

The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz

IET Position Statement - May 2006

Summary

The Institution of Engineering and Technology – the “IET” (formerly the Institution of Electrical Engineers – the IEE) Biological Effects Policy Advisory Group on Low-level Electromagnetic Fields (the “Group”) has concluded that the balance of scientific evidence to date does not indicate that harmful effects occur in humans due to low-level exposure to electromagnetic fields (“EMF”). This conclusion remains the same as that reached in its previous position statements, the last being in May 2004, and has not been substantially challenged by the peer-reviewed literature published in the past two years.

At low frequencies, the cumulative evidence from the large body of literature built up from intensive research over the past 25 years suggests that the existence of harmful health effects remains unlikely. No generally accepted exemplar of any biological effect of such fields has been established. However, pooled analyses of epidemiological studies have suggested an association between higher magnetic field levels and childhood leukaemia, and a recent major U.K. study suggests an association with residential proximity at birth to high voltage overhead power lines. In the absence of convincing mechanistic and biological evidence of 50/60Hz (“power frequency”) field effects these epidemiological findings are difficult to interpret as evidence for a causal link.

At higher frequencies, the existing data do not suggest any harmful effects exist. However, the Group is of the opinion that further research, both epidemiological and laboratory based, should be supported. This view is consistent with the conclusions of major reviews published elsewhere, and is based on public concern and the ubiquitous nature of our exposure to such fields rather than a likelihood that harmful effects exist. The UK Mobile Telecommunications and Health Research (“MTHR”) programme goes some way to addressing this need, with about 30 research projects being funded (http://www.mthr.org.uk/research_projects/funded_projects.htm). These projects were chosen either to address gaps in the literature or to replicate key findings as identified by the 2000 Stewart Report. The projects started in 2002/3 and their results are starting to appear in the refereed literature. The first three experimental studies to be published have failed to confirm the findings of the original work on which they were based.

Failed replications of high profile studies are of concern to the Group and indicate the likely fragility of much of the literature. It would now appear that a number of earlier studies have erroneously heightened public anxiety. The Group continues to hold the view that scientists have an over-riding responsibility to ensure that their findings are robust before publication, notwithstanding the various pressures to publish their work.

The Group continues to regard the replication of studies as essential in order to improve the robustness of the existing literature at both low and high frequencies. In view of the difficulties that are being encountered in replication studies it continues to recommend that isolated reports of biological effects or epidemiological findings should be treated with caution until confirmed by independent groups.

In summary, the absence of robust new evidence of harmful effects of EMFs in the past two years is reassuring. The Group is of the opinion that this should be a major factor to take into account by policy makers when considering both the implementation of precautionary approaches to public exposure and also during the development of exposure guidelines.

Introduction

The Institution of Engineering and Technology – the IET (formerly the Institution of Electrical Engineers - the IEE) created the Biological Effects Policy Advisory Group in November 1992 to consider the possible harmful effects of low-level, low frequency electromagnetic fields (EMFs), primarily at power (50/60Hz) frequencies. The Group first reported in June 1994, and then approximately every two years since that date. Its reports form the basis of the IET’s position on these matters. In January 1998 the terms of reference of the Group were extended to include frequencies up to 300 GHz to reflect public concern over possible health effects of radiofrequency (“RF”) fields, especially from mobile communications systems. The Group has produced a FactFile that introduces the subject area and discusses some of the key public concerns:

<http://www.theiet.org/publicaffairs/bepag/emfhealth.pdf> .

The Group uses refereed full papers as its source material, retrieved from a broad literature search of a range of electronic databases. The methodology and sources used are described in the attached Appendix.

The literature searches retrieved a total of 825 relevant refereed full papers in 2004 and 2005 combined, a publication rate largely unchanged since 2000. Of these 51% (previously 58%) covered static and low frequencies, primarily relating to power frequency fields associated with power generation and distribution. 37% (previously 34%) of the papers dealt with RF fields, of which 55% (previously 43%) were specifically related to mobile phone frequencies (equivalent to 21% (previously 15%) of the total relevant literature). These figures show the continuing trend for EMF research to refocus from power frequencies towards mobile phone frequencies which has also been observed in our previous reports.

