



Collective **inspiration**

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

2010 Position Statement
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About This Position Statement

The Institution of Engineering and Technology (IET) acts as a voice for the engineering and technology professions by providing independent, reliable and factual information to the public and policy makers. This position statement aims to provide an accessible guide to the findings of the IET's Biological Effects Policy Advisory Group (BEPAG). This position statement encapsulates the IET's position on the possible harmful biological effects of low-level electromagnetic fields of frequencies up to 300 GHz.

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The Institution of Engineering and Technology

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Summary

The Institution of Engineering and Technology (IET) has a special interest in any possible health effects of occupational and general-population exposure to electromagnetic fields (EMFs). The IET remains determined to be at the forefront of the examination of the scientific evidence for any such effects and thus identify any emerging hazards as early as possible. To this end it maintains its Biological Effects Policy Advisory Group (BEPAG) on low-level EMFs.

BEPAG 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 EMFs. This conclusion remains the same as that reached in its previous position statements, the last being in May 2008, and our findings have not been substantially altered by the peer-reviewed literature published in the past two years.

At power frequencies (50 or 60 Hz), the balance of evidence from the large body of scientific papers built up over several decades suggests that the existence of harmful health effects from environmental levels of exposure has not been substantiated but remains a possibility. No generally accepted experimental demonstration of any biological effect, harmful or otherwise, due to such fields has been established. Pooled analyses of epidemiological studies show an association between childhood leukaemia and higher levels (greater than about 0.4 microteslas) of power-frequency magnetic fields in the home. However, in the absence of convincing mechanistic and experimental evidence, these epidemiological findings do not provide good grounds for concluding that there is a causal relationship. Problems of study design and selection bias problems remain a possible explanation of these results.

At higher frequencies, the existing data do not provide persuasive evidence that harmful health effects exist. Perhaps the greatest area of public concern remains the possibility of adverse effects from long-term mobile-phone use. Mobile-phones have been in widespread use for just over a decade and hence epidemiological studies of long-term health effects are currently limited to this time frame. The international collaborative INTERPHONE study provides the largest analysis of long-term users to date. The INTERPHONE Study Group conclude that its results do not show an increase in brain tumours which could be interpreted as causal, but that possible effects of long-term heavy use of mobile phones requires further investigation. The ubiquitous nature of our exposure to such fields means that, even if the risk to individuals is low, a large number of people could still experience health effects. However, experimental studies have failed to demonstrate consistent effects and no mechanism has been established whereby low-level exposure to radiofrequency fields can cause harm. Environmental power levels from base stations, often a cause of public concern, are broadly similar to those from other broadcast radiofrequency sources such as television and radio transmitters and are many times lower than the peak values experienced when using a mobile-phone handset.

High-profile experimental studies that fail replication continue to be of concern to BEPAG. A number of studies erroneously heightened public concern, whilst careful replications have been unable to substantiate the original effect. BEPAG continues to hold the view that scientists have a responsibility to ensure that their findings are as robust as possible before publication. It remains concerned that pressures on scientists to publish their work may encourage the reporting of apparent effects that have not been adequately investigated.

BEPAG regards the independent replication of experimental studies as essential in order to improve the quality of the existing literature and to verify any claimed effect. It recommends that isolated reports of biological effects or epidemiological findings should be treated with caution, until confirmed by independent groups. BEPAG is also of the view that a journal which publishes an EMF study should be under an obligation to publish a well-conducted replication study if this fails to confirm the original findings.

In summary, the absence of robust new evidence of harmful effects of EMFs in the past two years is reassuring and is consistent with findings over the past decade. The widespread use of electricity and telecommunications has demonstrable value to society, including health benefits. BEPAG is of the opinion that these factors, along with the overall scientific evidence, should be taken into account by policy makers when considering the costs and benefits of both the implementation of precautionary approaches to public exposure and also in the development of public-exposure guidelines.

