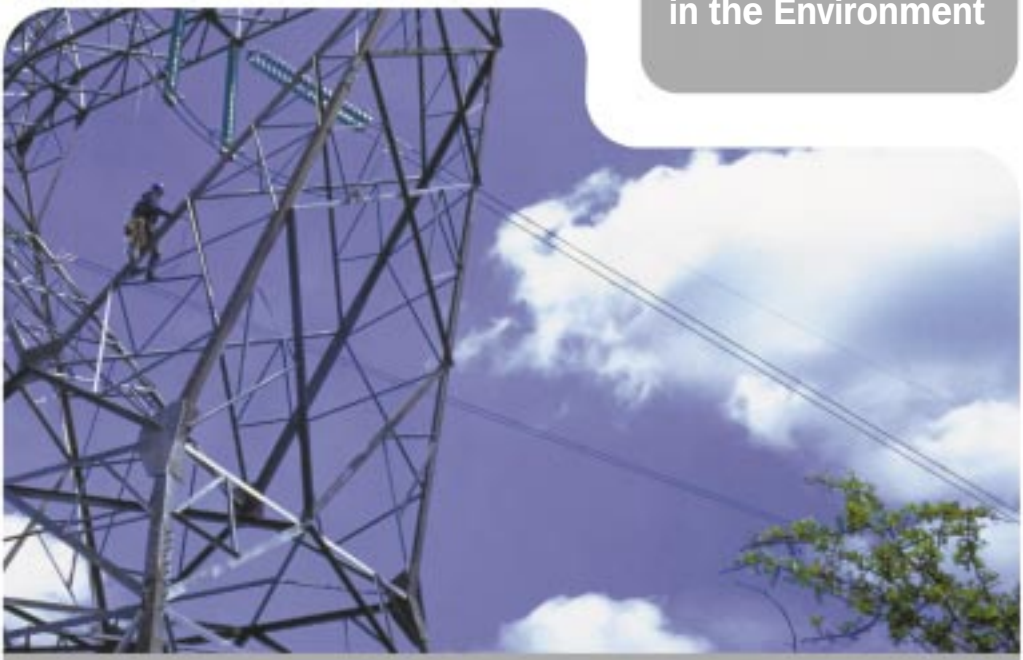
Electric and Magnetic fields in the Environment



Contents

The possible health effects from electric and magnetic fields (EMF's) associated with the transmission, distribution and use of electricity have caused some level of public concern both in Ireland and internationally in recent years. The main interest of most people in this country has centred around the fields produced by ESB power transmission lines, but questions have also been asked about the fields produced by other electrical sources such as appliances, distribution lines and substations.

ESB regards the protection of the health,safety and welfare of its staff and the general public as a core company value.

In accordance with our desire to deal in an open manner with this issue we are providing you with this information on the subject of electrical and magnetic fields. The quality of your living and working environment, along with the welfare of livestock and farm crops is of the utmost importance to us at all times.

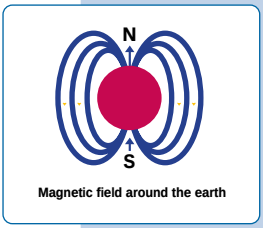
All of the ESB networks comply with the most up to date international EMF guidelines and recommendations. Despite over 20 years of intensive research into power frequency EMF's, the international scientific consensus is that there is no evidence to prove that these EMF's can cause any harm.

We hope you find this booklet useful and informative and that it provides the answers to the questions currently being asked on this issue, which has become a talking point during the 1990s.

To explain any technical terms used in the following pages, a glossary has been included on page 21.

What is a field?

A field describes the influence of an object on its surrounding space. For example, a temperature field may exist around a hot object. Within nature, a number of electric and magnetic fields occur. The earth is itself an immense natural magnet with magnetic poles near the North and South Poles. *(Fig. 1)* This permits the use of a compass for accurate direction finding. Electricity is a natural phenomenon which occurs as lightning and within the human body as electric fields and currents which allow information to flow within cells and tissues. Apart from these natural phenomena, electric and magnetic fields are produced wherever electric power is in use.



