ANALYSIS OF THE BIOLOGICAL EFFECTS OF EMF ON HUMAN HEALTH

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Mehrdad Khaledi : Analysis of the Biological Effects of EMF on Human Health

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ABSTRACT

In the past decade, wireless and personnel communications have grown faster than any body predicted. Inexpensive phones with built-in facilities and lower per-call rates have made mobile phones an essential part of life. However, despite the many wonderful convenience of using electrical and magnetic fields in power and communication systems, the biological effect of these fields remain the most controversial aspects that needs more investigations. Some times in publications can be find diametrical opposite conclusions.

The publications based on epidemiological studies suggest that a link may exist between exposure to electric and magnetic fields and certain types of human health problems. The publications from technical Institutions have shown that if level of exposure is limited by certain safety standards, biological effects of electrical and magnetic fields are negligible.

The objective of this thesis is to provide an independent analysis and systematisations of the research works on biological effects of electrical and magnetic fields and evolution of practical recommendations.

For this purpose the background problems related with health effects from exposure to power line frequency electric and magnetic fields and to radio frequency fields from cellular and personnel transmitters are examined. International mandatory standards for regulating human exposure to electromagnetic radiation are analysed.

Table of Contents

1. Introduction

1.1 What is EMF?

EMF (or Electromagnetic Field) is a broad term, which includes electric fields generated by charged particles; magnetic fields generated by charged particles in motion, and radiated fields such as TV, radio, and microwaves. Electric field is measured volt per meter or V/m. Magnetic field intensity H is measured in ampere per meter or A/m. The field is always strongest near the source and diminishes as you move away from the source. Despite the many wonderful conveniences of electrical technology, the effects of EMF on biological tissue remains the most controversial aspect of the EMF issue with virtually all scientists agreeing that more research is necessary to determine safe or dangerous levels. Iron, necessary for healthy blood and stored in the brain, is highly affected by EMF. The permeability of the cell membrane of our nerves, blood vessels, skin, and other organs is affected. The intricate DNA of the chromosomes has been shown to be effected by EMF as well. In fact, throughout our bodies, every biochemical process involves precisely choreographed movement of EMF-sensitive atoms, molecules, and ions.

Power lines, electrical wiring, and appliances all produce electric and magnetic fields. EMF lines are invisible lines of force that surround any electrical device. Electric and magnetic fields have different properties and possibly different ways of causing biological effects. The electric fields are easily shielded or weakened by conducting objects (eg, trees, buildings, and human skin). Both electric and magnetic fields weaken with increasing distance from the source.

Even though electric and magnetic fields are present around appliances and power lines, more recent interest and research have focused on potential health effects of magnetic fields. This is because epidemiological studies have found associations between increased cancer risk and power-line configurations, which are thought to be surrogates for magnetic fields. No such associations have been found with measured electric fields.

1.2 Power-Frequency EMF

The electromagnetic spectrum covers an enormous range of frequencies. These frequencies are expressed in hertz (Hz). Electric power (60 Hz in North America, 50 Hz in most other places) is in the extremely-low-frequency range, which includes frequencies below 3000 Hz.

The higher the frequency, the shorter the wavelength and the greater the amount of energy in the field. Microwave frequency fields, with wavelengths of several inches, have enough energy to cause heating in conducting material. Still higher frequencies like X-rays cause ionisation, the breaking of molecular bonds, which damages genetic material. In comparison, power frequency fields have wavelengths of more than 3100 miles (5000 km) and consequently have very low energy levels that do not cause heating or ionisation. However, AC fields do create weak electric currents in conducting objects, including people and animals [1].

1.3 EMF Produced by Earth

The earth produces EMF, mainly in the form of DC (also called static fields). Electric fields are produced by thunderstorm activity in the atmosphere. Near the ground, the DC electric field averages less than 200 volt per meter (V/m). Much stronger fields, typically about 50,000 V/m, occur directly beneath electrical storms.

Magnetic fields are thought to be produced by electric currents flowing deep within the earth's molten core. The DC magnetic flux densities average around 500 milli-gauss (mG). This number is larger than typical AC electric power magnetic fields, but DC fields do not create currents in objects in the way that AC fields do.

1.4 Radiofrequency Radiation

Mobile phones and their base stations transmit and receive signals using electromagnetic waves (also referred to radio waves). Frequencies between about 30 kHz and 300 GHz are widely used for telecommunication, including broadcast radio and television, and comprise the radiofrequency (RF) band.

In the most of the countries, AM radio uses frequencies between about 180 kHz and 1.6 MHz, FM radio ranges from 88 to 108 MHz, and TV ranges from 470 to 854 MHz. Cellular mobile phone services operate within the frequency ranges 872– 960 MHz and 1710– 1875 MHz. Waves at higher frequencies but within the RF region, up to around 60 GHz, are referred to as *microwaves* and have a wide variety of uses. These include radar, telecommunications links, satellite communications, weather observations and medical diathermy; intense sources of 2.45 GHz microwaves confined within ovens are used for cooking. At even higher frequencies, radiation takes the form of infrared, then visible, ultraviolet, X-rays and eventually the γ-rays *(gamma* rays) emitted by radioactive material. Electromagnetic radiation is also characterised by its wavelength λ*(lambda*), which equals the velocity or speed of the wave (the speed of light) divided by its frequency.

A RF wave used for radiocommunication is referred to as a carrier wave. The information it carries – speech, computer data, etc – has to be added to the carrier wave in some way, a process known as modulation. The information can be transmitted in either analogue or digital form. For example, the electrical signal from a microphone produced by speech or music is an analogue signal at frequencies up to about 15 kHz. So the signal varies significantly with time on a scale of a few microseconds or μs. At a particular time it might have any value within quite a large range. So if this signal is sent by analogue transmission, the size or amplitude of the RF carrier wave at any instant is made proportional to the size of the electrical modulating signal at that instant (this is called amplitude modulation and other forms of modulation can also be used. The carrier wave varies very much faster than the signal so that the modulation produces a relatively slow oscillation in the amplitude of the carrier wave. Information can also be transmitted in digital form. In this case only a small number of symbols are used. Printed language is an example of digital information since it only uses the symbols of the alphabet. Morse code is another and only uses two symbols, dots and dashes, so is called a binary system. Analogue signals are described by a number, which in general is not an integer (whole number), and the first step in digitising it is to round this to the nearest integer. For example, if the strength of an electrical signal from a microphone at a particular instant is 12793.56 microvolt or μV the number 12793.56 is rounded to 12794. This can then be expressed in binary form in which it is represented by a series of zeros and ones, and these can be transmitted digitally to a receiver that converts them back to a signal of strength 12794 μV. Digital transmission, usually binary, offers many technical advantages over analogue transmission systems. It is, for example, less susceptible to distortion by interference and electrical noise, and it is replacing or has replaced analogue transmission in radio, TV , mobile phones, etc.

