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PROJECT: **PROPOSED RELOCATIO OF SMALL SECTION OF 132KV POWER LINE IN COOPER ROAD, BIRRONG, NSW.**

REPORT: **COMPUTER MODELING AND CALCULATION OF MAGNETIC FIELD EMISSION FROM EXISTING AND RELOCATED FEEDERS.**

1. Introduction

As part of the residential development in Potts Hill, in the area previously occupied by Sydney Water Authority, it is proposed to relocate a small section of the existing 132kV overhead power line. The section of the power line in question is currently located at the back of the residential housing blocks in Cooper Road. The total length of the section of the power line subject to relocation is approximately 200m long and it is located just south of the Sydney - Bankstown railway truck.

It is proposed to relocate this section of the power line into Cooper Road.
The drawing in Fig.1 below shows the position of the existing section of the power line marked by the red colour dashed lines and its proposed new position marked by the blue colour dashed line.

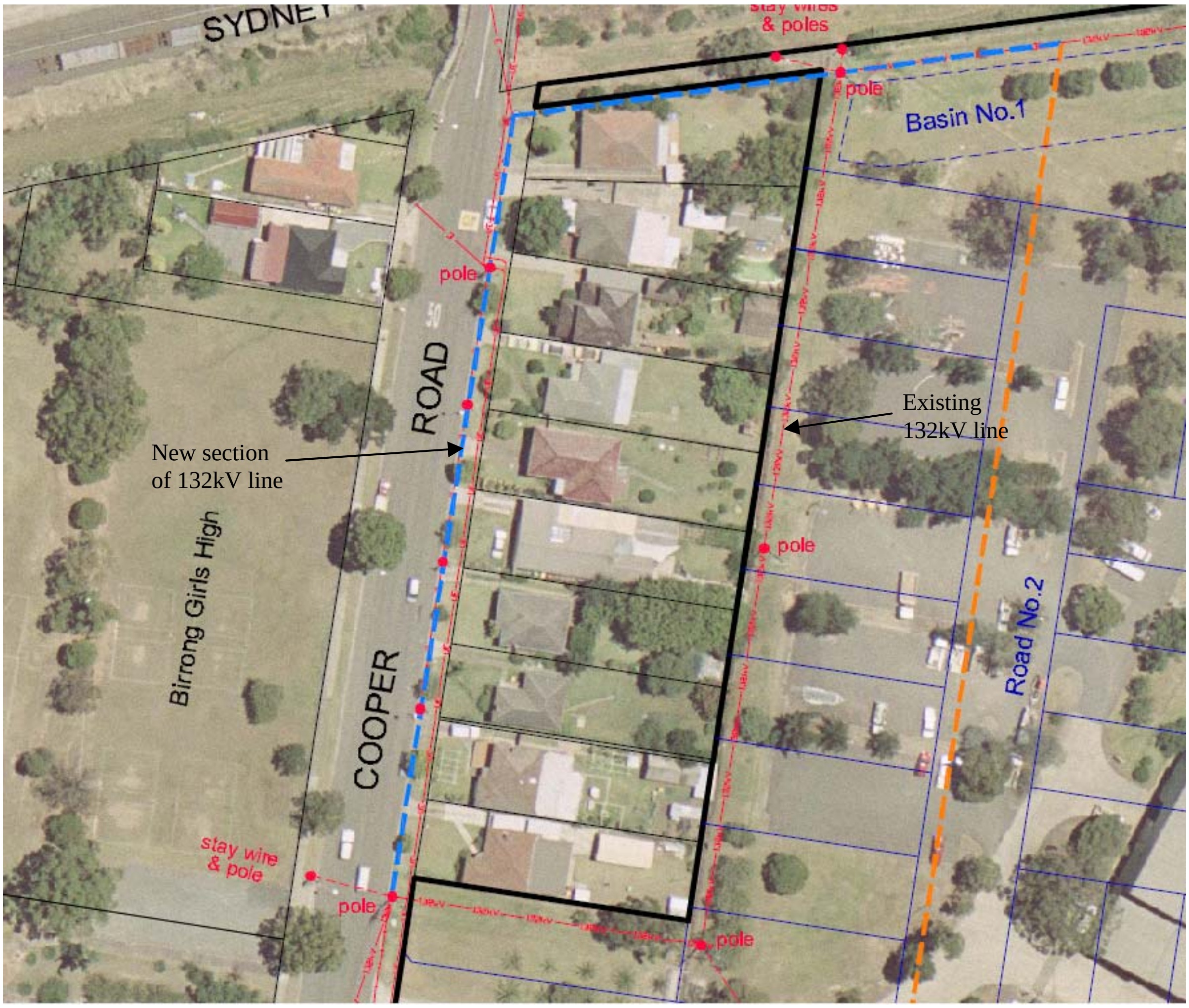

Fig.1 Existing and proposed new position of 132kV feeder in Birrong

Please note that the house at 15 Cooper Road (the top-most house in Fig.1) has been removed for a public walkway.