Introduction

The Institution of Engineering and Technology (IET) is a registered charity in England and Wales (no 211014) and Scotland (no SC038698) with more than 150,000 professionally qualified members worldwide, all of whom are exposed to electromagnetic fields (EMFs, the electric and magnetic fields created by the flow of electricity) in both their professional and private lives. Some are particularly exposed because of their employment in industries where there can be relatively high levels of EMFs. Thus the IET has an interest in possible health effects of EMFs on behalf of both its members and the general public, and remains determined to be at the forefront of the examination of the scientific evidence for any effects of such exposures and thus identify any emerging hazards as early as possible.

Given this situation the IET (in its former existence as the Institution of Electrical Engineers – the IEE) created the Biological Effects Policy Advisory Group (BEPAG) on low-level electromagnetic fields (a phrase used to describe relatively weak fields that are lower than international exposure guidelines) in November 1992. Its initial brief was to consider the possible harmful effects of low-level low-frequency EMFs, primarily at power frequencies (50 or 60 Hz), and it was charged with objectively and systematically reviewing the scientific literature on behalf of the public and

the Institution's members. BEPAG is made up of experts in particular science and engineering disciplines; some come from within the Institution's own membership, but some are drawn from other professions so as to obtain the necessary specialist expertise. They are not remunerated by the Institution for their work on its behalf.

BEPAG first reported in June 1994, and then approximately every two years since that date. Its reports constitute the IET's position on these matters. In January 1998, the terms of reference of BEPAG were extended to include frequencies up to 300 GHz to reflect public concern over possible health effects of radiofrequency (RF) fields, especially from mobile-phones. BEPAG has produced a Factfile that introduces the subject area and discusses some of the key public concerns.

■ <http://www.theiet.org/factfiles/bioeffects/emfhealth.cfm>

BEPAG uses refereed (also known as peer-reviewed) scientific papers as its source material, in order that the papers it reviews meet a minimum quality standard. These are retrieved from a broad search of a range of electronic databases. The methodology and sources used are described in the Appendix.

The searches retrieved a total of 813 relevant papers in 2008 and 2009 combined, a publication rate largely unchanged since 2000 and just 2% lower than in 2006/2007. Of these 44% (previously 47%) covered static and low-frequencies, primarily relating to 50 and 60 Hz fields associated with power generation and distribution. 46% (previously 42%) of the papers dealt with RF fields, and 64% of these were specifically related to mobile-phone frequencies, a figure unchanged from 2006/7. The overall figures show a decrease of the previously observed trend for EMFs and health research to refocus from power frequencies towards mobile-phone frequencies.

An analysis of those papers which contain new experimental data shows that, at electrical power frequencies (50 or 60 Hz), 81% of the 88 such papers report biological effects, whereas at mobile-phone frequencies the figure is rather lower, 54% of 144 papers. In many cases, the effects amount to small changes in one or more physiological parameters where the impact on health is unclear. At low-frequencies, in the range earmarked for possible medical applications (typically a few Hz to a few kHz, but excluding power frequencies), 91% of the 91 papers show effects. Overall 75% of experimental studies report the detection of field effects suggesting that such effects are common and readily demonstrable. Set against this, attempts to replicate key studies, for example, the body of work of the EMF Biological Research Trust and of the Mobile Telecommunications and Health Research (MTHR) programme, have been unable to confirm any of the original reports. This represents an important conundrum: the high proportion of original experimental studies reporting effects implies that they are reasonably easy to find. However, the identification of even a single robust effect which could be used as a test-bed to determine such factors as dose-

response curves (the variation of effect with exposure level and duration), whether the effects are caused by electric or by magnetic fields and to allow investigation of the mechanism (how the effects are caused), has proved problematic and, in the view of BEPAG, has yet to be achieved. Arguably this remains the key goal for future laboratory studies of EMF effects.

■ <http://www.emfbrt.org/index.shtml>
■ http://www.mthr.org.uk/documents/MTHR_report_2007.pdf

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

The literature has been further divided into five scientific areas: epidemiology, human studies, animal studies, cellular studies, and mechanisms of interaction, to reflect the main categories of experimental studies.