1.5 Electric and Magnetic Fields, Intensities

An electromagnetic wave consists of electric and magnetic fields that oscillate between their peak (largest) values (positive and negative) and zero. The size of a field can be indicated either by the magnitude of the peak value or by an average value. Since the field is positive for half the time and negative for the other half, its mean value is zero. So the average used is the rms or root mean square value which is equal to the peak value divided by 1.4 ($\sqrt{2}$). If an electrically charged object such as an ion (an atom or group of atoms which has lost or gained one or more electrons) or a cell is exposed to an electric field, it feels a force of magnitude proportional to the field. If, however, it is exposed to a magnetic field it only feels a force if it is moving at an angle to the field. The size of the force is proportional to the magnetic field and to the speed at which the object is moving across the field.

Magnetic fields can also interact strongly with magnetic material such as iron. The power density, of an electromagnetic wave is the power passing through 1 m^2, as illustrated in Figure 1.1. The power is usually measured in watts (W), and the intensity is measured in watts per square metre or W/m^2. Since the area of a sphere surrounding a source increase as the square of its radius, then in an ideal case (in the absence of any nearby objects including the ground) the intensity falls off as $1/(\text{distance})^2$, the inverse square law.

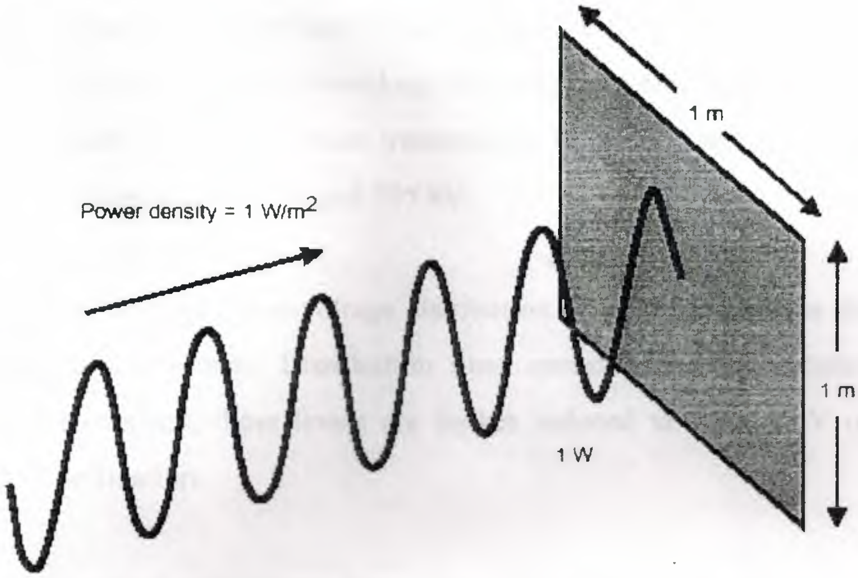

Figure 1.1 Electromagnetic wave passing through $1m^2$

The properties of an electromagnetic field change with the distance from the source. They are simplest at distances of more than a few wavelengths -around a metre or more at the frequencies of interest here which is referred to as the far-field region. In this region, the electromagnetic wave consists of an electric field E and a magnetic field H oscillating at right angles both to each other and to the direction in which the power of the wave is travelling (the direction of the intensity).

In the near-field region, however, the situation is more complicated. The amount of power being radiated outwards is the same as that in the far-field region, but near to the antenna a considerable amount of electromagnetic energy is also being stored. So as well as the net radiated energy flowing outwards, there is additional energy that oscillates to and from. These oscillating flows occur perpendicularly to the outward direction from the antenna as well as along it so the net energy flow is tilted with respect to the outward direction. The E-field and H-field are still at right angles to each other and to the direction in which the energy is being carried, but they are no longer in phase and their values çan differ appreciably from the simple expressions that apply in the far-field region.

1.6 Electric Power Facilities

There are two basic types of power lines: transmission lines and distribution lines. Transmission lines are high-voltage power lines. The high voltage allows electric power to be carried efficiently over long distances from electrical generation facilities to substations near urban areas. Most transmission lines use alternating current (AC) and operate at voltages between 50 and 765 kV.

Utilities Use lower-voltage distribution lines to bring power from substations to businesses and homes. Distribution lines operate at voltages below 50 kV. For residential customers, these levels are further reduced to 120/240 V once the power reaches its destination.

Electrical substations serve many functions in controlling and transferring power on an electrical system. Several different types of equipment may be present, depending on the functions of the particular substation. For example, transformers change the high voltages used by transmission lines to the lower voltages used by distribution lines. Circuit breakers are used to turn lines on and off.

1.7 Alternating Current and Direct Current

Appliances that operate either with batteries or by plugging into the household wiring usually come equipped with an AC /DC switch. If switched to AC, the appliance Uses electric power that flows back and forth or "alternates" at a rate of 60 hertz, or 50. If DC is chosen, current flows one way from the batteries to the appliance. AC fields induce weak electric currents in conducting objects, including humans; DC fields do not, Unless the DC field changes in space or time relative to the person in the field. In most practical situations, a battery-operated appliance is unlikely to induce electric current in the person using the appliance Induced currents from AC fields have been a focus for research on how EMFs could affect human health.

1.8 Effects of EMF on Living Things

AC fields create weak electric currents in the bodies of people and animals. This is one reason why there is a potential for EMF to cause biological effects. Currents from electric and magnetic fields are distributed differently within the body. The amount of this current, even if you are directly beneath a large transmission line, is extremely small (millionths of an ampere). The current is too weak to penetrate cell membranes; it is present mostly between the cells.