The objective of this study is to calculate the level of the power frequency magnetic field (EMF) produced by the existing overhead power line located behind the back fences of ten residential properties in Cooper Road and then compare this level against the case when the power line is relocated to Cooper Road in front of the same residential properties.

In its proposed new location the 132kV power line will be closer to the Birrong Girls High school located on the eastern side of Cooper Road. Therefore, it is also interesting to know what impact the relocated section of the power line would make on the EMF level within the school ground.

2. Existing Power Lines in Cooper Road

It should be noted that there are one 11kV underground cable and two low voltage overhead feeders already located on the eastern side of Cooper Road.

As it is planed to erect several new poles for supporting the relocated section of the 132kV power line wires these poles would also be utilised for supporting the existing two low voltage (LV) distributors.

However, as part of the electrical works program in this area it is also planned to replace the two open wire LV feeders (bare non-insulated conductors attached on insulators to a crossarm) with one or possibly two aerial bundled conductors (ABC). This would substantially reduce the EMF emitted by the low voltage distributors.

Due to its physical construction and also because it normally carries a 3-phase symmetrical current, the 11kV underground cable emits negligibly small EMF at distances greater that 1m, even if the cable is heavily loaded with current.

The ABC cable, due to its helical twist and also due to close proximity of all four PVC insulated conductors (three phases and the neutral), emits much smaller EMF as compared to its open wire counterpart. However, due to the multiple neutral earthing system used in the LV network in Australia, a portion of the neural current might by-pass the ABC neutral cable and flow back to the source via the underground metallic structures and water pipes. As a result, in majority of practical cases the EMF emitted by the LV ABC cable can be an order of magnitude larger than the EMF emitted by a 3-core 11kV cable with comparable load current.

2. EMF Modelling and Calculations

The following conditions and assumptions were used for computer modelling and calculation of EMF emission from the 132kV feeder.

a) The electrical load duration curve for the 132kV feeder is shown in Fig.2 below. This figure contains three graphs that represent the duration of time during which the feeder would be loaded to a certain level in respect to its maximum demand.

   In accordance with the established procedure the EMF is calculated for the 85% of the maximum load. Therefore, we will be using the following feeder loading values in our EMF calculations:
   - Summer load = 84A
   - Winter load = 104 A
   - Annual load = 84 A

