ARPANSA has carried out, or commissioned, two extensive surveys of actual EMR levels around base stations and has been able to show that measured values are less than the levels given in prediction reports. A summary of these results is presented together with some of the lessons learned in the course of undertaking these surveys.

Measurements of EMR levels can serve several purposes in addressing public concern. Measurements can demonstrate that levels near a selection of base stations comply with national exposure limits and through comparison with predicted levels, the results can increase confidence in the prediction methods and extend their ability to usefully inform the public. Prediction methodologies necessarily include some simplifying assumptions and appropriate measurements can explore the validity of these assumptions.

In planning a new, ongoing program of measurements, ARPANSA with the cooperation of ACMA, will try to answer directly the public's questions about cumulative effects of multiple, adjacent sites and RF EMR levels in buildings located close to antennas.

## Are mobile phones or their base stations dangerous?

Dr Bernard Veyret

Laboratoire PIOM, ENSCPB, Université de Bordeaux, France and  
Dipartimento Elettronica, Università La Sapienza, Roma, Italy.

Mobile (or cellular) telephony has developed very rapidly over the past ten years. It is now part of the basic equipment of modern life and over 1.5 billion phones are in use worldwide. Concerns about health effects caused by exposure to the microwaves emitted by mobile telephones and base stations have increased over the last years, becoming a major societal issue in some countries. Stories about health risks from radiofrequency radiation (RFR) from mobile phones and base stations have become common in the media over the past five years. In contrast, the media do not often communicate on official scientific reports firmly concluding that there is no evidence of a health hazard from mobile phones.

### *Laboratory studies*

The scientific approaches to health risk assessment related to non-ionizing electromagnetic fields are the same as in the ionizing range, i.e. epidemiology, experimental studies on humans, animals, and cells in culture. The experimental protocols are also similar but the choice of exposure systems and biological models are different.

The WHO and IEEE databases list about 1,300 peer-reviewed publications, from biophysical theoretical analyses to human epidemiological studies. Recently, 11 review papers have been published on cancer, reproduction, calcium efflux, behaviour, thermoregulation, the nervous system, ocular and auditory effects, homeostasis and metabolism, longevity, epidemiology, and in vitro studies<sup>14</sup>. About half of all published studies are directly relevant to the issue of whether low-level exposure to RFR initiates or promotes cancer.<sup>15</sup>

### *Human studies*

In spite of the obvious limitations of human experiments in terms of endpoints and exposure characterization, several investigations have been performed using various models. Findings have either been negative or difficult to replicate (sleep, EEG, cognitive functions, etc.). There is some evidence of biological effects but not of detrimental health effects of mobile telephones.

However, a report from a Dutch laboratory has drawn a lot of attention from the media and the scientific community as it reported minor effects on the well-being and cognitive functions of volunteers exposed to weak base-station signals.<sup>16</sup> This work, which is not yet published, has been heavily criticized but its protocol is serving as the basis of some more-refined confirmation work.

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<sup>14</sup> Reviews of Effects of RF Fields on Various Aspects of Human Health, in *Bioelectromagnetics* as Supplement 6 (2003), ([www3.interscience.wiley.com/](http://www3.interscience.wiley.com/)).

<sup>15</sup> [www.who.int/peh-emf/research/database/en/](http://www.who.int/peh-emf/research/database/en/)

<sup>16</sup> Zwamborn A.P.M., Dr. ir. Vossen S.H.J.A., Ir. van Leersum B.J.A.M, Ing. Ouwens M.A., MakeI W.N., Effects of global communication system radio-frequency fields on well being and cognitive functions of human subjects with and without subjective complaints. Sept 30, 2003, TNO-report FEL-03-C148 [www.tno.nl](http://www.tno.nl).

Clearly, the main issue today is the potential greater sensitivity of children to mobile telephone RFR. Their lifetime exposure, the fact that their CNS is still developing, and, possibly, increased RFR absorption in the head, have led to concerns that cannot be easily resolved through laboratory investigations and numerical modelling. A WHO scientific meeting, held in Istanbul in June 2004, was devoted to this issue.

### *Animal studies*

A large number of animal experiments have been performed over the past forty years, using various RFR frequencies and modulations. It is clear from these data that the vast majority of the reported biological effects are due to heating. These effects result either from a rise in tissue or body temperature exceeding 1°C or in physiological and behavioural responses aimed at minimising the total heat load.

Major improvements in exposure system design have made it possible to better characterize the SAR within the organism, and allow for either local exposure that mimics mobile telephone use (e.g. loop antenna, carousel) or whole-body exposure related to base-stations (e.g. Ferry's wheel, reverberation chamber, circular waveguide).

Results on most of the non-cancer endpoints have been negative (memory, EEG, hearing, etc.) except for data on the permeability of the blood-brain barrier, which was found to be increased by two research groups but not by several others. Therefore, most of the major ongoing studies deal with cancer models. All of the long-term bioassays or sensitized studies have given negative results except for one using transgenic mice, genetically modified to increase the background incidence of lymphomas, in which an increased tumour incidence was found following GSM exposure. No such finding emerged from a recent confirmation study, using a different design. While awaiting the results of a further replication study, there is no convincing evidence from animal investigations that the incidence of lymphomas and other types of tumours is influenced by lifetime, daily exposure to mobile telephony RFR.

### *Cellular studies*

In spite of their inherent limitations related to the lack of cell-to-cell interactions and altered genetic characteristics, in vitro investigations on cells have provided some useful information at a fast rate and moderate cost. A number of replication studies that addressed some positive findings on enzyme activity, gene expression, and DNA alteration have all proven negative so far. Research is currently actively investigating possible alterations of heat shock proteins, seen as potential markers for RFR exposure and/or leading to physiological alterations in cells.

A wide range of short-term, low-level in vitro experiments have shown that exposure did not cause cell death, implying that RFR is not a toxic agent. Furthermore, the weight of evidence available today (induction of DNA strand breaks, chromosome aberrations, micronuclei formation, DNA repair synthesis, sister chromatid exchange, and phenotypic mutation) supports the conclusion that RFR is not genotoxic. However, this conclusion is now disputed based on some of the results of the Reflex programme. Moreover, the synergy of RFR with chemical agents or other physical agents still needs further investigation.

## *Conclusion*

There is much scientific evidence, based on existing research, that warrants limiting exposure to high-level RFR due to the "thermal effects" caused by heating of the tissues at SAR<sup>17</sup> levels that correspond to a temperature elevation of a few degrees. However, this does not occur with mobile telephones. The search is thus for "non-thermal" effects and most of the research activity has been aimed at defining the thresholds for these effects, with respect to existing exposure guidelines which are based on acute effects known to be due to heating.

The process of health risk assessment by bodies such as ICNIRP, IEEE, IARC, and WHO relies heavily on judging the quality of investigations. The quality of exposure systems has greatly improved and can now be considered adequate. The use of well-grounded experimental protocols (sham-exposure, blinding of exposure and biological tests, positive controls) has become generalized. Moreover, it is now common practice in the field of bioelectromagnetics to ascertain that any positive results are replicated in at least one independent laboratory. In spite of these improvements, it should be noted that only a few top-level biology laboratories have engaged in this type of research, partly due to interferences created by societal and media pressure.

Within its EMF International Programme, WHO has reviewed the science and issued the research recommendations (to be updated soon). The main conclusion from these reviews is that EMF exposures below the limits recommended in the ICNIRP guidelines do not appear to have any known impact on health. However, there are still some key gaps in knowledge requiring further research to provide definitive health risk assessments: IARC will issue a cancer classification of RFR in 2006 and WHO and ICNIRP's evaluations on RFR and health are due later.