Because of the relatively clear distinction between low and high frequency studies, coupled with the different types of sources involved and the likelihood that any mechanisms of interaction are different, the Group has again divided its assessment of the literature into these two frequency bands without attempting to define them rigidly.

We have further divided the literature into five areas: epidemiology, human studies, animal studies, cellular studies, and mechanisms of interaction to reflect the main groups of experimental studies. The points below summarize the views of the Group on the latest literature in all these areas, and on which the conclusions in this statement are based.

Epidemiology

- The measurement of exposure to power frequency EMFs continues to be a problem for epidemiological studies. Methods vary between indirect or inferred levels of exposure from information such as job title, wiring configuration of a house or residential proximity to a power line. Studies incorporating direct exposure measurement of individuals tend to be smaller in scale and potentially lacking in ability to detect increased risks. Comparison of exposure from inferred and direct measures suggests that the latter may provide more reliable estimates. Thus interpretation of epidemiological studies must include an evaluation of exposure measurement methodology and its validation.
- In 2001 the International Agency for Research on Cancer (“IARC”) classified power frequency magnetic fields as possibly carcinogenic. One source of relatively high exposure to power frequency EMFs in the UK are high voltage overhead power lines. In England and Wales a large study of the birth addresses of children diagnosed with cancer has reported an association between birth addresses of children with leukaemia, but not other cancers, and their distance from high voltage power lines. There is no satisfactory explanation of this increased risk being associated with exposure to power frequency EMFs at the time of birth, as the association is observed not only near the lines, but also at distances from the power line (up to 600m) where exposure is known to be equivalent to the ‘background’ exposure of the population.
- Other studies of the possible adverse health effects of exposure to low frequency EMFs continue to be published. Potential risks for testicular cancer, breast cancer, bladder cancer, malignant melanoma skin cancer, brain tumours, childhood cancer, cardiovascular disease, sleep patterns, fatigue and Alzheimer’s disease have been investigated by studies of varying size and methodology. Potential risks associated with exposure at work have included both general occupational studies as well as job specific investigations including radar operators and arc and resistance welding. None of the findings have provided any consistent evidence of a positive association between exposure to power frequency EMFs and risk of disease.
- Scientific and public concern continues to be expressed over the possible adverse health effects of exposure to RF fields. The Interphone case control study has collected data from 13 countries worldwide to investigate the risk of brain tumours (gliomas and meningiomas), acoustic neuromas (benign tumours of the auditory nerve next to the ear) and salivary gland tumours and the use of mobile phone handsets. A key feature is the use of a detailed past history of mobile phone use reported at interview supplemented by validation studies of emitted power from handsets in different countries. All participating countries have followed a common protocol; the IARC has co-ordinated the study and is conducting the combined analyses. Publication of the findings is expected shortly.

- Four of the countries participating in the Interphone study (Denmark, Sweden, UK and Germany) have already published their national results on the risks of brain tumours (glioma and meningioma) and mobile phone use. All the papers conclude that their findings do not provide any evidence for an increased risk in the short or medium term. Each individual study had insufficient numbers to draw conclusions on longer term use of over 10 years.
- Mobile phone use and the risk of acoustic neuroma has recently been addressed in publications from two independent Swedish groups and a pooled analysis of data from five European countries (which are partners in the Interphone project). Two individual studies have reported a raised risk, particularly in the longer term but the larger pooled analysis did not support an increased risk in the decade after first starting to use a mobile phone. The possibility of a risk associated with longer-term mobile phone use remains open.
- Mobile phone base stations remain a cause of considerable public concern. A study funded by the MTHR to investigate this specifically in relation to cancer in children under 5 years continues to be challenged by issues of exposure measurement. The rapidly changing environment in relation to the technology and installation of base stations, such as the recent deployment of 3G and TETRA systems (TETRA is a mobile communication system used primarily by the emergency services) provides additional difficulty for epidemiological studies.
- A large cohort study is to investigate any possible impact of the use of Airwave (a TETRA based system) on the health of police officers in England. The study will take approximately 12 years to complete, and more information is available at:
<http://www1.imperial.ac.uk/medicine/about/divisions/ephpc/eph/projects/eresh/tetra.html> .