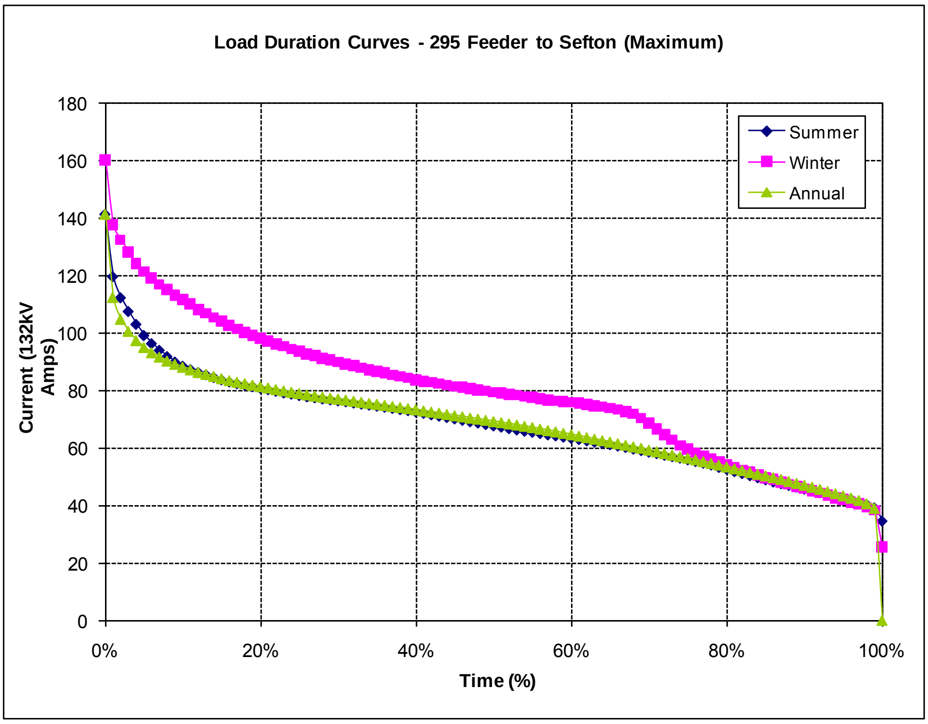

Fig.2 Load duration curves for 132kV feeder on Birrong

b) Except where specifically stated, the magnetic field was calculated at mid-span where the wires of the power lines are at their smallest ground clearance. All relevant geometry including the minimum ground clearance for the existing and upgraded feeders at each critical location along the route was provided by EnergyAustralia. At mid-span the lowest phase conductor to ground clearances for the existing and new 132kV section of the power line is 9.2m (average of 12.2m at poles with 3m sag in mid-span). A typical pole structure used for construction of this power line with details of conductor attachments is shown in Fig.3 below.
c) The magnetic field profiles were calculated for the height of 1m above the ground.
d) There are no zero sequence or negative sequence currents flowing in the feeder
e) There are no harmonic currents flowing in the feeder.
f) Due to the ABC construction of the two LV distributors we include no EMF contribution from them. We also assume zero net current in the two LV distributors.
g) We included no contribution to the resultant EMF from the 11kV underground cable.

- There are no metallic structures near the feeders that can act as magnetic shields.
- No EMF contribution from any other sources that might be present in the area beyond those listed above, was included in the modelling and calculations.

The magnetic field profiles for each critical location for the existing and for the relocated sections of the feeders are presented in the graphical and tabular forms.