Magnetic field around the earth

Fig. 1

In Ireland, electricity varies at a power frequency of 50Hz (i.e. alternating back and forth 50 times each second) and produces characteristic electric and magnetic fields. At home and at work similar fields are produced by wiring and by electrical appliances in everyday use.

What is an electric field?

An electric field is produced within the surrounding area when voltage is applied to a conductor (or wire). Just as the area around a hot water pipe is affected by the temperature of the pipe, the area surrounding an electrical conductor is influenced by the conductor voltage. The strength of an electric field at a given location depends on two factors — the level of voltage applied to the conductor and the distance from it.

The magnitude of an electric field is measured in volts (or thousands of volts – kilovolts) per metre. This is written as V/m or kV/m. *(See calculation of electric fields, Figure 2).*

The electric field to which members of the public may be exposed from a power line is strongest directly under the line where the conductors are nearest the ground. This is usually near the middle of the span between two adjacent support structures. By moving away from a power line the strength of the electrical field decreases rapidly.

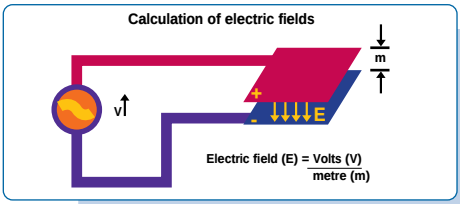


Fig. 2

The normal maximum electric field strength at ground level 30m from the centre of the lines ranges from 0.08kV/m for a 110kV line to 1.29kV/m for a 400kV line as shown in Table 1, Page 6.

For distribution lines (i.e. 38kV and below) field levels are correspondingly lower.

What is a magnetic field?

Magnetic fields are produced where electric current is present. The strength of a magnetic field at a given location depends on the level of current flowing in the conductor or wire and the distance from it. Magnetic fields are normally expressed in terms of a quantity called the magnetic flux density, expressed in terms of tesla (T). This relatively large unit is often expressed in submultiples such as microtesla (μT - one millionth T). *(See calculation of magnetic fields, Figure 3).*

Magnetic fields produced by power lines are strongest directly under the line where the conductors are nearest the ground.

Typical magnetic flux densities at 30m from ESB transmission lines are shown in Table 1, Page 6 and range from 0.2μT for a 110kV line to 2.61μT for a 400kV line.

These levels are well below the magnetic field strength produced close to many common electrical appliances, see page 10.

The difference between the magnetic fields produced by power lines and electrical appliances is that the magnitude of the fields produced by appliances falls off very rapidly with distance. The fall off from power lines is less rapid. The fields from power lines tend to be constant over time, while the magnetic fields produced by appliances only arise when they are in use.

Electric and magnetic fields — photographs in this booklet show typical values of electric and magnetic field strength where electric power is transported or used.

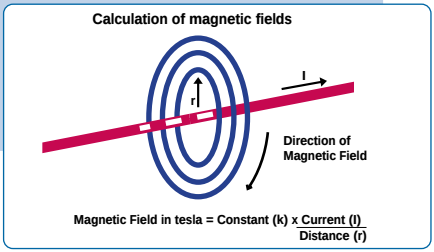
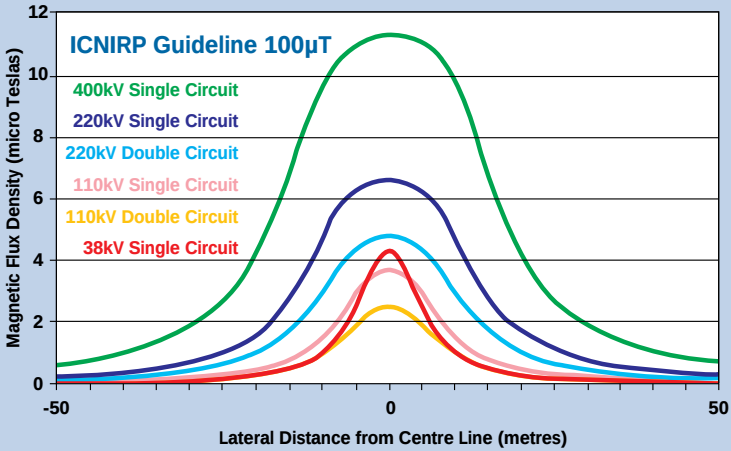