Currents from 60-Hz EMF are weaker than natural currents in the body, such as those from the electrical activity of the brain and heart. Some scientists argue that it is therefore impossible for EMF to have any important effects. Other scientists argue that, just as a trained ear can pick up a familiar voice or cry in a crowd, so a cell may respond to induced current as a signal, lower in intensity yet detectable even through the background "noise" of the body's natural Currents. Numerous laboratory studies have shown that biological effects can be caused by exposure to EMF. In most cases, however, it is not clear how EMF actually produce these demonstrated effects **[2]**.

2. Technology of Cellular Mobile Phones

2.1 Cellular radiofrequency networks

A mobile phone sends and receives information (voice messages, fax, computer data, etc) by radiocommunication. Radiofrequency signals are transmitted from the phone to the nearest base station and incoming signals are sent from the base station to the phone at a slightly different frequency. Once the signal reaches a base station it can be transmitted to the main telephone network, either by telephone cables or by higher frequency (such as 13,23 or 38 GHz) radio links between an antenna (eg dish) at the base station and another at a terminal connected to the main telephone network. These microwave radio links operate at rather low power and with narrow beams in a direct line of sight between the antennas, so that any stray radiation from them is of much lower intensity than the lower frequency radiation transmitted to the phones. **(The maximum intensity on the ground 15m from an antenna of a microwave link is stated to be 45 $\mu W/m^2$)**

Signals to and from mobile phones are usually confined to distances somewhat beyond the line of sight. They can reach into buildings and around corners due to various processes including reflection and diffraction, that allows the radiation to bend round corners to some degree, but the coverage area from a base station is partly governed by its distance to the antenna's horizon. In the current GSM system a timing artefact in the signal processing within the receivers limits the maximum distance over which a mobile phone can be used to about 35 km (22 miles). For such reasons an extensive network of base stations is needed to ensure coverage throughout a large area of a country. An ideal network may be envisaged as consisting of a mesh of hexagonal cells, each with a base station at its centre (Figure 2.1), but in practice the coverage of each cell will usually depart appreciably from this because of the topography of the ground and the availability of sites for the base stations. The sizes of the cells are usually less than the 35 km maximum because obstruction by hills, buildings and other ground features reduces the effective range. Frequencies are reused several cells away and the capacity of a network (the number of simultaneous phone calls which may be made) depends on the extent of the frequency spectrum available, the cell diameter and the ability of the system to work against a background of interference from other cells. To accommodate the steadily increasing volume of users, cell sizes have to be progressively reduced (for example, by using base station antennas of lower height and reduced power) so that the frequencies may be reused more often. Indeed in large cities, base stations may only be a few hundred metres apart. The thousands of so base stations in the so many countries.

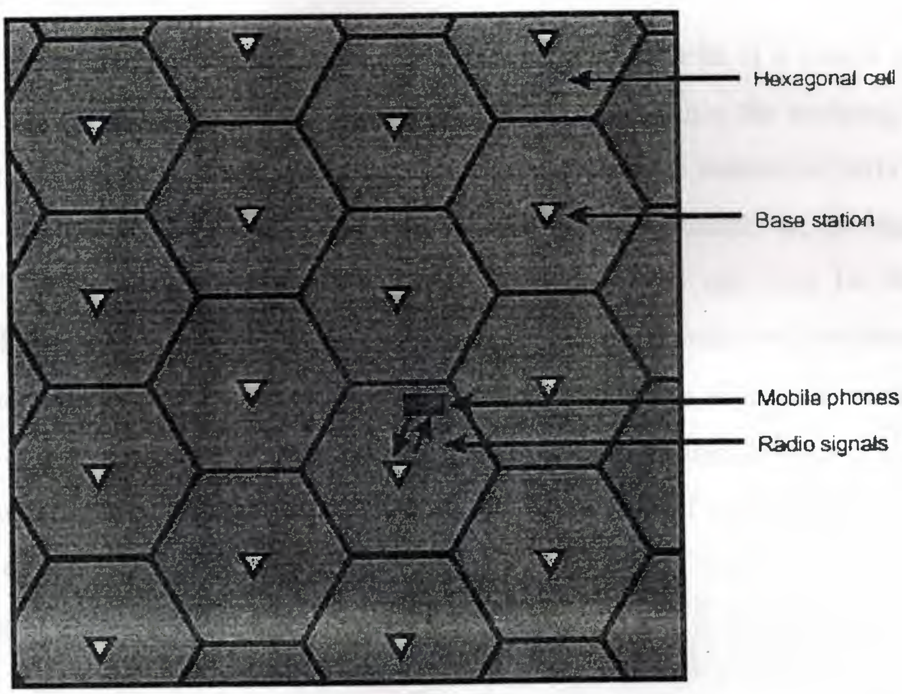

Figure 2.1 Network of base stations at the centre of hexagonal cells

2.2 Cellular Coverage

The major problems with radio distribution arise from electromagnetic wave propagation. The power of radio waves decreases with the inverse of the squared distance; however, it must be remembered that this applies only in empty space. As a consequence, propagation at ground level in an urban environment with different obstacles is more difficult, and varies typically with d-4.

A second problem is spectrum scarcity: the number of simultaneous radio communications supported by a base station is therefore limited.

Cellular coverage allows a high traffic density in a wide area despite both problems at the expense of infrastructure cost and of complexity. Because of the limited transmission range of the terminals, cellular system is based on a large number of receptions and transmission devices on the infrastructure side (the base stations).

2.3 Cluster

The cells are grouped into clusters. The number of cells in a cluster must be determined so that the cluster can be repeated continuously within the covering area of an operator. The typical clusters contain 4, 7, 12 or 21 cells. The number of cells in each cluster is very important. The smaller the number of cells per cluster is, the bigger the number of channels per cell will be. The capacity of each cell will be therefore increased. However a balance must be maintained in order to avoid the interference that could occur between neighbouring clusters. This interference is produced by the small size of the clusters (the size of the cluster is defined by the number of cells per cluster). The total number of channels per cell depends on the number of available channels and the type of cluster used. There are following types of cells: Macrocells, Microcells, selective cells, and umbrella cells.