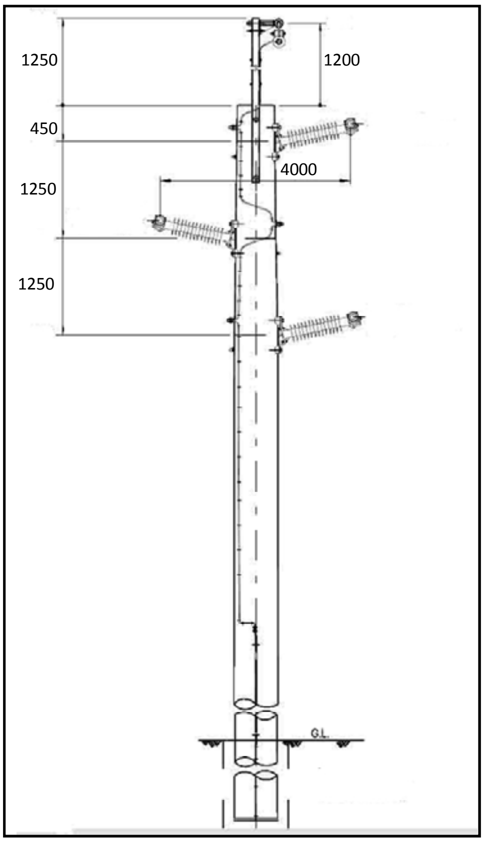

Fig.3 Typical 132kV power line support structure

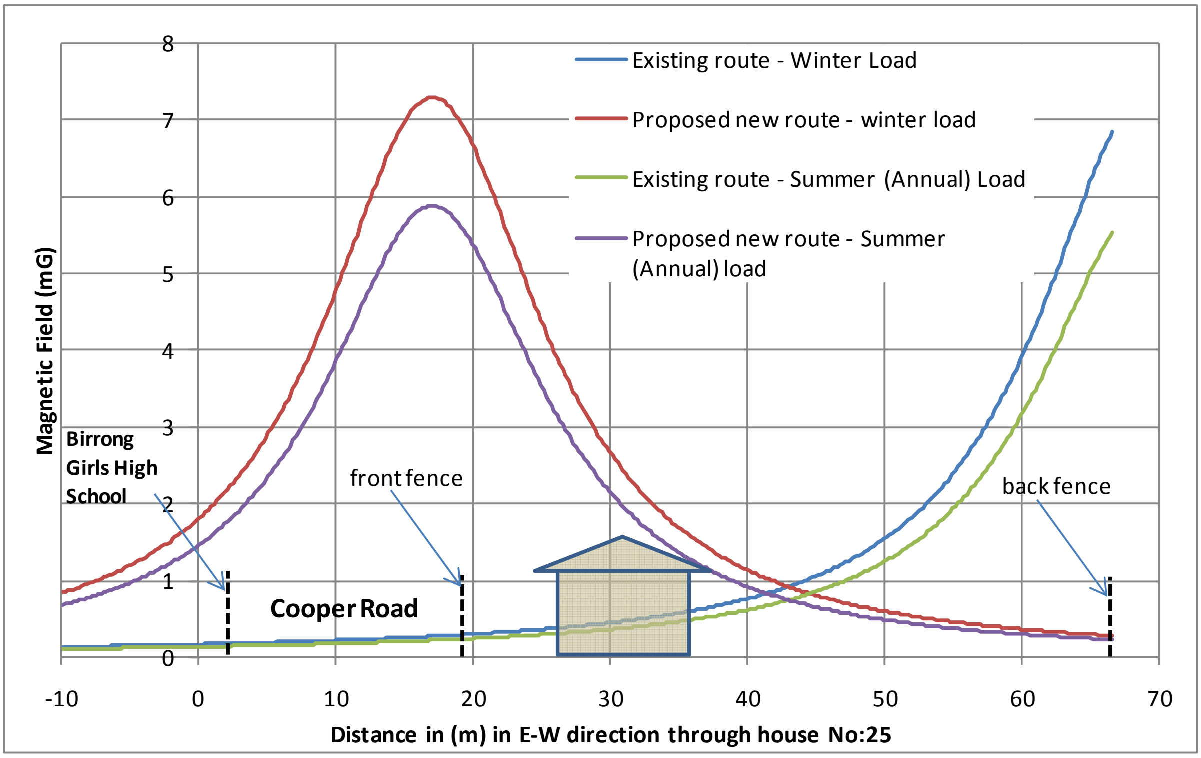

Fig.4 Magnetic field profiles calculated at 1m height above ground across the existing and proposed new sections of 132kV feeder in Cooper Road in East-west direction through the middle of property No:25.

2.2 Birrong Girls High School

The Birrong Girls High School is located on the western side of Cooper road directly opposite the section of the 132kV feeder that in the new arrangement would be running along the eastern side of Cooper Road.

To determine the EMF impact that the new position of the 132kV feeder might have within the school ground we've carried out calculation of EMF profile in the direction cross Cooper Road. In fact the imaginary line along which the EMF was calculated is cutting by half the residential property at No.25 Copper Road.

The resultant EMF profiles for two different arrangements of the feeder and for two different loading conditions are given in Fig.4 above.

As can be expected the graphs in Fig.4 show that the proposed relocation of the feeder from the back of the properties to the street frontage would increase the EMF level at the front part of the school ground. However, this increase is reasonably small and well below the level at which an association between the EMF and childhood leukaemia was reported in scientific literature (see the section on EMF and Health in Appendix A).

2.3 Residential Properties in Cooper Road

EMF was also calculated to determine the impact of the proposed relocation of the 132kV feeder from the back of ten residential properties in Cooper Road to the front.

The EMF calculations were carried out along several imaginary lines that pass trough each of the ten properties in north-south direction with 5m and 10m intervals.

The results of such calculations are summarised in Table 1 below.