Fig. 3

Type of line	Electric Field Strength (kV/m)	Magnetic Flux Density (μT)
38kV Single Circuit	0.012	0.13
110kV Single Circuit	0.077	0.2
110kV Double Circuit	0.043	0.1
220kV Single Circuit	0.359	0.71
220kV Double Circuit	0.219	0.41
400kV Single Circuit	1.29	1.81
ICNIRP Guideline (see page 19)	5	100

Table 1: Typical Electric Field Strength and Magnetic Flux Density at 30 metres from ESB Overhead Lines.



These 'profiles' show the magnetic field near the ground for some typical overhead lines.

Fig. 4

Fields within the electromagnetic spectrum

There are many different sources of electric and magnetic fields and radiation. The Sun heats the Earth using electromagnetic radiation, vision is possible because of electromagnetic radiation, watching television and listening to radio are pastimes made possible by modern telecommunications and the ingenious use of electromagnetic fields. Not all these fields are the same, they are distinguished by their frequency which is measured in cycles per second or Hertz (Hz). *(See electro-magnetic spectrum page 8)* At the extremely low frequency end of the electromagnetic spectrum we find electric and magnetic fields typical of those associated with power lines. Because these fields operate at extremely low frequency, they contain very little energy and cannot directly break apart molecules.

Because of the characteristics of power lines no electromagnetic energy radiates from the lines as a result of the surrounding electric and magnetic fields.

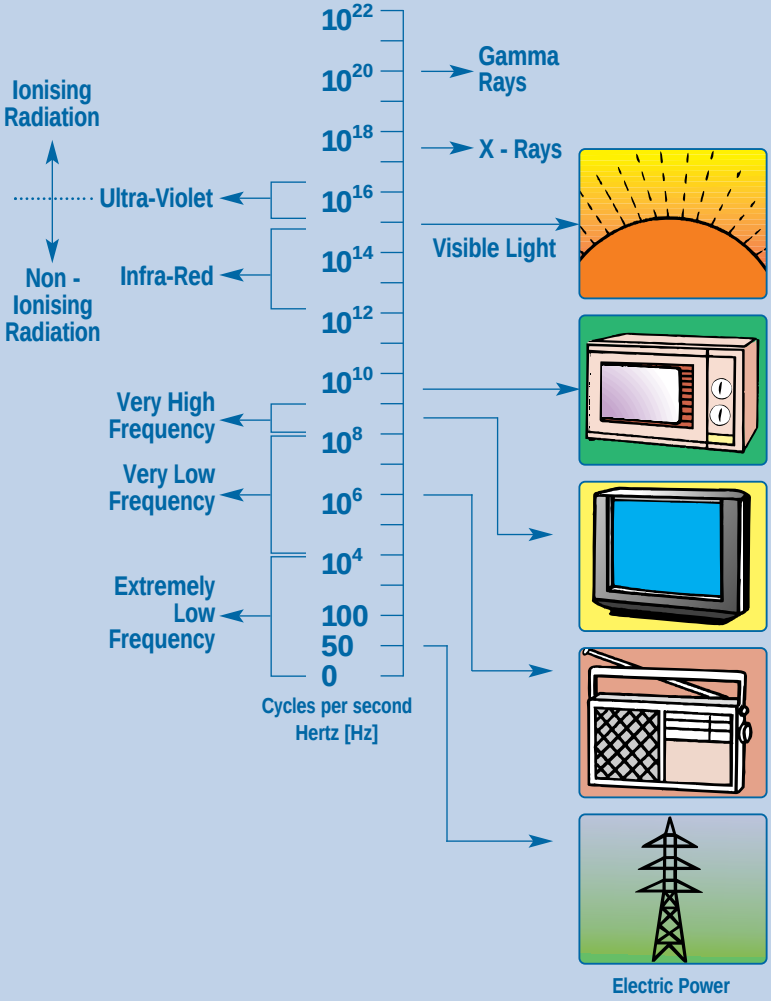
Moving up the spectrum we pass through radio, TV and microwave frequencies into visible light. Further up, in the ultra-violet region of the frequency spectrum, electromagnetic radiation becomes 'ionising radiation'. Ultra-violet light, X-rays and gamma rays are ionising radiation and have sufficient energy to break apart the molecules which make up genes. Excessive exposure to these forms of radiation is dangerous and can lead to cell mutations and cancer.