Macrocells: The macrocells are large cells for remote and sparsely populated areas.

Microcells: These cells are used for densely populated areas. By splitting the existing areas into smaller cells, the number of channels available are increased as well as the capacity of the cells. The power level of the transmitters used in these cells is then decreased, reducing the possibility of interference between neighbouring cells.

2.3.1 Selective cells

It is not always useful to define a cell with a full coverage of 360 degrees. In some cases, cells with a particular shape and coverage are needed. These cells are called selective cells. A typical example of selective cells is the cells that may be located at the entrances of tunnels where coverage of 360 degrees is not needed. In this case, a selective cell with coverage of 120 degrees is used.

2.3.2 Umbrella cells

A freeway crossing of very small cells produces an important number of handovers among the different small neighbouring cells. In order to solve this problem, the concept of umbrella cells is introduced. An umbrella cell covers several microcells. The power level inside an umbrella cell is increased comparing to the power levels used in the microcells that form the umbrella cell. When the speed of the mobile is too high, the mobile is handed off to the umbrella cell. The mobile will then stay longer in the same cell (in this case the umbrella cells). This will reduce the number of handovers and the work of the network.

The cells are often represented by hexagons, in order to model the system by paving the plane with a single geometrical figure. Hexagons nicely pave the plane without overlapping and arc commonly used for calculating theoretical frequency reuse in cellular system.

At the centre of each hexagonal cell is a base station consisting primarily of a power source, computer-processing devices, and a base antenna. Each of the seven base stations in the diagram operates on a different frequency, denoted by Fl, F2 . . . F7. In the Global System of Mobile Communication (GSM), the design was aimed at the beginning at medium-sized cells, of a diameter expressed in kilometres or tens of kilometres. Yet, the lower boundary is difficult to determine; cells of more than one kilometre radius should be no problem. Whereas the system may not be fully suitable to cells with a radius below, say 300 meters. One source of limitation is more economics than due to physical laws. The efficiency of the system decreases when cell size is reduced and then the ratio between the expenditure and the traffic increases, and eventually reaches a point where economical considerations call for a halt. Another important point is the capacity of the system to move communication from one cell to another rapidly, and GSM requires longer a time to prepare such a transfer to cope with fast moving users in very small cells. The cell size upper bound is more obvious: a first, non-absolute, limitation in GSM is a range of 35 kilometres. Cells of bigger sizes are possible but require specially designed cell-site equipment and incur some loss in terms of maximum capacity. The number of sites to cover a given area with a given high traffic density, and hence the cost of the infrastructure, is determined directly by the reuse factor and the number of traffic channels that can be-extracted from the available spectrum. These two factors are compounded in what is called the spectral efficiency of system seven cell configurations are used in industry, but so are 3 cell configurations, 4 cell configurations, 12 cell configurations, and even 21 cell configurations. Moreover even when a seven-cell configuration is employed, the signals from the individuals base stations do not span neat and clean hexagonal cells. Neat and clean coverage zones do not exists in the real world because, houses, buildings, and natural barriers together with unavoidable sources of RF interference create coverage regions that are shaped more like amoebas than circles or hexagonal cells.

2.4 Cellular Phone Technologies

2.4.1 TACS (Analogue)

The first cellular system employed in so amny countries was the analogue TACS (Total Access Communication System) for which the phones have a nominal output of 0.63 W . This system is being phased out so that the frequency channels it uses around 900 MHz may be allocated to more recent systems. It uses frequency modulation that results in only very small and essentially random changes in the amplitude of the carrier wave.

2.4.2 GSM (Digital)

Systems using the TACS standard have largely, although not entirely, been replaced by the European digital phone standard, GSM, the acronym for Global System for Mobile Communications and mostly operate in either the 900 MHz or 1800 MHz band. This standard is now widely used in many parts of the world. The digital processing uses phase modulation ~ that again results in only very small and essentially random changes in the amplitude of the carrier wave.

2.5 High Gain & Low Gain Antennas

The difference in the near and far field for an electric dipole antenna is illustrated in Figure 2.2 , which shows the directions in which most of the energy flows. (The electric field directions are in the plane of the paper and perpendicular to the

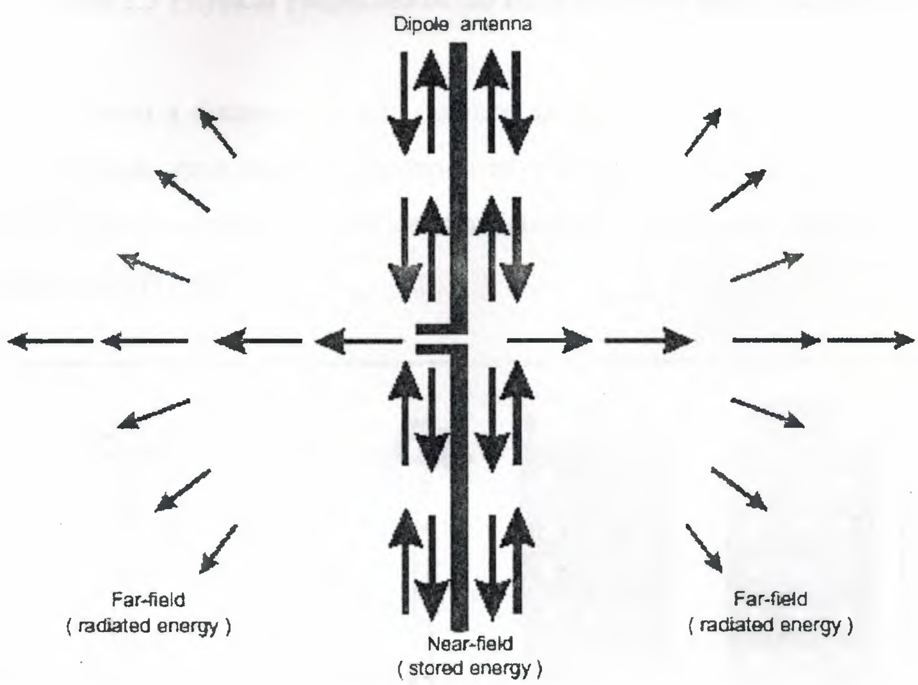

Figure 2.2 Near and Far Field Radiated Energy for a Dipole Antenna

directions of energy flow, while the magnetic field directions are perpendicular to the paper.) Far from the antenna, the energy flows outwards. However, near to the antenna, most of the energy is stored around the antenna, flowing to and from along its length, and only a small proportion is radiated outwards.