Human Studies

- Recent laboratory studies with volunteers provide little evidence to suggest that exposures to EMFs at levels usually found in the environment are capable of causing consistent and reproducible biological effects. Where effects have been reported, their potential impact on health remains unclear.
- At power frequencies, few studies with volunteers have been undertaken, and no consistent reports of field-dependent effects have emerged. In particular, experimental studies suggest no obvious effects on the electrical activity of the brain or on cognitive function although a few subtle changes have been reported.
- At frequencies associated with mobile phones research has continued investigating the possibility of subtle physiological effects on the brain. Generally, the recent studies on adults are well performed, and in contrast to some earlier studies, have not found effects on attention and other cognitive functions, or consistent effects on the electrical activity of the brain. In addition, two independent studies found no changes on cognitive function in children. Studies investigating short-term effects on auditory and vestibular function have also failed to find any consistent field-dependent effects. However, the results of

studies investigating effects on sleep are less clear and some subtle effects on sleep quality cannot be ruled out. Changes in blood flow to some regions of the brain have also been observed following acute exposure but these await confirmation.

- Electromagnetic hypersensitivity (“EHS”) is a poorly understood condition in which patients self report a wide range of non-specific symptoms of ill health. Several reviews have examined the evidence relating to EHS and exposures from mobile phones. It was concluded that that these fields were an unlikely causal agent, and that reported impairment of well-being did not appear to be associated with exposure. Little is yet known about the aetiology of the condition.
- Further studies have confirmed the distracting effects of conversations on mobile phones whilst driving, both for handheld and hands-free equipment.

Animal Studies

- Recent laboratory studies with animals exposed to low-level EMFs have continued to use a variety of biological models and exposure conditions. Apart from the possibility of some subtle changes on brain function, most studies have failed to demonstrate any consistent pattern of field-induced biological responses.
- At power frequencies, most recent studies with rodents provide little or no consistent evidence of field-dependent changes on reproduction and development, although some detrimental results have been reported.
- Interest in the effects of power frequency magnetic fields on the brain and behaviour have continued, and a number of independent studies have reported field-dependent changes in various learned and innate behaviours in rodents (although many of these are only observed following injection of specific drugs or chemicals); other studies have reported changes in biochemistry of the cells of the brain. Taken together, these results tend to add to the belief that the central nervous system shows the greatest sensitivity to the effects of magnetic fields, although the potential impact on health of the reported responses remains unclear.
- Research has also continued using the frequencies associated with mobile phones, with many studies reporting a lack of field-dependent effects on a wide range of endpoints, including mutagenesis and genotoxicity, the development of lymphoma, auditory function and hormone status. Recent behavioural studies confirmed that exposure had no significant effects on anxiety or spatial memory processes, although there was some evidence that exposure may engender subtle biochemical changes in the brain. Other studies failed to confirm earlier studies that exposure affects the integrity of the blood-brain-barrier, nor did exposure exert detrimental effects on rat testes function.

Cellular Studies

- There has been a very wide variety of biological systems investigated in the cellular studies; this is particularly obvious in the studies using static magnetic fields. The investigated systems cover the full range of biology, from bacteria and

fungi, through plants and seeds to animal and human cells. The magnetic field exposures tend to be high in comparison to the geomagnetic field, typically several tens of millitesla and upwards. Very few studies in this group relate to possible harmful effects, and because of the lack of independent replication, the robustness of the claimed effects is unclear at this stage.