Typical values directly underneath a 220kV transmission line 4kV/m 8µT

POWER lines used in Ireland

ESB uses high voltage transmission and distribution lines to transmit electric power to demand centres throughout the country and low voltage lines to individual houses. Overhead 110kV lines have been used in Ireland for almost 70 years, while 220kV lines are in operation for about 40 years. For the past 15 years 400kV lines have also been in use. Internationally, 220kV transmission lines have been widely used since the 1920s.

The Electromagnetic Spectrum



Investigations of EMF Effects

A debate about the possible effect on human and animal health of electric and magnetic fields has continued since the 1970s. Since then, many thousands of studies have been undertaken all over the world to assess any potentially harmful effects from power lines, electrical appliances and domestic wiring.

To date no conclusive evidence has been found proving that electric and magnetic fields are harmful.

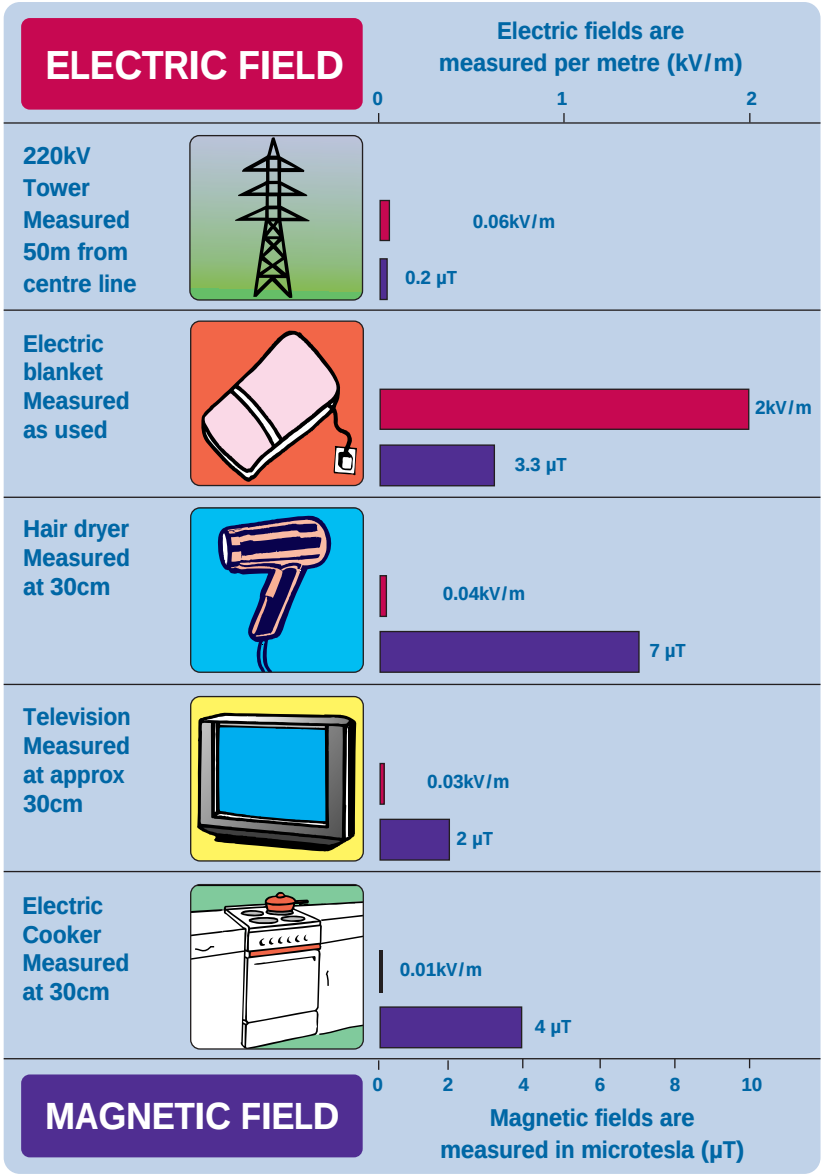
ESB is fully aware of the questions currently being raised and is actively supporting research programmes.