Because siting criteria for high- and low-gain antennas are different it is important to be able to tell them apart. Fortunately, the antennas look rather different (Figure 2.3)

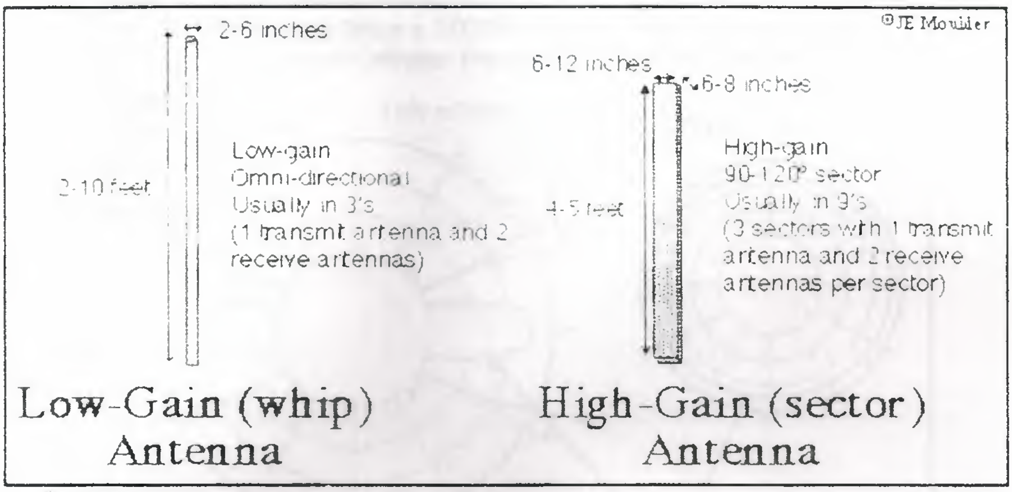

Figure 2.3 Physical Properties of the High and Low gain Antennas

Even from a distance the site (towers) for high- and low-gain antennas look different. When high- gain antennas are mounted on buildings, they may not be obvious, particularly if they are mounted to the sides of building, or more commonly to the sides of penthouses as in Figure 2.4

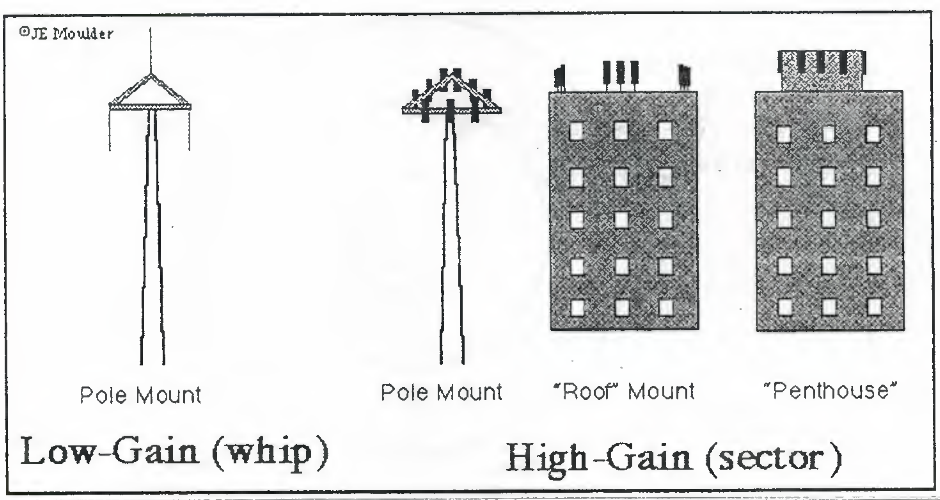

Figure 2.4 High and Low Gain Antenna used in Mobile Systems

2.6 RF Patterns For High Gain and Low Gain Antennas

The RF patterns for the two different types of antennas are very different for a low gain (whip) antenna of the type used by most cell

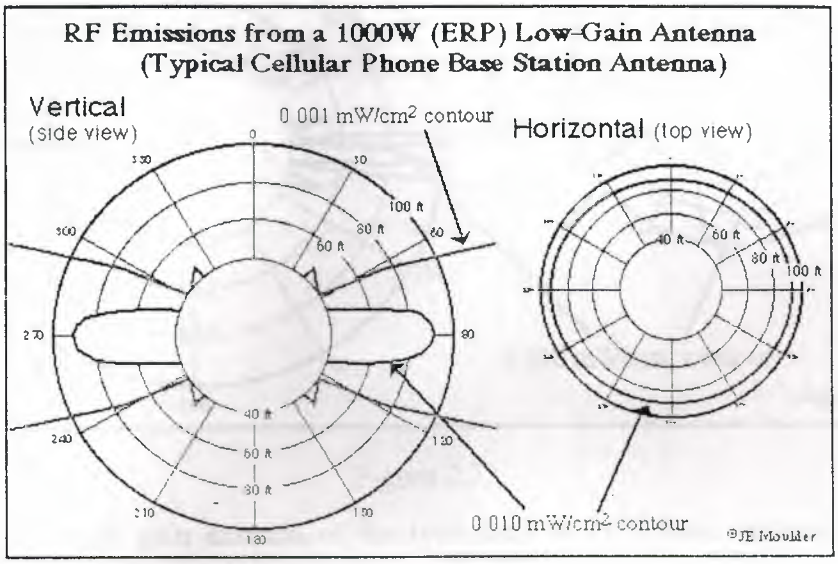

Figure 2.5

phone base stations, the patterns looks like in the Figure 2.5. Very close to the low gain antenna the power density around an antenna looks like Figure 2.6