Table 1

Location[1,2,3,4]	**Front fence**	**5m**	**10m**	**15m**	**20m**	**30m**	**40m**	**Back fence**
House No:33 - Existing feeder - New feeder	 2.3 mG 6.8 mG	 2.8mG 4.4 mG	 3.2 mG 2.7 mG	 3.4 mG 1.7 mG	 3.7 mG 1.1 mG	 4.4 mG 0.6 mG	 6.4 mG 0.3 mG	 7.4 mG 0.2 mG
House No:31 - Existing feeder - New feeder	 0.7 mG 6.8 mG	 0.9 mG 4.5 mG	 1.0 mG 2.7 mG	 1.1 mG 1.7mG	 1.3 mG 1.2 mG	 2.0 mG 0.6 mG	 4.2 mG 0.4 mG	 7.4 mG 0.2 mG
House No:29 - Existing feeder - New feeder	 0.4 mG 6.8 mG	 0.5 mG 4.5 mG	 0.6 mG 2.8 mG	 0.7 mG 1.7 mG	 0.9 mG 1.2 mG	 1.6 mG 0.6 mG	 3.9 mG 0.4 mG	 7.3 mG 0.2 mG
House No:23 - Existing feeder - New feeder	 0.3 mG 6.8 mG	 0.3 mG 4.6 mG	 0.4 mG 2.9 mG	 0.5 mG 1.8 mG	 0.7 mG 1.2 mG	 1.5 mG 0.6 mG	 3.7 mG 0.4 mG	 7.3 mG 0.3 mG
House No:19 - Existing feeder - New feeder	 0.2 mG 7.0 mG	 0.3 mG 4.8 mG	 0.4 mG 3.0 mG	 0.5 mG 2.0 mG	 0.6 mG 1.4 mG	 1.4 mG 0.9 mG	 3.6 mG 0.7 mG	 7.4 mG 0.6 mG
House No:17 - Existing feeder - New feeder	 0,2 mG 7.4 mG	 0.3 mG 5.6 mG	 0.3 mG 3.9 mG	 0.4 mG 2.9 mG	 0.6 mG 2.3 mG	 1.9 mG 1.0 mG	 3.4 mG 1.7 mG	 7.6 mG 1.6 mG
House No:15 - Existing feeder	 0.1 mG	 0.2 mG	 0.3 mG	 0.3 mG	 0.5 mG	 1.0 mG	 2.4 mG	 7.3 mG
- New feeder	House No:15 has been removed for public walkway							

<u>Notes:</u> [1] – *the load current is equal to the 85% of the maximum winterload current in 2014*
[2] – *no other sources of EMF were included in calculations*
[3] – *for each property the EMF was calculated along the line that passes through the middle of the property from the street fence to the back fence.*
[4] – *properties with house number 27,25 and 21 have the same EMFs as shown for house No:23*

As can be seen from the graphs in Fig.4 and from the data in the table, the most obvious change resulting from the proposed relocation of the feeder is that the peak of EMF has shifted from the back of the property boundary to the front. Its magnitude and its rate of reduction with distance remains the same as before.

The only other obvious difference between the existing and the proposed new route for the feeder is that the property at No.33 Cooper Road would have somewhat reduced EMF exposure.

3. Conclusions

As a result of computer modelling and calculations of the magnetic field emission for the existing and proposed new relocation paths of the 132kV feeder in Cooper Road the following conclusions can be made:

1. The proposed deviation of the power line route from the area behind the properties to the street frontage would not change the EMF peak and its rate of reduction with distance, but it would change the distribution of EMF across the residential properties along the existing and new paths.

2. The most affected by the proposed change would be the property at No: 33 Cooper Road located at the start of the section of the line proposed for relocation. This property would be exposed to less EMF however, the difference is not significant.

3. Relocation of the power line from behind the property line to the front of the property line in Cooper Road would not significantly increase the EMF within the Birrong Girls High School ground. However, the increase is reasonably small and well below the level at which an association between the long-term exposure to EMF and childhood leukaemia was reported in scientific literature.

4. The calculations also demonstrated that the highest magnetic field produced by the 132kV power line is well below the highest safe magnetic field exposure level for the general public as recommended in the national and international guidelines and standards (for details see Appendix A).

Please note once again that the above study was conducted on the basis of no contribution from any other sources of the EMF within the area of interest.

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Appendix A EMF Exposure Standards and Guidelines

A.1 IRPA and NHMRC Guidelines

In 1989, the International Radiation Protection Association (IRPA) approved interim EMF human exposure guidelines prepared by its International Non-Ionising Radiation Committee. In the same year these guidelines were adopted as the interim guidelines by the National Health and Medical Research Council of Australia (NHMRC). The guidelines recommended the following limits:

Exposure	Magnetic Flux Density
Occupational	
Whole working day	**0.5 mT (=5,000 mG)**
Short term	**5.0 mT (= 50,000 mG)**
For limbs	**25.0 mT (=250,0000 mG)**
General public	
Up to 24 hours per day	**0.1 mT (=1,000 mG)**
Few hours per day	**1.0 mT (=10,000 mG)**

Notes:

a) IRPA guidelines were developed *"primarily on established or predicted health effects produced by currents induced in the body by external [EMFs]".*

b) The guidelines were based on limiting current densities induced in the head and trunk by continuous exposure to 50/60 Hz electric and magnetic field to no more than about 10 mA/m^2.

c) Immediately observable minor biological effects have been reported in human studies in respect to induced current densities between 1 and 10 mA/m^2

d) The occupationally exposed population consists of adults exposed under controlled conditions in the course of their duties, who should be trained to be aware of potential risks and to take appropriate precautions.