The following is a brief guide to the body of research undertaken worldwide.

Human studies

Human volunteers have assisted in international studies. These detailed and thorough programmes exposed volunteers to electric and magnetic fields under strictly controlled laboratory conditions. The strengths employed were much stronger than people normally experience in their day-to-day lives — ranging up to 20kV/m and 5,000µT, with exposures of several hours. These presented much greater levels of exposure than the levels from ESB lines shown in Table 1, Page 6. Under these conditions, a wide range of performance and blood tests were carried out.

No marked ill-effects of these very high levels of exposure were observed. Small physiological changes were seen, such as changes in heart rate. But these changes were well within the normal range of variation. Such temporary physiological changes are not regarded as adverse to health.



Typical values of electric and magnetic fields in the environment

Epidemiological studies

Epidemiology is the study of illness in large human populations. It is used to obtain and test ideas about the origin of illnesses as they relate to the characteristics and environment of people.

Substantial epidemiological investigations relating to exposure or presumed exposure to power-frequency electric and magnetic fields as a possible threat to health have been conducted and published in various parts of the world. Such studies are statistical in nature and require large sample populations. They have not been undertaken in Ireland because of this country's relatively small population.

Many external factors can influence an illness and it is generally not possible to make allowance for all of these factors. Epidemiological study results attempt to indicate to what extent some factor is statistically associated with the occurrence of an illness and can also indicate the strength of this association.

Association does not, however, prove cause. To establish cause - particularly when the association is relatively weak - scientists generally require a consistency in results between independently

conducted epidemiological studies, a clear 'dose/response' relationship (i.e. as the dose gets stronger the response gets bigger), supporting evidence from animal studies and preferably an under-standing of the underlying biological mechanism.

Despite extensive scientific research none of these requirements have been met in any substantive form to allow any definite conclusions be made in the case of electric and magnetic fields.

Most of the concern about power lines and cancer stems from earlier epidemiological studies of people living near power lines. However, epidemiological studies completed in recent years show little evidence of a link between power frequency fields and cancer.

The US NATIONAL CANCER INSTITUTE STUDY

In 1997 the United States National Cancer Institute (NCI) published one of the largest childhood cancer epidemiological studies to date. This study examined 638 children with childhood leukaemia. The conclusion of the study was *"Our results provide little support for the hypothesis that living in homes with high time-weighted average magnetic field levels or in homes close to electrical transmission or distribution lines is related to the risk of childhood ALL"* (Acute Lymphoblastic Leukaemia).

Typical values 0.3kV/m 60μT

Animal studies

Through the use of animals in carefully monitored laboratory conditions, it is possible to achieve good control of the exposure to electric and magnetic fields. Such studies are very valuable in the investigation of effects on human health. However, difficulties remain in determining the relevance of these studies to human exposure. Generally, animal studies have concentrated on the effects on the nervous system. Again, the results of such studies are inconsistent, showing wide variations. Some have reported effects, for example on behaviour and on the levels of certain hormones, such as melatonin(a hormone produced in the pineal gland of the brain), but with inconsistent results. No disease-causing effects have been established.