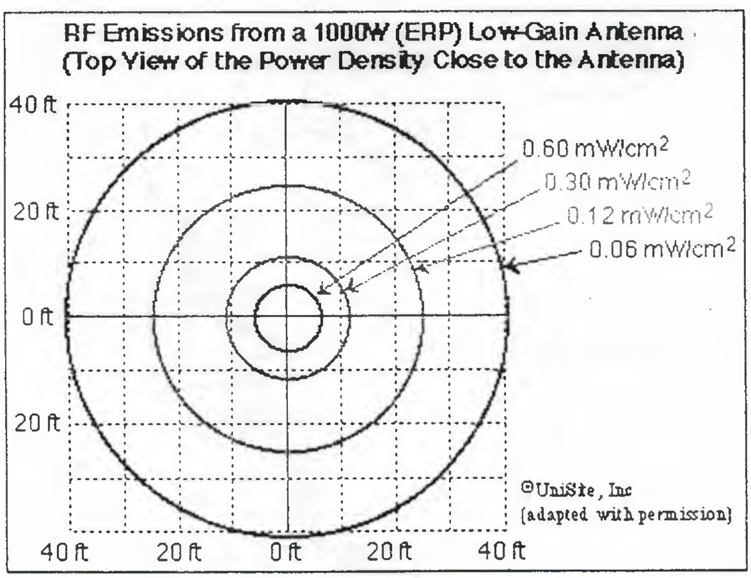

Figure 2.6

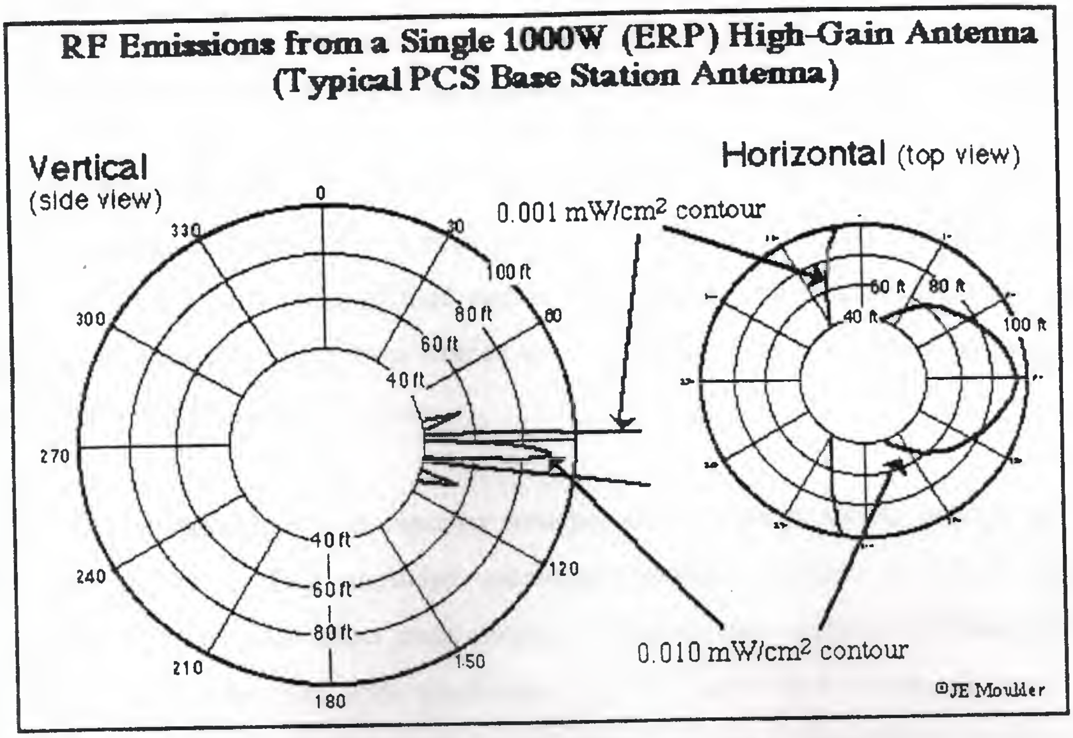

Figure 2.7

For a high gain antenna of the type used in PCS base stations, the pattern looks like Figure 2.7 Very close to a single high-gain antenna (in what is technically known as the "near field"), the power density around an antenna looks like Figure 2.8

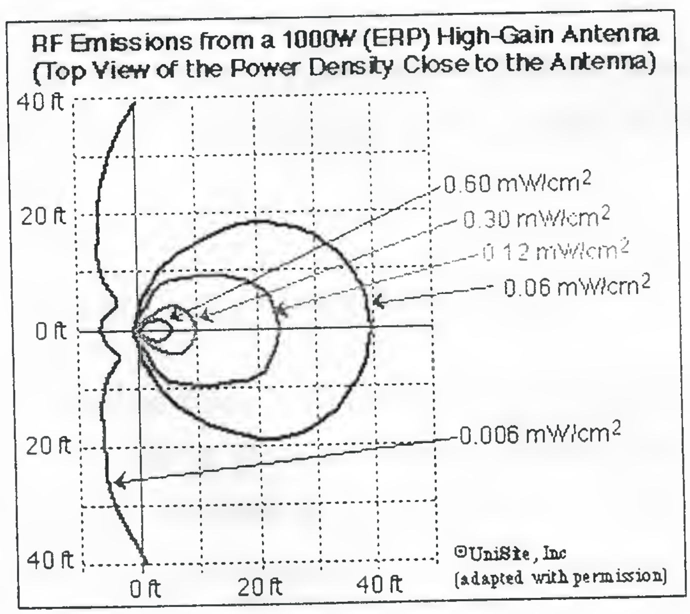

Figure 2.8

3. Effects of EMF on Human Health

3.1 Possible Effects of EMF on People

There is a type of research called epidemiology, The study of patterns and possible causes of diseases in human populations. Epidemiologists study short-term epidemics such as outbreaks of food poisoning and long-term diseases such as cancer and heart disease. Results of these studies are reported in terms of statistical associations between various factors and disease.

The challenge is to discover whether the statistical results indicate a true causal association. This includes assessing possible effects of other factors "confounders" that could affect study results. A "statistically significant" finding is one in which researchers are 95% confidants that an association exists. However, a statistically significant finding does not necessarily prove a cause-effect association. Usually, supplemental data are needed from studies of laboratory animals before scientists can conclude that a given factor is a cause of disease.