The points below summarize the views of BEPAG on the latest published refereed literature in these areas, and on which, together with the content of previous reviews, the conclusions in this statement are based.

Epidemiology

- Epidemiology is the observational study of the occurrence and distribution of diseases in populations. Exposure and other conditions in EMF studies cannot usually be well-defined and controlled. Interpretation of findings needs to consider potential biases in exposure assessment, selection of study subjects and data collection. Exposure assessment is a particular challenge because direct measurements are often not available or feasible and therefore exposure levels need to be inferred from information such as job title, wiring configuration of a house, or residential proximity to a power line, radio or mobile-phone mast. An additional complexity is that in case-control studies it is past, rather than current, exposure that is relevant in terms of possible disease causation, and this past exposure has to be retrospectively reconstructed. Recent studies have increasingly carried out direct measurements in subjects' homes or work place, which is an improvement, but assumes that these measurements are an accurate reflection of the relevant exposure in terms of disease causation. Epidemiological studies often have to rely on self-reported exposure information, such as past mobile-phone use, which is open to bias.
- In 2001, the International Agency for Research on Cancer (IARC) classified extremely low-frequency magnetic fields as possibly carcinogenic to humans. This decision was strongly influenced by epidemiological studies having observed increased risks of childhood

leukaemia at high levels (greater than about 0.4 microteslas) of magnetic field exposure to power-frequency EMFs. Studies published after 2001 have shown compatible results to those published prior to then. Two studies have suggested that exposure to EMFs may adversely affect survival in children already diagnosed with leukaemia. A pooled analysis of four childhood leukaemia studies, with direct measurement of EMFs, showed no evidence that night-time exposure accounted for the overall increased risk for childhood leukaemia. Potential reasons for the observed risks continue to be a common and unanswered topic of research. A recent study suggested an interaction between variation in DNA repair genes and exposure to residential EMFs on childhood leukaemia risk. This study was small and had many weaknesses, but the results are interesting and need to be investigated in further studies.

- Studies have investigated residential proximity to high-voltage overhead power lines, a source of relatively high exposure to power-frequency EMFs, in relation to overall mortality, general well-being, cancer, and recently, neurodegenerative disease. The childhood leukaemia studies were suggestive of an increased risk with closer proximity. A meta-analysis of 13 childhood brain-tumour studies did not show increased risk with close proximity, but could not exclude the possibility of a moderately increased risk at high measured or predicted exposure levels. A recent large Swiss study reported increased mortality from Alzheimer's disease in people living within 50 metres of an overhead power line, based on a small number of deaths in this group.
- Adverse health effects of exposure to low-frequency EMFs continue to be researched, in particular in occupational studies, where exposure levels are generally greater than in the general population, thus providing greater potential for detection of effects. Many health outcomes have been addressed including various cancers, cardiovascular disease, reproductive hormone and melatonin levels, and neurodegenerative disease such as Alzheimer's disease and amyotrophic lateral sclerosis (ALS). A pooled analysis of fourteen studies of Alzheimer's disease showed a raised risk in those occupationally exposed, but with considerable variation in results between studies, and without a dose response. In two later cohort studies, mortality from Alzheimer's disease was not increased in UK electricity generation and transmission workers but was increased in Swiss railway employees. Some association has also been reported for ALS. Diagnosis of dementias is particularly problematic and exposure assessment from job histories needs to be standardised. Further occupational studies of neurodegenerative disease in relation to power-frequency EMFs are needed. Epidemiological research has not indicated strong or consistent associations of occupational RF exposure with cancer risks or other health outcomes.
- A recent German study did not find evidence that occupational exposure of parents to power-frequency EMFs increased risk of leukaemia, non-Hodgkin's lymphoma and central nervous system (CNS) tumours

in their children. In contrast, a Canadian study observed increased risks of brain cancer in offspring after maternal exposures. Earlier, smaller, studies into childhood cancers did not find consistent increased risks.