Extensive studies have also been carried out on farm animals in relation to reproduction and development. No harmful influences have been proven from exposure to electric and magnetic fields.

CELL studies

Studies of cell and tissue cultures in the laboratory are often described as in-vitro (in glass), while the term in-vivo (in live state) is applied to animal studies. In-vitro research studies on electric and magnetic fields are numerous and results have been reported as producing both positive and negative results, making the overall picture both complex and inconclusive. As an added difficulty, it is not possible to predict by merely observing cell cultures whether effects if found will occur in animals or people. It is even more difficult to establish whether effects observed at the cell level would have any health implications. This matter is further complicated by the presence in whole organisms of control and repair mechanisms which are generally lacking in cell cultures and whose effect can not be studied in individual cell studies.

Certain reported effects appear to occur only within particular ranges or 'windows' of frequency, time or field strength — although no specific windows have yet been confirmed. However under these conditions higher field exposures do not produce a greater effect. It has also been shown that static magnetic fields comparable to the earth's have also been reported to influence some cell experiments.

Although individual scientific studies may appear to be very convincing, it is important to remember that such studies only become an accepted part of science when they have been replicated in several laboratories and related to current understanding.

Few of the many reported in-vitro effects of extremely low-frequency fields have been independently replicated. There is agreement in the scientific community that these fields do not cause cells to become cancerous.

A characteristic of agents such as ionising radiation, which do initiate cancer, is their ability to produce changes in the genetic material of the cell, either visible damage to chromosomes or genetic mutations.

Laboratory studies with electric and magnetic fields have not demonstrated such health risks.

There has been some speculation that electric or magnetic fields might accelerate or promote the development of cancers in cells which are or have become otherwise predisposed to cancer.

Typical everyday values 0.1kV/m 0.4μT

Despite extensive scientific research this hypothesised promotion effect has not been established.

Interaction mechanisms

Power-frequency electric and magnetic fields are incapable of disrupting molecules by ionisation or of causing any significant heating in tissue.

The only established mechanisms of action by these fields is via induced currents. Large induced currents can, for example, stimulate nerve and muscle cells. The international guidelines in place (see page 19) employ very large safety factors to ensure that these effects are not possible in individuals exposed to EMF levels at or significantly beyond the guideline levels.

Other research mainly centres on the effects at the cell surface or on the transport of ions which can act as biochemical ‘messengers’ across the cell membrane.

Several theoretical explanations of mechanisms have been proposed and it seems that more than one mechanism may exist. But such explanations are speculative and no comprehensive theory has been proposed which may be confirmed by laboratory experiment.

Typical values 0.1kV/m 0.3μT

One such theory which has attracted widespread media attention is the Henshaw Hypothesis. In February 1996 Professor Denis Henshaw, Bristol University published a paper proposing an attraction between radon gas and the electric field surrounding high voltage transmission lines. This hypothesis was described as being “implausible” and “purely speculative” by the NRPB (National Radiological Protection Institute, UK).

Scientific experiments to determine the validity of this theory by outdoor radon gas measurements under power lines, both in Ireland and the UK, found no evidence to support the theory.

Independent international medical and scientific bodies are continuing to review and monitor the possibility of health effects from exposure to extremely low-frequency electric and magnetic fields. The findings of these bodies carry considerable weight, as they reflect the judgments of groups of experts rather than the views of individuals. This section contains excerpts from the conclusions of two such bodies, along with some findings from an independent national scientific review by the Irish Government.

World Health Organisation (WHO) 'Non-ionising Radiation Protection'

In 1989 the WHO published the second edition of its book 'Non-ionising Radiation Protection'. The section on electric and magnetic fields at extremely low frequencies concludes:

"Exposure to ELF electric and magnetic fields does produce biological effects. However, except for fields strong enough to induce current densities above the threshold for the stimulation of nerve tissues, there is no consensus as to whether these effects constitute a hazard to human health. Human data from epidemiological studies, including reported effects on cancer promotion, congenital malformation, reproductive performance and general health, though somewhat suggestive of adverse health effects, are not conclusive."