Most governments have addressed the issue of mobile telephony and health and several international and national expert committees have written accurate summaries of current knowledge. Their conclusions converge towards an absence of health effects related to mobile telephones, but all encourage continuing research in some areas.

In answer to the question: "*mobile telephony: evidence of harm?*" one must conclude that the weight of scientific evidence does not support health concerns or indicate any health risks from mobile phones in normal use, nor that there is any accepted mechanism for potential health effects at the low levels associated with these devices. However, there are still some issues pending, in particular those related to the potentially greater sensitivity of children. The many ongoing research projects should help clarify these issues by the end of 2006.

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<sup>17</sup> Specific absorption rate in W/kg

## Mobile Telephony and Tumour Risk

Anders Ahlbom, PhD, Professor  
Karolinska Institute, Sweden

Safety limits for exposure to radiofrequency electromagnetic fields (RF) are set with considerable safety margins in relation to established thermal health effects. Both telephones and base stations result in exposure levels below those safety limits. Indeed, exposure from base stations is generally several orders of magnitude below these levels. While there is no strong hypothesis for any mechanism by which low level RF exposure could have detrimental health effects, there is a concern that our knowledge about consequences of RF exposure may be incomplete or not fully understood. This concern is currently amplified by some yet unconfirmed results, from in vitro studies, suggesting non-thermal genotoxic effects of RF exposure. Therefore epidemiologists study cancer risks in relation to telephone use and also, in a few instances, in relation to RF exposure from transmitters.

Most of the studies on phone have not found an association with brain tumor risk, but in some reports excess risks are seen among mobile phone users. The most clear excess risk is seen for acoustic neuroma and long term phone use. However, several methodological issues must be addressed before firm conclusions can be drawn. For short term use, however, most of the data seem to indicate that no risk elevation is present for any of the intracranial tumors that have been looked upon. Results are not completely consistent and some researchers have found clear associations between mobile phone use and brain tumor risk. The explanation to the conflicting results is not well understood. More results, particularly from the Interphone study are expected shortly and should shed further light on this issue.

The number of studies looking at RF exposure from transmitters is considerably smaller than the number of mobile phone studies. The reason is perhaps that the exposure is so much lower than the one experienced from the telephones themselves. As it turns out such studies are also more difficult to design. Even though some of the transmitter studies do show elevated risks among people living near the antennas they are all difficult to interpret due to small numbers and/or uncertain exposure assessments. Most of these studies have used radio and TV antennas as source of exposure. Only one has looked at mobile phone base stations and this is particularly difficult to interpret for methodological reasons.

## Does Modulation of RF Fields Matter?

Professor L J Challis

University of Nottingham, UK and Chair of UK Mobile Telecommunications and Health  
Research Programme Committee, United Kingdom

The talk will discuss three aspects of this question.

- Does modulation lead to new interaction mechanisms or modifications to existing mechanisms?
- Is there experimental evidence for new or modified interactions?
- What further research could be done to increase our knowledge?

It will be shown that it is unlikely that modulation produces significant changes in RF interaction in biological tissue. It could however result in new interactions if electric fields or currents are produced at the modulation frequencies. This would be of concern if these ELF fields exceeded the ICNIRP public exposure guidelines in the range 4-1000 Hz of about 20 mV/m for tissue conductivity of 0.1 S/m. So the important question is: can tissue produce sufficient demodulation of a modulated RF electric field of say 100 V/m to generate an ELF field of 20 mV/m ? This could occur if the response of biological tissue to RF electric fields were sufficiently non-linear.

Present experimental evidence appears to suggest this is not the case. Recent literature reviews concluded that there is no convincing evidence to date that modulation produces detectable biological effects (eg 2001 AGNIR report on TETRA; 2004 AGNIR review). However Foster and Repacholi (2004) noted that these reviews did not include some Russian work reporting modulation effects. The other main reports of modulation effects relate to Ca efflux although these are no longer widely accepted.

To obtain more information on the size of the ELF fields resulting from modulation, we need more information on the non-linear behaviour of tissue. An experiment to do this has recently been funded by MTHR. Further experimental work to look for biological effects produced by modulation would probably need to focus on neuronal activity

Recent discussions of this topic include Foster K.R and Repacholi M. (Radiation Research 162, 219-225, 2004) and Challis L J (Bioelectromagnetics, in press; published online bem.20119, June 1 2005)

**Scientific Basis for ICNIRP Standards**

**Speaker: To be Advised**

## WHO/EURO Booklet on Wireless Communication

Dr Colin Roy  
Director NIR Branch  
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

### The Problem

*“More than 1.4 billion people, that is around 20% of the World's population, have a mobile phone. A further 2 billion people in the world have yet to make a phone call and when it happens it will most likely be on a mobile phone not a fixed telephone line. This represents an unprecedented expansion of personal communications technology that requires extensive networks of radio transmitters - commonly called base stations”.*

Mike Walker, Vodafone, WHO Base Station Workshop, Geneva, June 2005

The deployment of wireless communication infrastructure has caused problems in many countries around the world. Many authorities who are required to make decisions on deployment are often not equipped with the appropriate knowledge. It was decided that a booklet would be developed within the WHO International EMF Project on Wireless Communication for local authorities. The booklet would build on the success of the EURO Booklet on 'EMF Fields' published several years ago.

The content of the booklet was discussed and agreed at the WHO Geneva meetings in June 2005 and a first draft is nearing completion.

### The Content

#### Overview

1. Telecommunication Technology
2. Health Effects
3. Addressing Public Concerns-Risk Communications.
4. Key Messages
5. Questions and Answers

Annex 1 - International Exposure Standards

Annex 2 - Exposures

Annex 3 - Base Station Siting - Case Studies

Annex 4 - Further Information

Glossary

The draft will be discussed and the timelines for publication will provided.

## Harmonizing Standards and Precaution

Dr Emilie van Deventer  
World Health Organization, Geneva, Switzerland

The development of guidelines or standards that limit EMF exposure should ideally be based on established scientific evidence; otherwise the limit values may be either not protective or unduly restrictive. Once the evidence is properly evaluated, usually through a health risk assessment of all scientific studies, it can then be used to develop and implement policy and standards. However, policy makers must also take public opinion into account and ultimately policy development should include both a scientific approach and a political process to produce accepted and effective outcomes.

Since protecting populations is part of the political process, it is expected that different countries may choose to provide different levels of protection against environmental hazards, responding to their national health policy. Various approaches to protection have been suggested to deal with scientific uncertainty. In recent years, increased reference has been made to cautionary policies.

With regard to the EMF issue, governmental and industry authorities have responded by implementing a wide variety of mandatory and voluntary precautionary approaches, based on cultural, social, and legal considerations. These include the weight given to avoiding a disease that affects mostly children; the acceptability of involuntary, as opposed to voluntary, exposures and the different weight given to uncertainties in the decision-making process. Examples in the RF frequency range include prudent avoidance (e.g. Australia/New Zealand), precautionary emission control (e.g. Switzerland) and precautionary exposure limits (e.g. Italy).

This diversity of approaches by national authorities led WHO's International EMF Project to develop a "Policy Framework" for rational and cost-effective guidance of policy options in areas of scientific uncertainty. A principal recommendation by WHO is that these types of policies be adopted in such a way as not to ignore scientific assessments of risk and science-based exposure limits. WHO specifically recommends not to reduce the limit values in international standards to some arbitrary level in the name of "precaution" since this undermines the science base on which the limits were based and can introduce an additional cost of compliance for no known health benefit. Also, from a sociological standpoint, there is increasing evidence that making arbitrary reductions in exposure limits leads to increasing public concern, rather than reducing it.