- There is continuing scientific debate and public concern over possible adverse health effects of exposure to RF fields from mobile-phones and base stations. Most reported studies investigated intracranial tumours. The INTERPHONE case-control study has been carried out in 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. The study was co-ordinated by IARC, with all participating countries following a common protocol. The INTERPHONE study has recently published its results on glioma and meningioma for all centres combined. There was an apparently overall decreased risk of tumours in regular users compared with people who did not use a phone regularly. As it seems implausible that mobile-phone use would have a protective effect, this possibly reflects participation bias (overrepresentation of mobile-phone users among controls) or other methodological limitations. There was no association of risk with time since first use, or cumulative number of calls. Risk of glioma was increased in users in the top decile (10%) of cumulative call time, but this category included individuals reporting implausible daily usage times, and there was no upward trend in the other nine deciles. Analyses restricted to regular phone users only, as a suggested potential method of correcting for participation bias, showed raised risks of glioma in subjects who started using a phone 2 or more years ago compared with those who started less than 2 years ago. This post hoc analysis assumed that the level of participation bias is independent from the duration of phone use; as there was evidence to the contrary these results need to be treated with caution. The study concluded that limitations in the data and lack of clear evidence of causality, such as dose-response, prevented a causal interpretation. Despite it being much the largest study done into this question, the study's power to investigate long-term risks was still limited. Future studies would need to address longer-term risks and rely less on self-reported exposure.
- A recent report showed that trends in brain tumour rates in four Nordic countries did not change during 1998-2003, when mobile phone use became widespread, which one might expect if substantial risks existed after an induction time of 5-10 years. No studies have yet reported on brain tumour risk in relation to mobile phone use in children; such studies are in progress.
- A Danish cohort study of 420,000 mobile-phone subscribers showed no increase in risk of hospital contact for Alzheimer's disease, other dementia, ALS or other central nervous system disease with time since having the subscription.
- Mobile-phone base stations remain a cause of considerable public concern, but few studies have reported specifically on this. Two recent studies, one of them in children, did not find evidence that measured

residential exposure to radiofrequency EMFs was associated with a variety of health complaints. The rapidly changing environment in relation to technology, the installation of base stations and the ubiquitous exposure of the population provide additional difficulty for epidemiological studies.

- Two large case-control studies have recently investigated exposure to fields from radio transmitters and childhood leukaemia risk. One, in South Korea, observed an excess risk of childhood leukaemia in proximity to AM transmitters, but not with individuals' predicted RF exposure levels. The other, in Germany, did not find excess risk at close proximity or with predicted exposure levels from AM or FM transmitters. These two studies weaken findings from earlier reports on leukaemia clusters around radio and television broadcast transmitters, which relied on distance alone as a surrogate measure of exposure.
- Studies of adverse effects of occupational exposures to RF, such as military personnel exposed to radar, include a large range of health effects. Overall no strong, consistent associations have been observed. Some recent studies looked at mortality, cancer and infertility. Some associations were reported, but the studies had weaknesses in exposure and outcome assessment as well as other methodological problems. Also, for cancer, it was often difficult to separate the effect of RF from other known hazardous exposures such as ionising radiation.

Human Studies

- Overall, recent laboratory studies with volunteers continue to suggest that short-term exposures to EMFs at levels usually found in the environment do not result in consistent or reproducible biological effects. Nevertheless, a number of studies have continued to report a variety of field-related effects, often using new exposures or novel biological endpoints. There is no obvious pattern or trend to the reported effects overall, nor obvious indications of a likely mechanism. Again, the absence of replication studies represents a major hurdle in evaluating this literature.
- Only a very few studies have investigated the effects of power frequencies. One study suggested that the fields produced by neonatal incubators used in hospitals and clinics may temporarily affect heart rate in young babies, but confirmatory studies are required to determine the significance of this observation.
- More studies have investigated the effects of exposure to the signals associated with mobile-phones. Well-performed studies have continued to report that these signals are without significant effect on attention and other cognitive functions, and while a number of studies have found subtle effects on some aspects of the electrical activity of the brain under specific conditions, other studies have reported an absence of such changes, making it difficult to draw conclusions. Consistent with earlier results, a number of studies showed that mobile-phone signals do not appear to affect hearing or balance,