The NHMRC guidelines state that: *"The occupationally exposed population consists of adults exposed under controlled conditions in the course of their duties, who should be trained to be aware of potential risks and to take appropriate precautions".* Based on this definition, the occupational exposure limits should only be applicable to skilled and trained workers who are directly involved with operation and maintenance of EMF emitting equipment and installations and who know how to limit the severity and duration of exposure to the power frequency electric and magnetic fields.

A.2 ICNIRP Guidelines

In 1998 the International Commission on Non-Ionising Radiation Protection (ICNIRP) published the new "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)". The new document replaces the previous IRPA guidelines.

The principal limitation of the guidelines is stated in the "BASIS FOR LIMITING EXPOSURE" section as follows:

> *Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF.*

The guidelines further state that:

> *In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP concluded that available data are insufficient to provide basis for setting exposure*

restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects and exposure at levels of 50/60 Hz magnetic flux densities substantially lower than those recommended in these guidelines.

The table below contains the ICNIRP reference levels for occupational and general public exposure to time-varying electric and magnetic fields.

Frequency range	E-field strength (V/m)	B-field density in μT, (mG)
	Occupational exposure	
Up to 1 Hz	-	200000, (2000000)
1 - 8 Hz	20,000	$2\times10^3/f^2$, $(2\times10^4/f^2)$
8 - 25 Hz	20,000	$2\times10^4/f$, $(2\times10^5/f)$
0.025 - 0.82 kHz	**500/f**	**25/f, (250/f)**
0.82 - 65 kHz	610	30.7, (307.0)
...	**...**	**...**
	General public exposure	
Up to 1 Hz	-	40000, (400,000)
1 - 8 Hz	10,000	$4\times10^4/f^2$, $(4\times10^4/f^2)$
8 - 25 Hz	10,000	5,000/f, (50,000/f)
0.025 - 0.8 kHz	**250/f**	**5/f, (50/f)**
0.8 - 3 kHz	250/f	6.25, (62.5)
...	**...**	**...**

Notes: a) 1μT = 10 mG
b) f - is the frequency of EMF in units given in the first column of the table.

From the ICNIRP table it follows that the maximum EMF exposure limit at the power frequency of 50Hz (this frequency is laying in the range between 0.025 – 0.8 kHz in the table) is 100μT (5/0.05kHz = 100μT) or 1000 mG (50/0.05kHz = 1000mG).

A.3 World Health Organisation - Fact sheet N°322 (June 2007)

A.3.1 Electromagnetic fields and public health - Exposure to extremely low frequency fields

The use of electricity has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances.

Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007).

This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003.

A.3.2 ELF field sources and residential exposures

Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μT). In some countries another unit called the gauss, (G), is commonly used (10,000 G = 1 T). These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance.

Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20 μT (200 mG) and electric fields can be several thousand volts per metre. However, average residential power-frequency magnetic fields in homes are much lower - about 0.07 μT (0.7 mG) in Europe and 0.11 μT (1.1 mG) in North America. Mean values of the electric field in the home are up to several tens of volts per metre.

A.3.3 Task group evaluation

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to 100,000 Hz (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007).

Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields.

A.3.4 Short-term effects

There are established biological effects from acute exposure at high levels (well above 100 μT or 1000 mG) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

A.4.5 Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia.

In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification issued to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT (3 to 4 mG). The Task Group concluded that additional studies since then do not alter the status of this classification. However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 μT (3 mG) in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease.

The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

A.3.6 International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits.

A.3.7 WHO's guidance

For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003).

International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers.

EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values.

Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.

- Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.

- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

A.3.8 Further reading

WHO - World Health Organization. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007.

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon, IARC, 2002 (Monographs on the Evaluation of Carcinogenic Risks to Humans, 80).

ICNIRP - International Commission on Non-Ionizing Radiation Protection. Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0-100 kHz). Bernhardt JH et al., eds. Oberschleissheim, International Commission on Non-ionizing Radiation Protection, 2003 (ICNIRP 13/2003).

ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.

IEEE Standards Coordinating Committee 28. IEEE standard for safety levels with respect to human exposure to electromagnetic fields, 0-3 kHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, 2002 (IEEE Std C95.6-2002).