## **Occupational Safety and Health in Australasia**

**Dr David Black, FAFOM  
Senior Lecturer in Occupational Medicine  
University of Auckland, New Zealand**

Australia and New Zealand are countries with British legal origins. The traditional occupational health and safety systems have been replaced with more modern statutory approaches, and both countries are working towards ratification of ILO conventions. Australia adopted a tripartite approach in the 1980's, New Zealand is currently reforming legislation to become tripartite. Statutory health and safety systems have to work within the context of compensation systems and these vary between the countries and the states in Australia. Both Australia and New Zealand have current improvements underway. In New Zealand the Workplace Health and Safety Strategy is a ten year plan launched in 2005 addressing work related disease in particular and developing principles with defined outcomes to achieve a vision of a healthy workforce in safe and productive workplaces. Health and safety maintenance in the context of work related exposure to electromagnetic energy is defined in the Australian and New Zealand Standards in a way which is compatible with these modern statutory approaches.

## Communicating with Stakeholders on the RF Issues

**Dr. Ray Kemp**

**Head, Risk Management Group, Galson Sciences Limited, United Kingdom**

This paper assesses the relative effectiveness of approaches to risk communication and community consultation for deployment of radio base stations in Australia and in the UK.

In both parts of the world, the intention has been to address the need for trust and dialogue that the WHO International EMF project has espoused in the past. Similarities and differences are highlighted, as are the practical steps that have been taken by regulators, industry and local authorities and other stakeholders to:

1. establish a framework for dialogue
2. engage with stakeholders in the development of best practice/consultation guidance
3. develop working guidance on consultation tools and techniques
4. implement the approaches
5. review the effectiveness of approaches

The paper presents practical examples of how health risk communication on EMF works well and where it goes wrong. The key lessons will point to:

1. the key distinction between "risk management" and "crisis management" and the need to encourage the former
2. the key role that the WHO International EMF Project has and does play in the risk communication process
3. the importance of health guidance and regulatory inputs that are "fit for purpose" and proportionate to the assessed and the perceived risks
4. the need for all stakeholders - carriers, regulators, local government and local publics to recognise that trust is a valuable commodity and that rights and responsibilities go hand in hand - this is a common societal problem that requires joined-up thinking
5. possible implications for the WHO, national regulators and other countries when facing the same issues.

## Communicating with Children about EMF via the Web

**Kwan-Hoong Ng, Heng-Loke Siow<sup>a</sup>, Siew-Eng Lee<sup>a</sup>, Nahrizul Adib Kadri<sup>b</sup>, Li-Kuo Tan**  
**Departments of Radiology, Maths and Science Education<sup>a</sup>, Biomedical Engineering<sup>b</sup>**  
**University of Malaya, Kuala Lumpur, Malaysia**

With the rapid advances in electromagnetic field (EMF) technologies and communications, children are increasingly being exposed to EMFs at earlier ages. Recent studies have shown that modern children will experience longer periods of exposure to radiofrequency (RF) fields from mobile phones than adults, this is because they start using mobile phones at an early age and are likely to continue using them (Kheifets et al. 2005, Schüz 2005). Recent trends in the enhanced mobile communication technology have led to a higher usage among children (Schüz 2005). They are also becoming the fastest growing group, representing 22%, of all mobile phone owners and are expected to spend up to USD one trillion in 2006 (mobileYouth 2005). Hence there is an urgent need to educate this important exposed group of the population. The development of a distance learning web program is one of the initiatives of the World Health Organization (WHO) International EMF Project to communicate scientific and health information about EMF to children between 5 to 16 years old.

A pilot survey was conducted to gather background information on the experience of using mobile phones among Malaysian school children. 381 students from five schools took part in this pilot survey: 11.3% (43) primary school (age 10 to 12) and 88.7% (338) secondary school (age 13 to 18). 86.6% (330) and 81.6% (311) owned mobile phones respectively and considered them as essential items. 79.4% (297) wanted to know how they work. Magazines or newspapers were the most popular sources of information about mobile phones followed by the internet, friends, and books. However, 58.8% (224) of them believed that using mobile phones made them ill and the most prevalent health effects perceived by them were (in descending order) headache, cancer and tiredness. 53.5% (204) understood that mobile phones use radio waves. This is supported by the findings of a review of science teaching in twelve countries which show that students start to learn electromagnetism from age 12 to 14.

This pilot survey acts as a foundation for an ongoing global on-line survey. (<http://radiology.um.edu.my/emfsurvey>) This on-line survey is targeted to a much wider cross-section of the global children population. The findings of the global survey will provide the baseline for determining the pre-instructional behaviour and prerequisite knowledge of learners and also in designing and developing this distance learning web program. The Systems Approach Model (Dick, Carey, Carey 2005) for instructional design and the e-learning design techniques (Clark & Mayer 2002) are used to develop an interactive and activity-based web program. The features to be included in the web program include simulation of concepts, animation, educational games, quizzes, resources and readers' forum. A work-in-progress web learning program will be demonstrated.

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## WHO'S RECOMMENDATIONS ON RF

**Dr Mike Repacholi**  
**Coordinator, Radiation and Environmental Health**  
**World Health Organization, Geneva, Switzerland**

Since the International EMF project was established by WHO in 1996, there has been a focus of activities to determine whether exposure to radiofrequency (RF) fields below the levels of the international guidelines could produce any adverse health consequences. Research at the so-called non-thermal levels of exposure have been promoted. Such research has been identified through international seminars that review the scientific literature, determine what effects have been established from RF exposure and recommend research that will fill gaps in knowledge.

Since 1996 WHO has identified a wide range of RF research, most of which has been conducted through national research programs and within the European Commission's 5<sup>th</sup> Framework program. Some US\$250 million has been spent on research against the topics recommended in WHO's research agendas. The results are now being published and will contribute significantly to the health risk assessment process now underway within the EMF Project.

In addition, specialized seminars have been conducted to address specific topics. These include:

1. Determining whether non-thermal effects of RF exposure produce adverse health effects
2. RF dosimetry
3. Effects of modulated RF fields
4. Children's are sensitivity to EMF exposure
5. Hypersensitivity to EMF
6. Mobile phone base stations and wireless networks

This paper will review the results of these seminars and provide WHO's recommendations on the management of RF fields. Further information can be obtained from the EMF Project web site at: <http://www.who.int/emf/>.

# ABSTRACTS

## Student Poster Presentations

As part of the Workshop, the Australian Centre for RF Bioeffects Research (ACRBR) will be offering 2 undergraduate and 2 postgraduate prizes for outstanding research in any area relating to RF Bioeffects. The abstracts below represent the finalists' submissions for these awards, with final judging of the related posters to be conducted during afternoon tea on the first day of the Meeting, by Professor Bernard Veyret (Bordeaux University, France) and Professor Kwan-Hoong Ng (University of Malaysia, Malaysia).

We thank the judges for their time and knowledge, and the students for the great work that they've been conducting.

# The Acute Effect of Electromagnetic Fields Emitted by a Mobile Phone on Working Memory.

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## *Background*

Concern has been raised about the possible effects of the electromagnetic radiation emitted by mobile phones on brain function (World Health Organization, 2000). Several studies have reported improved cognitive performance when human volunteers are exposed to mobile phone emissions compared to an inactive mobile phone (Cook et al., 2002). Although sporadic, these results are difficult to dismiss as fluke findings since there have been comparatively few reports of mobile phone emissions disrupting cognitive performance (Haarala et al., 2004). Replication of past studies using improved control of error variance is now required to confirm what is most likely a weak effect of mobile phone emissions on cognition (Haarala et al., 2004).