In 1996 WHO began a five year International EMF Project to re-examine all available literature and ESB has made a financial contribution towards this project.

US NATIONAL ACADEMY OF SCIENCES.

A major review of power frequency electric and magnetic field literature, and one of the most extensive to date was published in October 1996 by the United States National Academy of Sciences.

On its release Professor Charles Stevens, the chairman of the research committee, stated :

"Research has not shown any convincing way that EMF's common in homes can cause health problems, and extensive

Typical values 0.3kV/m 1µT

laboratory tests have not shown that EMF's can damage the cell in a way that is harmful to human health."

The report concluded :

"No clear, convincing evidence exists to show that residential exposures to electric and magnetic (EMF)are a threat to human health .....there is no conclusive evidence that electromagnetic fields play a role in the development of cancer, reproductive and development abnormalities, or learning and behavioural problems."

DEPARTMENT OF ENERGY(IRELAND)
"Assessments of Scientific Research on Electromagnetic Fields'

Dr T. Mc Manus — Chief Technical Adviser, Department of Public Enterprises — has prepared two extensive assessments of scientific research on electromagnetic fields. In his 1988 report to the Minister for Energy, he reported among his findings:

"An analysis of the situation leads to the conclusion that there is no health risk on the basis of present knowledge."

In a 1992 report, Dr Mc Manus summarised the views of national and international organisations as follows:

"Without exception these reports and the position taken by the organisations concerned do not see enough evidence to be able to indict electromagnetic fields as a hazard to health."

US NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES.

In June 1999, the NIEHS published their review of the EMF research conducted to date. This US$60 million research and communication effort was requested by the United States Congress and was carried out over a six year period.

The main conclusion of the report was that *"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak."* The report finds that some epidemiological studies have shown a small increased risk but that the mechanistic and animal studies fail to demonstrate any consistent pattern.

"Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weaken the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings."

SUMMARY OF STUDIES

The interpretation of the findings of international and national review bodies have one element in common — no health risks from power-frequency electric and magnetic fields, at levels which people are exposed in the environment have been established.

Typical values 0.1kV/m 0.3μT

Epidemiological studies completed in recent years show little evidence of a link between power frequency fields and cancer.

Laboratory studies have also failed to establish any mechanism whereby low level electric and or magnetic fields could cause any form of ill health effect.

A connection between power line EMF's and cancer remains biophysically implausible.

ESB and national and overseas bodies are continuing to monitor and support research developments and to keep society fully informed.

International guidelines for Exposure

Any guidelines for restricting the exposure of people to certain agents must rest on a solid scientific basis. The induction of currents in the human body is the only certain interaction of power frequency electric and magnetic fields.

The World Health Organisation, in its 1987 Environmental Health Criteria review of magnetic fields, stated that up to an induced current density of 10mA/m^2 is acceptable. Naturally occurring current densities within the body, caused for example by the action of heart muscles, are also of similar value.

Typical values at 2 metres distance 0.02kV/m 1µT

Typical values 0.1kV/m 1.0µT

International Commission on non-ionising radiation protection (icnirp)

In 1998 ICNIRP published its most recent guidelines for exposure to time varying electric, magnetic and electromagnetic fields (up to 300GHz). The commission consists of an international panel of independent top experts in electromagnetic fields. The exposure guidelines in the 1998 document were based on avoiding known effects of high EMF levels on the body.

The following is a quotation from the 1998 guidelines:

"It is the view of the ICNIRP that the results from the epidemiological research on EMF exposure and cancer, including childhood leukaemia, is not strong enough in the absence of support from experimental research to form a basis for setting exposure guidelines."