- The research using low frequency exposure is dominated by pulsed EMF studies which in general are orientated towards medical applications and are looking for beneficial effects of EMF exposure. A broad analysis of the studies which use isolated cells, animals or humans shows a wide range of claims predominantly associated with repair or pain relief in musculoskeletal disorders. Encouragingly there have been several double blind studies undertaken, however, some of these have been poorly conducted and lack sufficient participant numbers to achieve meaningful conclusions.
- At power frequencies there is still little convincing evidence that EMF exposure can cause carcinogenic changes in cells. A large European programme of research (REFLEX) has been undertaken to investigate possible cellular effects of both power frequency and RF fields. The programme was designed to have the benefit of common exposure systems so that results were comparable. One study in particular generated some intriguing findings regarding types of susceptible cells and exposure paradigms. In particular it suggested that intermittent, rather than continuous exposure (at both mobile phone and power frequencies) had greater effects. However, like so many of the findings in this area of research, the independent replications undertaken, so far, cast doubt about the validity of the initial findings.
- There has been an increase in the number of research papers devoted to possible effects of exposure to RF fields, mainly investigating the frequencies used by mobile telecommunications. Unlike the studies of the other frequencies the mobile phone studies show a high number of negative findings. There is no convincing evidence of direct carcinogenic effects, and independent replications have again failed to confirm earlier studies.
- Hence, there continues to be doubt about the validity of claimed cellular effects of EMF exposure at all frequencies using field strengths to which the public might be exposed. There is a poor record of reproducibility of findings and even the effects that are claimed do not appear to form a consistent or cohesive pattern in terms of exposure parameters or biological response. A major difficulty in understanding possible effects, or predicting biological systems sensitive to EMF, is the lack of a known mechanism of action between physics and biology for these low energy signals.

Power Frequency Mechanisms

- The absence of a plausible biophysical mechanism operating at environmental levels of exposure to power frequency EMFs remains a significant component in the balance of the evidence against health effects. Considerable research effort remains centred round the effect of magnetic fields on free radicals as a possible

mechanism. It remains doubtful whether this mechanism could produce effects at the microtesla level implicated by the epidemiology. Even more problematical, this mechanism depends on the instantaneous total field, i.e. the superposition of alternating and static fields. It seems likely that any effect of power frequency fields at the microtesla level would always be small, if not negligible, compared to effects of the earth's static magnetic field (about 50 microtesla) and changes in it due to nearby ferromagnetic objects, such as cars, lifts, or household appliances, or regional variations in geomagnetic field. Thus it is extremely hard to see how free radicals could be a mechanism to explain the associations observed in the epidemiology.

- The large childhood cancer and line proximity study has focussed attention on the possibility that there could be a mechanism, other than magnetic fields, operating at distances up to several hundred metres from power lines. One candidate mechanism is the production of corona ions and their effect on airborne pollutants. The doubts previously raised about the size of any effects produced by this mechanism remain; further, the study authors state that an initial test of this hypothesis performed on their data did not support the idea, though it could not rule it out either. Another possibility is that the findings of this study result from characteristics of the population who live near, or of the area close to, the power lines. At present this is speculative, but given the failure to establish any satisfactory explanation for the epidemiological findings despite over 25 years of intensive research, the Group is of the view that it deserves further investigation.
- Another hypothesised explanation not requiring a direct physical effect of magnetic fields is “contact currents”. It has been observed that two of the main mechanisms which produce elevated magnetic fields in homes – high-voltage power lines, and currents in earth systems and water pipes – also result in small voltages between different metal objects in the home which are nominally all at earth potential, specifically between water taps and drains. If these voltages produce imperceptible but still significant currents in the bone marrow in the arms of children, and if these resulted in leukaemia, this would provide a mechanism for the disease which would be associated with magnetic fields though not caused by them. This is an intriguing idea but several of the links in the chain are largely speculative at present.
- The ‘melatonin hypothesis’ has been the subject of some enthusiastic support. This hypothesis is based upon melatonin being oncostatic (i.e. it suppresses the development and growth of cancers) and that exposure to magnetic fields alters normal melatonin synthesis. A report from the U.K. independent Advisory Group on Non-Ionising Radiation (“AGNIR”) has recently reviewed the evidence for this hypothesis in breast cancer. It concludes that, whilst further research is needed, the evidence to date does not support the hypothesis that exposure to power frequency EMFs affects melatonin levels or the risk of breast cancer.