Working memory is the ability to temporarily hold and manipulate information within the mind to enable cognitive activity (McEvoy et al. 1998). Several studies suggest that mobile phone emissions improve performance on working memory tasks (Cook et al., 2002). Koivisto et al. (2000) further suggested that the effects of mobile phone emissions increase in proportion to the working memory demands of a task. To test this hypothesis, Koivisto et al. (2000) tested the effect of mobile phone emissions on the n-back working memory task. This task requires participants to attend to a series of letters presented on a computer screen and press a "yes" or "no" after each letter depending on whether or not it matches the letter shown "n" letters beforehand, respectively. By varying the value of "n" from 1-3 over different versions of this task, memory load was manipulated whilst keeping other task parameters constant. Koivisto et al. (2000) found that participants that mobile phone emissions significantly improved speed without reducing accuracy on the 3-back task, whilst having no-effect on the 1- and 2-back tasks. This supported their hypothesis that mobile phone emissions have a stronger effect on tasks which place greater demands on working memory.

A subsequent replication study has failed to find any effect of mobile phone emissions on the 1-, 2-, or 3-back working memory task. Unlike Koivisto et al. (2000), Haarala et al. (2004) used a double-blind protocol and controlled for raised experiment-wise error due to multiple comparisons by using a Bonferroni correction, lending greater credibility to their results. However, the n-back task used in the replication study was substantially different from the first study: Koivisto et al. (2000) used a version of the n-back task in which letter-case was varied, while Haarala et al. (2004) used only capital letters. Hence participants in the former study would have relied mostly on verbal memory, whilst participants in the latter study could have relied equally on visual imagery to complete the task. This provides an alternative explanation for the discrepancy in results between these two studies.

## *Aim*

The aim of this study was to 1) investigate the effect of mobile phone emissions on cognition, and more specifically, on working memory performance as indexed by accuracy and reaction time as a function of memory load, and 2) attempt to replicate the findings of Koivisto et al. (2000) using a near-identical version of the n-

back. It was predicted that mobile phone emissions will decrease reaction time (i.e. increase speed) on the 3-back working memory task (Koivisto et al., 2000).

### ***Methods***

8 females and 5 males, aged between 22 and 28, attended two testing sessions held about a week apart. Participants performed computerised 1-, 2- and 3-back tasks twice: during exposure to an inactive mobile phone in one testing session and an active phone during the other testing session. In both sessions the mobile phone was placed next to the left ear and set according to a double-blind protocol. Both the order of the n-back conditions and the mobile phone conditions were partially counterbalanced across participants.

Reaction time analysis only included data for correct responses that were two standard deviations below the mean reaction time for each participant under each EMF x stimulus type x memory load condition. Mean reaction times for each participant were then recalculated for each (EMF x stimulus type x memory load) condition. A mixed-design analysis of variance (ANOVA) was conducted where the recalculated mean reaction time was the dependent variable; exposure condition (EMF vs. sham), memory load (1-back vs. 2-back vs. 3-back) and stimulus type (target vs. non-target) were the within-subject factors; and exposure order (EMF-SHAM vs. SHAM-EMF) was the between-subject factor. Using these same factors, another ANOVA was performed using percentage error rates as the dependant variable. Post-hoc tests were conducted for significant results involving multiple factors or factors with more than two levels. A Bonferroni correction was used to correct for multiple comparisons.

### ***Results***

Accuracy and reaction time for the 1-, 2- or 3-back working memory task did not differ significantly between mobile phone conditions (RF vs. Sham). There was a significant effect of memory load on both reaction time and accuracy. Post-hoc tests revealed that reaction time was significantly greater in the 3-back than the 2-back condition, and the 2-back than the 1-back condition. Significantly more errors were made in the 3-back condition than the 2-back condition, although there was no such difference between the 2-back and 1-back conditions.

### ***Conclusion***

The 1-, 2- and 3- back working memory tasks place progressively increasing demands on working memory, as revealed by a decline in performance with increasing memory load. This study found no evidence of mobile phone emissions on working memory function in humans regardless of task difficulty. This suggests that discrepancies between past studies may be better explained by differences in statistical analysis and blinding procedures than differences in task parameters.

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# Physical Validation of Canonical Computational Electromagnetic / Thermal Model of Radio Frequency Exposure in the 1 – 10 GHz Range

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## *Background*

The objective of this student project is to provide physical validation of computational electromagnetic / thermal modelling to be used in a project, taking place at the Telstra Research Laboratories, which hopes to determine the frequency at which the incident power density model is a better approximation for energy absorbance than the SAR approximation.

Currently, compliance with human radiofrequency (RF) exposure limits is based on the metric Specific Absorption Rate (SAR, W/kg). The SAR is calculated using volume averaged over a mass of 10 grams and a time frame of six minutes, to provide correlation with human thermal responses, which are not instantaneous in time or space. However, as the frequency of exposure increases, the absorption of energy is found to take place mostly at the surface of the body rather than in deeper regions. At some point within the 1 – 10 GHz range, it is expected that the volume averaged SAR will stop providing a good correlation to absorption at the surface (where the greatest temperature rise occurs), and that the incident power density (S) will be the more accurate alternative metric.

To determine the frequency at which the transition between SAR and S should be made, the SAR produced in a numerical model of human exposure (based on a FDTD voxel [volume element] model) will be calculated. This SAR will then be used in a further calculation based on the bio heat equation, also implemented in the FDTD voxel model, to predict the temperature change at the surface. This calculation is not sensitive to the surface nature of absorption, as technically, SAR for thermal calculations is based on point SAR values, rather than a volume average. The actual thermal distribution at the surface will be compared to the S and SAR (10 gram averaged) distributions to determine which provides the best correlation at each test frequency, thereby determining the transition point.

While the exposure to be modelled is intended to represent human exposure to telecommunication signals, it is proposed that the primarily surface nature of the interaction allows significant simplification of the model so that simple surface layer models (of skin and fat tissues for example) without significant morphological detail will be adequate. However, even for these simple models, no physical validation (laboratory measurement) of the predicted results has been attempted to ensure that the electromagnetic and thermal analyses are appropriate. This physics final year project will therefore define a canonical model to be modelled using the above electromagnetic and thermal modelling environments to predict temperature distributions at the surface and inside the volume of the exposed sample. These predictions will then be tested by measurements made in the laboratory.

## *Experimental Considerations and Method*

The canonical model used in this project was to be physically realised in a laboratory environment where temperature measurements within the volume (and possibly on its surface), during the RF exposure could be achieved. Things to be considered were the resources available in the laboratory, the physical dimensions of the model, the tissue properties of sample, power and frequency of exposure, distance between source and sample and extent of temperature changes to be measured. Safety

procedures were to be strictly adhered to during all stages of the project and experiment.

The dimensions of the physical structure to be tested was decided after considering the time it would take to run computational models in XFDTD as well as the equipment available to build the structure. The shape decided upon was a cube, due to its ease of construction. The size was made large enough to allow us to ignore any edge effects from the corners of the cube. It was decided that the temperature distributions inside the volume would be measured using an array of fluoroptic temperature probes placed strategically inside the surface, so as to provide the temperature profiles in the x, y and z-directions. RF exposure would be achieved using RF sources, amplifiers and waveguides available in the laboratory and the experiment would be conducted in TRL's purpose built shielded chamber. The frequency was chosen to be 1.8 GHz, since the amount of information available was significantly greater for this frequency due to its relevance in the current telecommunications technology spectrum. It was determined through testing that the power available from the waveguide at this frequency would fall between 20 – 25W, and that the sample should be placed as close as possible to this source in order to achieve measurable temperature rises in roughly 2 hours of experimental time.