or to alter heart rate or blood flow, although one study found that mobile-phone use in men attending an infertility clinic was associated with decreased sperm count and viability, with the highest users showing the greatest effects. It is still not clear whether children are at any greater risk than adults from the use of mobile-phones, but one study suggested exposure from mobile-phone signals during pregnancy increased heart rate in offspring. Again, further studies are required to determine the significance of this particular observation.

- Electromagnetic hypersensitivity (EHS) continues to be a poorly understood condition in which patients self-report a wide range of non-specific symptoms of ill health which they believe to be in response to exposure to EMFs. Contrary to anecdotal experience, recent laboratory studies have found that both those who report EHS, and those who do not, cannot reliably detect the presence of a mobile-phone signal, nor do they respond with increased symptom severity. The scientific evidence against the symptoms linked to EHS being related to EMF exposure is now quite strong. However, there is some evidence of basic physiological differences between those with EHS and those without, and those with EHS may suffer worse health generally.
- Pulsed EMFs have continued to have been studied for possible beneficial effects in a plethora of medical applications including fracture healing, pain relief, swelling reduction and wound healing. Both positive and negative results are reported and a clear picture as to whether robust effects exist has yet to emerge.

Animal Studies

- Laboratory studies with animals have continued to use a wide variety of models and exposure conditions. Although many of these studies have reported various field-related biological changes, some of these are contradictory, and very few responses appear to have been independently replicated. The potential impact on human health of these changes, if any, remains unclear.
- Work using low-frequency fields has continued. A few studies suggest that power frequency electric or magnetic fields may have an effect on antioxidant defence mechanisms or free-radical activity in rodent tissues. Some studies using magnetic fields indicate effects on hormone levels or lipid biochemistry, and others report effects on calcium metabolism using pulsed fields. Magnetic fields have also been reported to improve myocardial function in rats following ischemic reperfusion injury, due to the induction of heat-shock proteins. Several studies provide further evidence that power-frequency magnetic fields do not cause or increase the development of chemically induced cancers in animals, one study even suggested combined exposure to static and low frequency magnetic fields may reduce the growth of carcinomas in mice.
- Results of experiments investigating effects of power-frequency magnetic fields on fertility, reproduction and development in rodents are mixed, although studies using complex or pulsed fields have tended to report

more field-related effects than those using sinusoidal fields, with some suggestion of effects being mediated by changes in nitric-oxide activity. One study found that long-term exposure of rats to magnetic fields increased apoptosis in male and female germ cells.

- Behavioural studies, some using complex or pulsed magnetic fields, have reported changes in rodents, and particularly changes in spatial-memory abilities. Others have reported concomitant changes in neurochemistry or effects on the electrical activity in the brain. One study reported that body orientation of cattle was influenced by distance from overhead power lines, suggesting these fields may affect natural behaviours. This unexpected possibility should be investigated further, with a particular emphasis on the mechanism of detection of the EMFs.
- Research has also continued using the frequencies associated with mobile-phones. Consistent with earlier results, recent studies using various animal models have reported that long-term exposure was not associated with an increased risk of cancer or change in life expectancy. However, in contrast to most earlier reports, impairments in learning have been reported in both young and adult animals. The natural behaviour of bats and kestrels in the wild has been reported to be modified by exposures to radio waves.
- Studies have continued to investigate physiological effects of low-level mobile-phone frequency exposures in rodents, with largely inconsistent results. A few studies reported long-lasting effects on the blood brain barrier (BBB). However, the study that found short-term exposure could induce changes in the permeability of the BBB and cause adverse changes in brain cells could not be independently replicated. Other studies also reported a lack of effects on BBB function using molecular assays, and a lack of effect on molecular, cellular and pathological endpoints. Furthermore a replication study, using improved methodology and techniques, failed to confirm earlier findings that suggested exposure was associated with impaired immune function: the original studies had been highly influential in setting human-exposure guidelines in Russia and other countries. Other studies reported anti-inflammatory and pain-reducing effects using fields around 60 GHz, and increased oxidative damage using GSM signals.
- Sporadic effects on fertility and development have continued to be reported, with some studies reporting adverse effects, even using very weak signals. For example, sperm motility has been reported to be decreased in rats (but not in rabbits) by the signals from a commercial mobile-phone, and the incidence of cataracts in veal calves have been associated with distance from base stations. Two studies reported that prenatal or early postnatal exposure resulted in a loss of brain cells in the hippocampus, and another study reported that prenatal exposure of mice led to a deficit in hippocampal-dependent learning. However, roughly equal numbers of studies have not found any effects on a variety of endpoints: for example, the continuous exposure of four generations of mice to 3G signals was found to be without any adverse consequences.