Radio Frequency Mechanisms

- At radiofrequencies well-established numerical dosimetry techniques have been refined and increasingly applied to the comparative assessment of exposure of the

head of adults and children to radiation from mobile phones. The question of whether or not there are systematic differences specific to children is still being debated; the current consensus veers more towards the view that there are no significant differences.

- Refinements to numerical dosimetry have also been applied to cell cultures used in *in vitro* studies. The complexity of the problem and the multiplicity of contributing factors have been identified, along with the importance of incorporating detailed dosimetric data into the results.
- No plausible mechanism has emerged by which high frequency EMFs can have biological effects at levels below those that cause heating. Free radical reactions continue to be investigated as a possible mechanism, but experimental evidence to support this in biological systems has yet to be found.
- The hypothesis that localised regions of high power deposition may occur at sub-cellular level is being studied using microdosimetry modelling of continuous and pulsed fields. There are also parallel theoretical studies of non-linear interactions and plausible mechanisms. The design of experiments to test such theories is notoriously difficult and experimental data have yet to be reported.
- The magnetic properties of most biological materials is close to that of free space, which implies that there is no direct interaction with the magnetic component of EMFs at low field strengths. However relatively recent reports of the presence of magnetite in human nervous tissue may provide a mechanism for direct interaction with the human central nervous system. Mechanisms have been proposed whereby biogenic magnetite could act as a transducer of both low frequency magnetic fields and RF fields. These models rely on the fact that magnetite will couple strongly to the magnetic fields either through ferromagnetic resonance effects or mechanical effects on membrane ion channels and could disrupt the normal functioning of cells in the brain. The work in this field is still very limited, the plausibility of the mechanisms is being debated, and the role of magnetic materials in organisms is only just beginning to be unraveled.

Appendix

Search Criteria

The Policy Advisory Group concentrates on peer-reviewed literature retrieved by broad category, computerised, monthly searches of three major databases: INSPEC, MEDLINE and BIOSIS.

INSPEC is a database maintained by the Institution of Engineering and Technology – the IET (formerly the Institution of Electrical Engineers – the IEE). Coverage is centred on four main subject areas: physics; electrical engineering; electronics and communications; computers, computing and information technology.

MEDLINE is the database maintained by the US National Library of Medicine (NLM). It provides access to articles published in more than 3,900 biomedical journals published around the world.

BIOSIS is an American ‘not-for-profit organisation’ that publishes biological abstracts and zoological records. It provides access to 6000 periodicals covering biological and biomedical sciences.

Group Reports

1. ‘The Possible Biological Effects of Low-frequency Electromagnetic Fields’ (Public Affairs Board Report No 10 - July 1991)
2. ‘The Possible Biological Effects of Low-frequency Electromagnetic Fields’ (Supplement to PAB Report No 10 - June 1994)
3. ‘Possible Harmful Biological Effects of Low-level, Low-frequency, Electromagnetic Fields’ (IEE Position Statement - November 1996)
4. ‘Possible Harmful Biological Effects of Low-level, Low-frequency, Electromagnetic fields’ (IEE Position Statement – May 1998)
5. ‘The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz’ (IEE Position Statement – May 2000)
6. ‘The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz’ (IEE Position Statement – May 2002)
7. ‘The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz’ (IEE Position Statement – May 2004)

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