Tissue properties of the sample could have been achieved either using animal tissue (easily be obtained from a butcher or veterinary service) or by preparing the tissue equivalent gels in the laboratory. Since the human head is one of the regions of most concern in regards to RF signals, it was decided to create a model that best represented this area of the human body. Having conducted a literature search into the depths of layers in the human head (skin, subcutaneous fat, muscle and bone) and their respective dielectric values (conductivity and permittivity), it was discovered that the values change rather rapidly following death, and also vary substantially between man and other species. For the sake of accuracy, it was therefore decided that the tissue sample would be constructed in gel-form ('goop' for 1.8 GHz) in the laboratory, rather than by obtaining cadaver samples. In accordance with the standard human head model for RF exposure experiments, a sample was created that complied with the average head dielectric values.

Due to time restrictions, the computational modelling is being carried out by Dr. Robert McIntosh. It has also been decided that the scope of this project is to obtain temperature profiles within the contained volume of the model and not on its surface, due to complications such as transient heat transfer coefficients. The examination of other scenarios such as the above mentioned will be conducted outside the time allocated to the final year physics project.

### ***Preliminary Results/Conclusions***

At this stage, the goop mixture has been made, the foam container with a cubical cavity has been manufactured and the RF sources have been set-up and tested for power, return losses etc. The first of two runs of the experiment has been carried out that describes the variation of the temperature in the goop as we move away from the RF source (profile in the z-direction). The results obtained indicate a linear rise in temperature (0.1 degree every 15 seconds) for the first 15 minutes at four different distances in the goop, moving away from the waveguide source. After 15 minutes, there is a sharp rise in temperatures and the strictly linear relationship disappears, instead replaced by fluctuations following a linear trend with a lower gradient than before. From a starting temperature of 22.7 degrees, the goop rose to 37.3 degrees within 2 hours, with an RF input power of 22 W. The box, made of polystyrene foam, seems to have been a good choice as it tested out to be invisible to the RF radiation and also performed remarkably well as an insulator.

The second test, to be run later this week, will consist of testing the temperature profile in different regions of a single plane across the face of the foam box. This will effectively give us the temperature variations in the x and y directions. Comparing this result as well as that given above, to those obtained via computational modelling of the same set-up, will allow us to determine the validity of computational modelling as well as an estimate of its accuracy.

Currently, the results obtained seem very promising in matching up to those obtained by modelling, however, it will be another two weeks before the second experimental run is completed and the computational results are in hand for analysis, comparison and the drawing of a conclusion.

# The Effect of GSM900 Exposure on Human Brain Activity and Performance

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Other Members of Research Team: RJ Croft, AW Wood, C Stough, J Spong

## *Background and Rationale*

Over the last ten years since their introduction, digital mobile phone (MP) connections have grown rapidly to over one billion worldwide. As MP handsets are commonly used in proximity to the head and emit electromagnetic fields (EMFs) in particular radio-frequency (RF) ranges not traditionally investigated, there has been much demand for science to keep up with evolving technologies and to address public concern regarding the impact of MP use on human health and safety.

An area of particular and growing interest is the possible effect that MP-emitted EMFs may have on human brain function and behaviour. Some consistency has been found in relation to GSM900 exposure on auditory processing. This includes various reports of event related spectral power modulation in response to auditory tasks requiring discrimination [1,2]. A recent pilot study used a similar task to investigate any effect of exposure on auditory Event-Related Potentials (ERPs) and found the amplitude and latency of a sensory component N100 to decrease and the latency of a later cognitive component (P300) to increase [3]. Similar findings have since been reported in relation to modulation of the early sensory component [4]. Several previous studies dismiss the claim of MP-related effects but have often suffered methodological limitations [5]. Frequently, exposure durations were brief and the source was an unmodified MP undergoing adaptive power control, discontinuous transmission (DTX) and therefore minimal power output. Additional contributors to null findings may include small, unrepresentative samples and the lack of double-blinding.

Performance measures, such as reaction time (RT), have also been utilised in the search for MP-induced bioeffects. Although several researchers have reported no effect [2, 6, 7], others have observed a change in RT after 1hr of active exposure [3, 8]. Studies examining the effect of MP exposure on RT generally incorporated larger sample sizes and longer exposure durations in comparison to previous studies focusing solely on ERPs, however, the issues of accurate dosimetry and the use of double-blinding techniques remain common methodological limitations.

The current study aimed to provide results of a more definitive nature by employing a large sample size for adequate statistical power to detect even the most subtle effects, and a stringent methodological design to account for past limitations such as single-blinding, inadequate dosimetry and variable exposure conditions. Specific hypotheses were derived to test the results from a previous pilot study [3], as well as recent positive findings more generally [2, 4, 8]. These hypotheses were that the N100 amplitude and N100 latency would decrease and that the P300 latency and RT would increase under active exposure relative to sham exposure during the auditory task. Any effects on the visual P100, P300 and RT, auditory P300 amplitude were also examined but treated as exploratory.

### ***Materials and Methods***

The sample comprised 120 volunteers who were required to attend two sessions one week apart. In double-blind, counterbalanced conditions half underwent active exposure in the first session, the other half in the second. In both sessions, once the participant had been fitted with EEG recording apparatus, a phone set to sham exposure was mounted over the temporal region. Subjects then performed an auditory oddball task and a visual oddball task. The second administration of both tasks was then given with the handset set to active/sham exposure (duration 30 minutes). The MP was set via laptop and manufacturer software to continuously transmit an 895 MHz signal at a mean power output of 250 mW, thus avoiding DTX and adaptive power control. This signal was pulse modulated (217 Hz) with a duty cycle of 12.5% and a pulse width of 576  $\mu$ s. SAR measurements were conducted using a precision robot RF Dosimetric Assessment System. The average SAR measured over 10g of tissue in-line with the phone's antenna was 0.110 W/kg. EEG was recorded using Neuroscan Synamps amplifiers and data acquisition software. Average waveforms were calculated using Neuroscan Edit software.

For all analyses, difference scores were employed as dependent variables. Difference scores were calculated by subtracting each of the electrophysiological (amplitude and latency) and performance (RT) endpoints measured during the baseline period, from the corresponding endpoints during the experimental period. Statistical significance was tested with paired samples t-tests for each of the four ERP components' amplitude and latency measures, and RT measures. Differences for hypothesis-driven tests (auditory N100 amplitude and latency, P300 latency and RT) were directional (one-tailed) and considered significant at  $p = 0.05$ . The more exploratory tests (pertaining to the auditory P300 amplitude and visual task endpoints) were non-directional (two-tailed) and considered significant at the Bonferroni corrected  $p$  value of 0.008 (0.05/6).

### ***Results***

No significant differences were found between sham/sham differences and sham/active differences for any of the electrophysiological components of interest. Additionally, no differences were found in relation to RT for either auditory or visual tasks. Although non-significant, there was a trend towards a difference in the auditory RT caused by an increase over the sham/active session compared to the sham/sham session.