Cellular Studies

- Cellular studies are used to assess the possible effects of various chemical or physical agents on biology. The advantage of these studies is that a wide range of biological systems and a variety of exposures can be tested relatively quickly in well-defined and controlled conditions. This can highlight effects in areas of interest, for instance DNA damage, or indicate mechanisms involved in the interactions. The disadvantage is that the experiments use very simplified biological systems, such as isolated cells grown in Petri-dishes, and the observed cellular effects may not translate into real changes in animals or humans. Therefore the effects found in these experimental systems, although very useful indicators, cannot be directly extrapolated to a health risk.
- There has been a very wide range of biological systems investigated in cellular studies from bacteria and fungi, to isolated cells from plants, animals and humans.
- Exposures used in static-magnetic-field cellular studies tend to be high in comparison to the geomagnetic field, typically several tens of milliteslas and upwards (the earth's static field being approximately 50 microteslas). Most published studies claim effects, including increased rate of cellular growth and changes to cell membranes, but the lack of independent replication makes the robustness of the claimed effects uncertain.
- About one in four of the cellular studies looks for the effects of low-frequency exposure (excluding power frequencies) and is dominated by investigations of pulsed EMFs. These tend to be aimed at medical applications and are in general looking for beneficial effects, predominantly associated with repair or pain relief in musculoskeletal disorders. In general, the cellular studies that show effects (which are the majority) claim the outcome is potentially beneficial to health.
- At power frequencies there is little evidence that EMF exposure can cause carcinogenic changes in cells. Despite the association between exposure and childhood leukaemia shown in epidemiological studies there is still no convincing evidence that isolated cells are susceptible to low field strengths and no plausible mechanism by which the interaction could occur. Concerns have been expressed about the scientific integrity of some findings from one particular research group that found potential carcinogenic effects of exposure. And furthermore the results were not able to be confirmed by an independent study. Like so many of the findings in this area of research the few independent replications undertaken have cast doubt about the robustness of the initial experiments and add to the controversy as to whether claimed effects are real. A possible exception is a study which has confirmed independently the need for a short unique sequence of DNA to be present in order to get cells to regulate specific gene expression in response to EMF exposure. The robustness of this finding and its relevance has yet to be determined.
- There have been many research papers devoted to possible cellular effects of exposure to RF fields. This has been maintained at almost one in three of the total EMF

studies undertaken, showing the perceived importance of these exposures. Particular attention is being paid to the frequencies used by mobile telecommunications. Unlike at other frequencies, many mobile-phone studies show no effects of exposure, although these are now outnumbered by reports claiming an effect. However, there is still no convincing evidence of direct carcinogenic effects, and independent replications have failed to confirm earlier studies showing effects.