Based on the findings referred to above, guidelines on exposure have been prepared by the International Commission on Non-Ionising Radiation Protection. For the general public these are 5kV/m and 100µT for electric and magnetic fields respectively.

Typical values directly underneath a 10kV distribution line 0.24kV/m 5µT

ESB's commitment to safeguard public health

ESB regards the protection of the health, safety and welfare of staff and the general public as a core company value.

Arising from concerns about possible adverse health effects resulting from exposure to electric and magnetic fields (EMF) from electrical equipment, such as power lines and appliances, ESB has decided to clearly state its policy in relation to this issue as follows.

- Design and operate its generation, transmission and distribution networks in accordance with the most up-to.date recommendations and guidelines of the various expert and independent international bodies.
- Closely monitor and support engineering and scientific research in this area.
- Provide advice and information to staff, customers and the general public on this issue.

Glossary of Terms Used in this Booklet

Carcinogenic	Causing cancer
Chromosomes	The part of a cell involved with cell division and hereditary characteristics
Current	The movement of an electrical charge analogous to the rate of fluid flow in a pipeline
Electric fields	Invisible fields of force where voltage is present
Electricity	A form of energy created by the flow of current or the presence of voltage
Epidemiology	A type of research that tries to find statistical links between the occurrence of specific diseases and people's exposure to possible causes
Frequency	The number of repetitions of an electric wave per second
Induced current	Current which flows in a body as a result of an interaction with an electric or magnetic field
Ionising radiation	Radiation, such as X-rays, which has sufficient energy to break chemical and electrical bonds
Magnetic fields	Invisible fields of force found where electric current is present
Melatonin	A hormone produced in the pineal gland in the brain
Molecule	The smallest particle of a substance that retains the properties of that substance
Power frequency	The type of electric power that is used in Ireland, in 50 Hertz (Hz)which current alternates back and forth 50 times per second
Radiation	Any of a variety of forms of energy propagated through space
Voltage	The measure of potential strength of electricity. Voltage in a power line is analogous to pressure on a pipeline.

Additional Suggested Reading

- **World Health Organisation**
  Environmental health criteria 35. Extremely low frequency (ELF) fields. WHO 1984.

- **World Health Organisation**
  Environmental health criteria 69. Magnetic fields. WHO 1987.

- **World Health Organisation**
  Fact Sheet WHO/205 November 1998
  Electromagnetic Fields and Public Health: Extremely low frequency (ELF)

- **International Commission on Non-Ionising Radiation Protection,**
  Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz). Health Physics, Vol. 74, No. 4, April 1998.

- **International Conference on Large High Voltage Electric Systems**
  (CIGRE) Electric Power Transmission and the Environment: Fields, Noise and Interference. Working Group 36.01 (Corona and Field Effects).

- **Department of Energy Ireland. (Available from Government Publications)**
  - Electromagnetic Fields from High Voltage Transmission Lines, 1988.
  - Electromagnetic Fields, 1992.
  Author: Dr T. Mc Manus, Chief Technical Adviser.

- **National Academy of Sciences, Possible health effects of exposure to residential electric and magnetic fields,**
  National Academy Press, 1996.

- **National Cancer Institute, Residential exposure to magnetic fields and acute lymphoblastic leukaemia in children, Linet et al,**
  The New England Journal of Medicine, Volume 337, Number 1, July 3 1997.

- **National Radiological Protection Board (NRPB-UK) Electromagnetic Fields and the Risk of Cancer.**
  Vol. 3 No. 1 1992. Board Statement on Restrictions on Human Exposure to Static and Time-Varying Electromagnetic Fields and Radiation. Vol. 4 No. 5 1993.

- **Electromagnetic Fields and Human Health, Powerlines and Cancer,Frequently Asked Questions,**
  Dr.John E Moulder, Professor of Radiation Onocology,Medical College of Wisconsin.
  http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html

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The ESB hopes that this booklet has been informative and provides a greater understanding of the possible health risks associated with electric and magnetic fields.

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June 1999