### ***Discussion and Conclusions***

Results of the current investigation indicate that acute exposure to EMFs emitted by GSM MPs do not alter human brain activity in the form of the early auditory (as indexed by the N100), early visual (as indexed by the P100) or later cognitive responses (as indexed by the auditory and visual P300 components). Specifically, the change in ERP responses from pre- to post-sham exposure did not differ from that of pre- to post-active exposure along the midline of the scalp (where signal-to-noise ratios are largest). The findings also suggest that resultant behaviour (as indexed by RT) is also unaffected by exposure. We conclude that there is currently no clear evidence in support of a MP-related EMF effect on ERPs or RT. The current results also highlight the importance of adequate sample size, dosimetry, exposure duration and in particular the use of double-blinding techniques.

[1] Eulitz et al. 1998 [2] Croff et al. 2002 [3] Hamblin et al. 2003 [4] Maby et al. 2004  
[5] Hamblin and Wood 2001 [6] Preece et al. 1999 [7] Haarala et al. 2003 [8] Koivisto et al. 2000

## Techniques and Methods for Non-Invasive Personal Radio-Frequency Dosimetry

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Other Members of Research Team: R McKenzie, I Cosic

### ***Background:***

To address health concerns regarding exposure to radio-frequency (RF) fields, expert international bodies such as the International Commission on Non-Ionising Radiation Protection (ICNIRP)<sup>1</sup> have developed RF exposure limits to protect against known hazard mechanisms involving tissue heating and electrostimulation. ICNIRP provides two types of RF exposure limits: basic restrictions and reference levels. Basic restrictions provide the most direct means of assessing RF exposure but are also very difficult and impractical to measure as they relate to the RF fields and current densities induced on the surface or inside the body. Since there are no practical methods to directly measure the internal fields and currents in exposed people, ICNIRP also provides reference levels, based on free space fields and induced body currents, that are simpler to measure and which may be used as an alternate way of showing compliance with the mandatory basic restrictions. However, measurement of these quantities only provides a crude surrogate for the induced fields and current densities in an individual which will vary from person to person. This work aims to develop techniques and methods that will allow non-invasive, personalised assessments of the internal fields and current densities in a human body.

### ***Rationale:***

Radio technology is a pervasive and ubiquitous part of day-to-day life bringing wireless communications within easy reach to all members of society. The spread of radio communications has raised important questions about the short and long term health effects of exposure of humans to radio frequency (RF) energy. This issue is of immediate concern to people who work in radio-frequency (RF) environments and are exposed in the course of their work to RF energy at levels above those experienced by the general public. In more recent times, public concern has focussed on the potential health impact of radiation from mobile telephony base-stations and mobile handsets, and radio broadcast towers.

To address these concerns, national and international scientific (e.g. ICNIRP) and standards organizations (e.g. IEEE, International Electrotechnical Commission (IEC)) have developed RF safety standards to provide guidance to government, industry and the community on safe levels of exposure to RF energy. The fundamental RF exposure limits are known as basic restrictions and are stated in terms of the fields and current densities induced in a human body and which are generally impractical to measure in a person. The key benefits of this project will be to develop new tools that will enable researchers and industry practitioners to provide a direct assessment of the fields and current densities induced in people exposed to RF energy.

The following are some examples that show how this research could provide benefits to industry, community and scientific researchers:

- 1/ Since the actual RF dose that is received by a person in an RF environment can only be estimated, the true exposure (energy deposited in the body) remains largely unknown. A better estimate of true exposure will provide greater certainty when assessing RF safety risk and will reduce the cost to industry and the community of complying with safety standards. Accurate information also assists government and industry when

communicating exposure risk to the public thereby reducing concern about health risks;

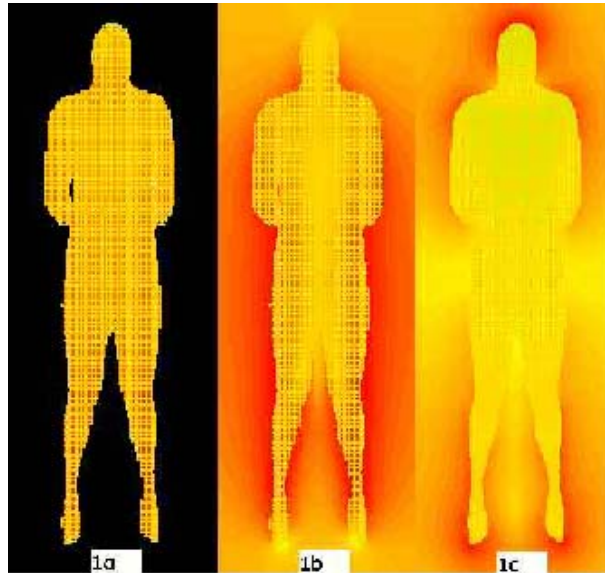
- 2/ This research will quantify the link between ambient electromagnetic fields and the actual RF dose received by a person for a range of electromagnetic environments. In RF safety standards, reference levels have been derived on the basis on generic human shapes and for RF exposures in limited situations so that their relationship to the basic restrictions remains uncertain. A better understanding of this relationship will provide valuable input to the development and revision of RF safety standards to ensure that reference levels (e.g. ambient field strength limits) and basic restrictions are compatible and technically consistent with each other;
- 3/ Personal RF dosimetry techniques and methods are crucial in epidemiological studies that seek to establish a causal link between RF exposure and impact on human health. Epidemiological studies, such as those promoted by the World Health Organisation's International EMF Project (<http://www.who.int/peh-emf/research/rf03/en/>), provide the most direct information about the risks of adverse effects of RF in humans. However a major difficulty in such studies is the lack of information regarding the actual RF dose received by humans. This project can significantly overcome this issue by providing techniques and methods for directly assessing the actual RF dose in humans.

***Method:***

The current phase of the study is being conducted using analytic and computer modelling to determine the induced specific absorption rate (SAR) induced in a range of human body models. Initially SAR data has been obtained for homogeneous tissue models of the human body based on prolate spheroid<sup>2,3</sup> and cylindrical shapes. More realistic shapes based on the Visible Human Project<sup>4</sup> and the UK NRPB NORMAN<sup>5</sup> model is also being examined. Computer modelling has been performed using a commercial implementation of the electromagnetics computational method known as finite difference time domain (FDTD). The modelling data provides information on the whole body average (WBA) value of SAR in the body models, and the location and value of the peak SAR level for the different models. It also provides information on the relationship between fields external to the body and the induced SAR. This becomes important for determining which external parameters can be measured by non-invasive means to best estimate the induced RF dose received by a person.

***Results:***

Initial modelling shows that the maximum value of WBA SAR obtained with the simplified and realistic shapes are very similar which suggests that the detailed shape of the body is not crucial to obtaining a good estimate for WBA<sup>5</sup>. In contrast, peak spatial SAR is more dependant on actual structure and shape of the body and can be up to 3 times greater than WBA for the prolate spheroid model and more than 10 times greater for the Visible Human model. The modelling also gives insight into the distribution of the fields immediately external to the human model and the SAR induced within the model. It shows that the distribution of the external magnetic field near the surface of the body is well correlated with induced RF fields and may provide a useful, non-invasive estimate of SAR (see Fig. 1).



**Conclusion:**

Initial results of modelling show that there can be a wide difference in the RF energy absorbed by people. It also shows that energy deposition can be concentrated in regions where the cross-sectional dimensions of the body constrict the flow of RF current to narrow regions. It provides a clue as to where measurements should be performed of RF exposure in real situations. More modelling is required at higher frequencies followed by the development of measurement probes to validate the work and to provide a basis for measurement of exposures in real situations.

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## The Effect of Electromagnetic Fields Emitted by Mobile Phones on Human Sleep

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### **Background:**

The development of mobile phone technology has led to substantial advancements in communication, however, this expansion and increase in use has also led to concerns about possible effects this technology may have on human health and performance. Of particular interest are the effects digital mobile phone emissions may have on conventional sleep parameters and the sleep electroencephalogram (EEG).