- Overall there continues to be serious doubt about the robustness of claimed cellular effects (both beneficial and harmful) due to EMF exposure at all frequencies using field strengths to which the public might be exposed. Very few independent replications of claimed effects are undertaken and the majority of these fail to confirm the original observation. Even those 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. Research around the effect of magnetic fields on free radicals as a possible mechanism has, if anything intensified over the last two years. Interest also continues on the possibility that changes in the hormone melatonin caused by exposure to power-frequency magnetic fields may result in increased risk of cancer, reinforced by evidence that shift work (which may result in changes to melatonin) may be linked to an increased risk of some cancers.
- Just as in previous years, there are major obstacles in the way of accepting any of the current candidate mechanisms as an explanation for the associations suggested by epidemiological studies. For free radicals, for example, it remains doubtful whether this mechanism could produce effects at the microtesslas level implicated by the epidemiology, and whether any effect of power-frequency fields at these levels could be significant when compared to effects of the larger earth's static magnetic field and its variation with location around the world and due to distortion by ferromagnetic objects such as car bodies, lifts, reinforcing steel in buildings etc.
- However, in view of the importance of establishing a mechanism if there are in fact health effects, BEPAG considers that these and any other suggested mechanisms should continue to be studied objectively, but rooted firmly in their relevance to public exposure.

Radiofrequency Mechanisms

- At radiofrequencies, well-established modelling and measurement techniques have been refined and

applied to the comparative assessment of exposure of adults and children to EMFs from mobile-phones and environmental sources. Research in this field was driven by the requirements for testing compliance with exposure guidelines it is now increasingly dedicated to assessing the exposure of people from complex environmental fields to provide data for epidemiological studies. High-resolution modeling is used to assess the exposure from high frequency sources up to and including the terahertz range.

- No mechanism has been established by which high-frequency EMFs can have biological effects at levels below those that cause heating; all known effects are heat-mediated.
- The hypothesis that localised regions of high-power deposition may occur at subcellular level is being studied using microdosimetry modeling of continuous and pulsed fields. With pulsed fields comes the possibility that they may give rise to non-linear interactions and that there might be some cellular component capable of demodulating these pulsed fields. The design of experiments to test such theories is notoriously difficult but a UK funded project intended to detect non-linear responses at 900 MHz has failed to confirm the presence of a non-linear effect. At this stage, the hypothesis remains speculative.
- The magnetic properties of most biological materials are close to those of free space; however, relatively recent reports of the presence of magnetite in brain tissue may provide a mechanism for direct interaction of magnetic fields with the CNS. Mechanisms have been proposed whereby biogenic magnetite in the brain 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. In theory, these effects could influence membrane ion channels and 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 magnetite in the human brain is the subject of current research.

UK low frequency EMF stakeholder engagement – a commentary

In 2009, the UK Government responded, in the form of a Written Ministerial Statement, to the First Interim Assessment of the Stakeholder Advisory Group on ELF EMF (SAGE) of 2007. SAGE had considered, in detail and with input from the complete range of stakeholders, possible precautionary measures to decrease public exposure from high-voltage power lines, domestic appliances, and house wiring. The Government agreed with most of the recommendations (and where it rejected recommendations, this was not because it disagreed with the principle but because it was advised there were better ways of achieving it). The guiding principle both of SAGE's recommendations and the Government's response was that any measures should be proportionate to the evidence, which in practice means they should be low-cost.

Accordingly, for example, the UK now has a formal policy that certain high-voltage power lines should incorporate a design feature called “optimum phasing”, which reduces fields at low cost; but the UK does not have a policy of restrictions on the proximity of homes and power lines on EMF grounds, which was judged disproportionate. The IET has actively supported, and been represented on, SAGE throughout. It is a noteworthy achievement that UK national policy is now clear and unambiguous, and, in a contentious area, has been formed after extensive involvement of stakeholders representing the whole spectrum of views, whilst remaining based firmly on scientific data and analysis.

Appendix

Search Criteria

BEPAG 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 IET. Coverage is centered 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.

Previous BEPAG 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)
8. 'The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz' (IET Position Statement – May 2006)
9. 'The Possible Harmful Biological Effects of Low-level Electromagnetic Fields of Frequencies up to 300 GHz' (IET Position Statement – May 2008)

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