The language of epidemiology can appear, to the uninitiated, more precise than it actually is. An odds ratio estimate. Epidemiologists must calculate, along with the odd ratio, the range over which they are confident that this estimate is reliable. Sample size is a key factor in this calculation and the smaller the sample, the less reliable the information.

3.2 Studies of Cancer in People Living Near Power Lines

To date, 14 studies have analysed a possible association between proximity to power lines and various types of childhood cancer. Of these, eight have reported positive associations between proximity to power lines and some form(s) of cancer. Four of the 14 studies showed a statistically significant association with leukemia.[5]

The first study to report an association between power lines and cancer was conducted in 1979 in Denver.. It was found that children who had died from cancer were

2 to 3 times more likely to have lived within 40 m (131 ft) of a high-current power line than were the other children studied. Exposure to magnetic fields was identified as a possible factor in this finding. Magnetic fields were not measured in the homes. Instead, the researchers devised a substitute method to estimate the magnetic fields produced by the power lines. The estimate was based on the size and number of power line wires and the distance between the power lines and the home. [5]

A second Denver study in 1988, and a 1991 study in Los Angeles, also found significant associations between living near high-current power lines and childhood cancer incidence. The L.A. study found an association with leukemia but did not look at all cancers. The 1988 Denver study found an association with all cancer incidences. When leukemia was analysed separately, the risk was elevated but not statistically significant in neither of these two studies were the associations found to be statistically significant when magnetic fields were measured in the home and used in the analysis. Studies in Sweden (1992) and Mexico (1993) have found increased leukemia incidence for children living near transmission lines. A 1993 Danish study, like the 1988 Denver studies, found an association for incidence of all childhood cancers but not specifically leukemia. A Finnish study found an association with central nervous system tumours in boys. Eight studies have examined risk of cancer for adults living near power lines. Of these, two found significant associations with cancer. The following chart summarises results from studies involving cancer in people living near power lines. [5]

Although often characterised this way, these diverse studies can't simply be "added up" to determine weight of evidence or to reach a conclusion about health effects because many types of studies are included in these lists. Also, many studies that reported no statistically significant elevations in risk did report elevated risks (above 1.00). The risks in some cases may not be reported as "significant' because of small sample sizes. For studies included as significant, some found only one or a few significant risks out of several that had been calculated. When many risks are calculated, some can be "significant" due to chance. It is also worth noting that studies, which report positive associations, tend to receive more publicity than do studies, which find no association. in late 1992, researchers in Sweden reported results of a study of cancer in people living near high-voltage transmission lines. The Swedish study generated a great deal of interest among scientists, the public, and the news media. Relative risk for leukemia increased in Swedish children who lived within 50 m (164 ft) of a transmission line. The risk was found also to increase progressively as the calculated average annual 50-Hz magnetic field increased in strength. However, the risk calculations were based on very small numbers of cases. Figure 3.1 and 3.2 shows some statistical and theoretical predictions about the effects of EMF on human health. **[4]**

How Epidemiologists Conduct Case-Control Studies

The Process

1. A list of people with a particular disease is assembled. These are the **cases**.

2. A list is assembled of people who similar to the cases, but who do not have the disease. These are the **controls**.

3. The numbers of cases and controls who were *previously* exposed to factor X are estimated. This is often one of the most difficult parts of the study because exposures have often occurred many years in the past.

4. The exposure ratio of the cases is compared to that of the controls. If the ratios are the same, there is no association between factor X and the disease. If the cases have a higher ratio, there is a **positive association**, and factor X *may* be the cause of the disease. If the cases have a lower exposure ratio than the controls, there is a **negative association**. This would suggest that factor X may help protect people from the disease.

Examples

Here are 2 examples of possible outcomes of a study of a potential risk factor X, based on 300 cancer cases and 300 controls:

If 71 cases were exposed to factor X and 229 were not exposed, the case exposure ratio = 71/229 = 0.31. If 71 controls were also exposed, the control exposure ratio is also 0.31. Dividing the case exposure ratio by the control ratio gives the **odds ratio (OR)**, sometimes called the **relative risk** (.031/.031 = 1.00). An "OR" of 1.00 means that the odds that the cases were exposed to factor X was the same as for the controls. Therefore, in this example, there is no association between factor X and cancer.

Now suppose that 110 of the total 300 cases were exposed (ratio = 110/190 = 0.58), and 71 controls were exposed (ratio = 0.31). The "OR" is 0.58/.031 = 1.87. If the "OR" is above 1.00, there is a positive association between factor X and the disease. In this example, people exposed to factor X had an 87% increased risk of having cancer.

Figure 3.1

The Swedish researchers concluded that their study provides additional evidence for a possible link between magnetic fields and childhood leukemia. However, scientists have expressed differing opinions about this study. Some scientists believe the study is important because it is based on magnetic held levels presumed to have existed around the time the cancers were diagnosed. Others are skeptical because of the small numbers of cancer cases and because no cancer association was seen with present-day magnetic field levels measured in the home. [4]

Summary of Residential Power-Line Cancer Studies			
Study	Location	Leukemia	Other Cancers
Child Cancer Studies:			
Werthheimer & Leeper '79	Denver	OR=2.35*	All Cancer OR=2.22*
Fulton et al. '80	Rhode Island	OR=1.09	Not Studied
Tomenius '86	Sweden	OR=.030	CNS Tumors OR=3.70*
Savitz et al. '88	Denver	OR=1.54	All Cancer OR=1.53*
Coleman et al. '89	U.K.	OR=1.50	Not Studied
Lin & Lu '89	Taiwan	OR=1.31	All Cancer OR=1.30
Myers et al. '90	U.K.	OR=1.14	All Cancer OR=0.98
London et al. '91	Los Angeles	OR=2.15*	Not Studied
Lowenthal et al. '91	Australia	O/E=2.00	
Feychting & Ahlbom '93	Sweden	OR=3.80*	All Cancer OR=1.30
Olsen et al. '93	Denmark	OR=1.50	All Cancer OR=5.60*
Petridou et al. '93	Greece	OR=1.19	Not Studied
Verkasalo '93	Finland	SIR=1.60	All Cancer SIR=1.50
Fajardo-Gutierrez et al. '93	Mexico	OR=2.63*	Not Studied
Adult Cancer Studies:			
Wertheimer & Leeper '82	Denver	OR=1.00	All Cancer OR=1.28*
McDowell '86	U.K.	SMR=143	Lung Cancer SMR=215
Severson et al. '88	Seattle	OR=0.80	Not Studied
Coleman et al. '89	U.K.	OR=0.90	Not Studied
Youngson et al. '91	U.K.	OR=1.29	
Eriksson & Karlsson '92	Sweden	Not Studied	Multiple Myeloma OR=0.94
Feychting & Ahlbom '92	Sweden	OR=1.00	Leukemia Subtypes OR=1.70
Schreiber et al. '93	The Netherlands	No Cases	All Cancer SMR=85, Hodgkins Disease SMR=469