A number of studies have reported an increase in EEG spectral power within the 8-13 Hz frequency range, in both awake [2-4] and sleep states following RF EMF exposure [5-9]. Enhancements reported during sleep, however, have not been entirely consistent, with some earlier studies failing to find an effect [10-12], and others finding that the effects differ in terms of particular frequency band [5-9]. These reported inconsistencies following mobile phone exposures are likely to be due to a number of methodological issues, such as small sample sizes and variations in power output and exposure durations. It is thus not surprising that there are differences in study outcomes, and it is noteworthy that there *have been* several reports of enhanced sleep spectral power in the 8 – 15 Hz frequency range following RF EMF exposure [5-9]. Of these results, one study reported an increase of non-rapid eye movement (non-REM) sleep EEG power in the 11.5 – 12.25 and 13.5 – 14 Hz frequency ranges, which was present in the initial 30 minutes after lights out and only after 15 minutes of RF EMF exposure [7]. The same group also examined exposure *prior* to sleep using a more ecologically valid testing regime and also found an enhancement in the alpha band, but this time in the 12.25 – 13.5 Hz frequency range [8]. Thus although there are complexities in the literature, there is support for an enhancement in EEG spectral power during non-REM sleep, with the variability in the frequency ranges suggesting that the particular frequency sub-component may be sensitive to differences in methodology.

In addition to changes in spectral power, other conventional sleep parameters, such as rapid eye movement (REM) sleep and waking after sleep onset, have been reported to be affected by RF EMF exposure [5, 9-11]. Unlike spectral power changes, however, there is no consistency in the conventional sleep parameter findings. Further, that the positive findings [5, 9] have not been able to be replicated when tested with stronger methodological control (including dosimetry), suggests that there are no effects of RF EMF on conventional sleep parameters [6, 8, 10-12].

### **Rationale:**

The aim of the current study was thus to test for effects of mobile phone RF EMF on human sleep patterns. In order to improve on previous research limitations and simulate real life exposure conditions and sleep habits, the present study exposed participants to pulsed high-frequency EMF emitted by an actual mobile phone handset, with continuous transmission and constant power output, for a period of 30 minutes prior to a full night-time sleep episode. To this end we attempted to replicate the work of Huber et al. [7, 8] and test the hypotheses that the 11.5 – 12.25 Hz, 12.25 – 13.5 Hz, and 13.5 – 14 Hz frequency bands would be enhanced following RF EMF exposure. Additionally, we tested the hypothesis that RF EMF exposure influences

conventional sleep parameters, although as described above, no effects were predicted.

**Methods:**

Fifty Participants (27 males, 23 females; mean age = 27.9 years, SD = 10.9) slept a total of four nights in a sleep laboratory, attending two experimental sessions one week apart. Each of the two experimental nights were preceded by an adaptation night. On the experimental nights a GSM mobile phone, either transmitting (0.25 W, 217 Hz modulated, 895 MHz output) or turned off, was positioned next to the right hemisphere for a period of 30 minutes prior to sleep. The experiment was carried out double blind with regard to phone status. During sleep, EEG, ECG, EOG, EMG, SaO<sub>2</sub> and respiratory measures were monitored. Sleep was staged and scored according to standard criteria by an experienced sleep technician blind to the experimental condition. EEG channel data was further analyzed to provide power spectral density estimates (FFT routine, Hanning window, averages of 4-second epochs) for the first 30 minutes of NREM sleep.

**Results:**

A repeated measures analysis of variance revealed a decrease in REM sleep latency following pulse modulated EMF exposure,  $F(1,48)=5.797$ ,  $p= 0.02$ . Other conventional parameters showed no evidence of alteration. Spectral analysis of the sleep EEG from the first 30 minutes of the first non-REM period revealed a significant enhancement of EEG power density in the 11.5-12.25Hz frequency range following EMF exposure  $F(1,48) = 5.56$ ,  $p = 0.022$ . No significant enhancement was present in the 12.25-13.5 Hz or the 13.5 – 14 Hz frequency ranges. Effect sizes (partial eta squared) were also calculated for the 0-25 Hz region. The largest effect is seen at 11.5 Hz, partial  $\eta^2 = 0.105$ , which corresponds to a relatively modest effect of the EMF on EEG spectral power in the first non-REM period.

**Conclusion:**

Exposure to EMF emitted by digital mobile phones prior to sleep significantly affects sleep EEG by enhancing power in the 11.5-12.25 Hz frequency range. The increase of EEG spectral power was present in the first 30 minutes of non-REM sleep and was enhanced in the frequency range corresponding to slow sleep spindles. Enhancement of non-REM sleep spectral power induced by high frequency EMF in the frequency ranges largely determined by slow and fast sleep spindles has also been found in a number of previous studies [5-8]. The significance of an enhancement of spectral power in this frequency range during the initial part of sleep remains unknown. It has been suggested previously that subcortical regions, such as the thalamus, may be more sensitive to RF EMF than other structures of the brain, and because spindle oscillations are generated in the thalamus, RF EMF may be stimulating cortical neurons to induce alterations in sleep spindle activity [7]. The exploratory analyses also suggested that RF EMF may cause a decrease in REM latency. However, as a decrease in REM sleep latency following EMF exposure has not been reported previously, this effect needs to be replicated before any conclusions can be drawn.

Despite the inconsistencies regarding the band-width of spectral enhancement in previous research, which could be due to the differences in experimental designs, the current results show that brain function is altered under the influence of RF EMF. This study thus demonstrates that a short exposure to mobile phone type radiation has an effect on subsequent sleep EEG, although no conclusions can be made regarding adverse health consequences as the mechanisms of the effects are still unknown.

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## Characterisation of Magnetic Field Generated by Mobile Phone Handsets and their Batteries

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### *Background*

There have been concerns among the scientific and general community regarding the effects of mobile phones, specifically their radiation, on their users. A substantial amount of research has gone into this area and much more is underway. There are certain knowledge gaps in the area that require further research. These gaps are primarily concerned with one purported mechanism of interaction of electromagnetic/magnetic radiation and biological organisms. Bioeffects arising from electromagnetic/magnetic radiation are classified into two broad categories which are the thermal effects and the non-thermal or athermal effects. The gaps relate to the latter and arise because no mechanism has been identified up to present which will account for these non thermal bioeffects [1].

The radiation that is emitted by the antenna of a mobile phone belongs in the radiofrequency (RF) range. Because this signal is modulated, when we look at its demodulated frequency spectrum we observe extremely low frequency (ELF) components in it. It is stressed that it is necessary to demodulate the signal to observe these ELF frequencies. It can be deduced from published literature that pulsed radiofrequency (RF) radiation, in this case meaning the one that contains ELF components, is necessary to elicit brain wave activity or (EEG) changes [2]. This brings us to the proposition that suggests that for the brain to be affected by the pulsed modulated RF signal differently than the pure RF signal it is necessary for some process somewhere in the brain to demodulate the signal. It is suggested that these ELF frequencies are more potent in the cases were they coincide with the frequencies that exist in the human EEG.

Apart from this pulse modulated RF field that has been described above, mobile phones carry another radiation field. This one, unlike the previous which comes from the handset's antenna, originates from the battery of the handset. It belongs to the ELF range and its nature is magnetic rather than electromagnetic. As of yet and to the best of our knowledge, this radiation field, as such, has not been used in any exposure setups involving human studies.

The aim of this work is to characterise this field with the purpose of utilising it in human exposure studies.

### *Rationale*

One of the research focus areas has been on the effects of the radiation on the human brain as measured by the electroencephalogram (EEG). In such studies human subjects were exposed to radiation very much similar to that that stems from a mobile phone antenna and their EEG was recorded.

As described in the previous section there is also another source of radiation associated with mobile phones which is created by the currents that flow in the battery and handset. This radiation is magnetic in nature. Although this field most likely carries characteristics that are of great interest when it comes to EEG effects it has not been studied as a stressor to the brain in any studies. It should be pointed out that there exists a substantial body of literature that has looked at pure ELF magnetic

fields as a stressor to the human brain as measured by the EEG [3]. Fundamentally these studies looked at radiation that is in some ways similar to that coming from the battery of mobile phone handsets but none attempted to mimic it, either its spectral content or intensities.

This magnetic radiation is expected to have frequency some components in the same range as the brain wave frequencies 0-50 Hz which are assumed to be more potent. In these experiments when analysing the radiation field the equipment and experimental setups will specifically allow us to concentrate on this frequency range as well as extend up to a few kilohertz. There have been some theoretical reports as to what can be expected from this battery switching in terms of power spectral content [4]. Recently there was a very thorough experimental study carried out that looked at the specific issue. In this, the spectral content starting from 217Hz to around 400 kHz was analysed [5]. They looked at the spectral content with relation to exposure standards and not to the specific effects that this study aims to look at. So as bottom line, there is no published work that addresses the influence of ELF radiation produced by mobile phones on human brain activity. This is the rationale behind this work.

### ***Methods***

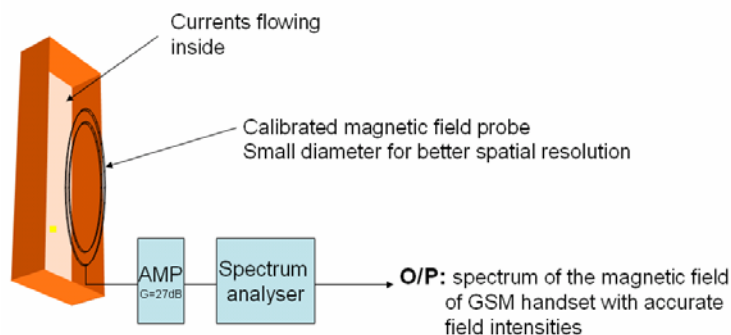
The intention of this work is to characterise the magnetic field generated by mobile phone batteries with focus on the part of it that can have an effect on the human EEG. To accomplish this, a sensitive magnetic field probe was designed, constructed, calibrated and is currently being used to analyse the spectrum stemming from the mobile phone battery.

Construction: A magnetic field pick up coil was designed with a radius 3 cm and 500 turns wire 0.2 mm cross section.

Calibration: The calibration was done using the standard field method [5].

Measurements: The measurements will take place in an anechoic chamber (Telstra research laboratories) for minimum noise levels. Note that the antenna of the mobile phone is disconnected so that RF radiation pick up does not occur which could possibly lead to error in measurements.

The signal is then amplified using an instrumentation amplifier which is configured for minimal noise and its output is fed to a spectrum analyser (DSA3561A). This configuration will allow for power spectral density in the vicinity of interest to be measured accurately.



### ***Results***

Results are pending but the expected outcome once experiments are concluded will be the characterisation of battery generated magnetic fields of 5 different mobile phones (Nokia 3310, Sony Ericsson T630 and Siemens A50) at standby conditions, during DTX mode, and normal talk mode. Full power measurements will also be performed using specially configured mobile phones (Nokia 6110).

### ***Conclusions***

This research once completed will achieve the following:

- Characterise the components of the magnetic field of the mobile phone as they relate to frequencies in the vicinity of EEG frequencies.
- Provide the opportunity for research studies that can identify possible mechanisms of interaction of mobile phone like radiation with brain function.
- Allow for exposure setups that will expose subjects both to pulsed RF mobile phone like radiation and ELF magnetic field mobile phone radiation simultaneously or independently. This will inturn open up opportunities to identify which part of the mobile phone handset radiation causes the strongest interaction.

It is expected that experiments and results will be completed before the end of October 2005.

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## Determining the Influence of Population Variation on Compliance with Radiofrequency Exposure Limits

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### ***Background:***

Currently, compliance with safety limits for human exposure to radiofrequency (RF) fields is demonstrated by methods that rely on certain assumptions and approximations, which include among other things human anatomical features, tissue types and the dielectric properties of these tissues. Physical models used for SAR measurement are necessarily much simplified (containing only one or two contiguous tissues), while computational models can be far more representative with many complex tissues incorporated in them. The SAR produced in such models from a given source is dependent on several key parameters, including shape and size of the exposed person, the type, location and size of the tissues considered, and their dielectric properties. Most studies assume that the average human is a Caucasian male, only two models of which are common among published results (and thus available for comparison): the Specific Anthropomorphic Mannequin (SAM, a single homogenous tissue model) and the Visible Human (VH, a complex multi-tissue model). Implications for compliance studies are that all members of the general population, including children and females are adequately treated as scaled male adults. Ramifications of such assumptions on SAR compliance are not well described in the current literature.

Generalisations in the literature are often made on the basis of specific models such as Visible Human or MRI data of a handful of human volunteers. Dielectric properties of tissues found in the literature were measured using different equipment, from dead tissue or from animal tissue. Frequently, data from a single subject was used to draw generalized conclusions. The implication is that a randomly chosen individual will provide sufficient information regarding the spread of human anatomical variation, which is unlikely.

### ***Rationale:***

This project involves a review of the available data and an investigation into which of the above assumptions are appropriate; what approximation can be used in physical and computational modelling of humans for specific energy absorption rate (SAR) calculations (a key compliance metric); and what trade-offs can be made between accuracy and modelling requirements for practical considerations.

This project aims to find a point of diminishing returns in additional complexity somewhere between the 32-tissue VH model and the single-issue homogeneous models. Key issues being investigated are how SAR varies between children and adults and between males and females, and what effect these variations have on SAR absorption. It is hoped this study will address many of the problems currently facing SAR assessment. Sub-populations such as racial groups may be investigated if time permits.

### ***Methods:***

Investigations will initially be limited to SAR inside the human head. A review of the current literature is used to obtain an estimate of variations in a set of key anatomical parameters affecting SAR - tissue dielectric properties, thickness, relative location and tissue size. This information is used to vary the model at the 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup>

percentiles of human anatomical range for five key tissues: skin, skull, brain, eye and ear.

Plane wave excitation is used as the source. The study may be expanded at a later stage to include more tissues and other forms of excitation. Mathematical modelling is performed using commercially available FDTD (finite-difference time domain) and methods of moments software packages. Phantom studies will be included for validation purposes. These will take place at the Telstra Research Laboratories (TRL) using SAM head phantoms; the TRL whole body phantom, which contains partitions for head, torso, arms and legs; and an IEEE P1528 compliant flat torso phantom.

***Results:***

A simplified model of the human head has been constructed. The model contains the five tissues of interest previously noted, the properties of which will be varied over the range of values for the human population as previously described. The shapes in this model may be varied parametrically, greatly reducing the effort required to undertake this extensive modelling task. Early work is continuing on this model with preliminary results providing useful information for further development.

***Conclusions:***

A review of existing data has identified a need to more closely examine the assumptions which SAR modelling techniques are based on. This study will critically assess current assumptions underlying SAR testing for compliance and research and postulates potential issues and implications for this work. An expected outcome of this study is a more efficient and accurate model for determining compliance with SAR based exposure levels for a range of RF devices.