Note: This table is intended to summarize briefly some of the selected, often-cited results of the residential cancer studies.
OR = Odds Ratio. An OR of 1.00 means no increased or decreased risk.
SMR = Standardized Mortality Ratio. An SMR of 100 means no increased or decreased risk.
SIR = Standardized Incidence Ratio. An SIR of 1.00 means no increased or decreased risk.
CNS = Central Nervous System
O/E = Observed number of cases divided by the expected number of cases.
*** = The number is statistically significant (greater than expected by chance).**

Figure 3.2

Information on adult cancer incidence was also collected and analysed in the Swedish study. Researchers reported in 1994 that adults with the highest cumulative exposure (over 15 years) to power-line EMF were twice as likely to develop acute or chronic myeloid leukemia as were less exposed adults. Although the total number of cases was small, which made the results of borderline statistical significance, the study provides some evidence for an association between exposure to magnetic fields from power lines and acute and chronic myeloid leukemia in adults. [5]

3.3 High Cancer Rates and Electric Power Facilities

Scientists call unusual occurrences of cancer in an area or in time a "cancer cluster". In some cases, a cancer cluster has served as an early warning of a health hazard. For most reports of cancer clusters, however, the cause is never determined, or the perceived cluster is not really an unusual occurrence.

Concerns have been raised about seemingly high numbers of cancers in some neighbourhoods and schools close to electric power facilities. In recent years, three state health departments have studied apparent cancer clusters near electric power facilities. A Connecticut study involved five cases of brain and central nervous system cancers in people living near an electrical substation. The local rates for these types of cancer were found to be no different from statewide rates. Examination of cancer rates at various distances from the substation also failed to show evidence of clustering. In North Carolina, several cases of brain cancer were identified in part of a county that included an electric power generating plant. An investigation showed that brain cancer rates in the county, however, were actually lower than statewide rates. Among staff at an elementary school near transmission lines in California, 13 cancers of various types were identified. Although this was twice the expected rate, the state investigators concluded that the cancers could have occurred by chance alone [4].

3.4 Risks of Cancer to Electrical Workers

Several studies have reported increased cancer risks for jobs involving work around electrical equipment. To date, it is not clear whether these risks are caused by EMFs or by other factors. A report published in 1982 by Dr. Samuel Milham was one of the firsts to suggest that electrical workers have a higher risk of leukemia than do workers in other occupations. The Milham study was based on death certificates from Washington state and included workers in 10 occupations assumed to have elevated exposure to EMFs. A subsequent study by Milham, published in 1990, reported elevated levels of leukemia and lymphoma among workers in aluminum smelters, which use very large amounts of electrical power.

About 50 studies have now reported statistically significant increased risks for several types of cancer in occupational groups presumed to have elevated exposure to EMF. Relative risk levels in these studies are mostly less than 2, and the possible influence of other factors such as chemicals has not been ruled out. At least 30 other studies did not find any significant cancer risks in electrical workers. Most of the earlier occupational studies did not include actual measurements of EMF exposure on the job. Instead, they Used "electrical" job titles as indicators of assumed elevated exposure to EMF. Recent studies, however, have included extensive EMF exposure assessments.

A 1993 study of 36,000 electrical workers at a large utility in California found no consistent evidence of an association between measured magnetic fields and cancer. Some elevated risks for Iymphoma and leukemia were observed, but they were not statistically significant. A 1992 study of Swedish workers found an association between average EMF exposure and chronic Iymphocytic leukemia but not acute myeloid leukemia. There was some evidence of increasing risk with increasing exposure. The Floderus study also reported an increase in brain tumors among younger men whose work involved relatively high magnetic held exposure **[6]**.

Results of a major study of electrical workers in Canada and France were reported in early 1994. The research team, led by Dr. Gilles Theriault, looked at 4151 cancer cases in 223,292 workers from two utilities in Canada and one in France. Workers with more than the median cumulative magnetic field exposure (31mG) had a significantly higher (up to three times higher) risk of developing acute myeloid leukemia. Workers who had the greatest exposures to magnetic fields had twelve times the expected rate of astrocytomas (a type of brain tumor), but according to the authors, this finding "suffered from serious statistical limits" and was based on a small number of cases (five) in the highest exposure category. In the analysis of median cumulative magnetic field exposure, no significant elevated risks were found for the other 29 types of cancer studied **[6]**.

There were inconsistencies in results among the three utilities and no clear indication of a dose-response trend. The authors concluded, therefore, that their results did not provide definitive evidence that magnetic fields were the cause of the elevated risks found in leukemia and brain cancer. However, they observed as "noteworthy" the fact that despite the enormous number of analyses done, the only two types of cancer for which a significant association with EMF was found (leukemia and brain cancer) were among the three for which an association had been hypothesized, based on previous studies. [6]

In another major study involving more than 138,000 utility workers, the authors concluded that the results "do not support an association between occupational magnetic field exposure and leukemia, but do suggest a link to brain cancer." A later analysis reported an association between exposure to short bursts of extremely high magnetic fields and increased risk of lung cancer.

3.5 Risk of Breast Cancer

There is some epidemiological evidence for an association between EMF exposure and breast cancer, but studies have also reported evidence to the contrary. A 1994 study examined death records of female workers and found that women employed in electrical occupations were slightly more likely to have died of breast cancer than were other working women. However, because the study could not control for factors such diet, fertility, and family history (which are known to affect breast cancer risk), the results are considered to be preliminary, not conclusive. A 1994 Norwegian study reported an excess risk of breast cancer among female radio and telegraph operators aboard ships. A 1993 Danish study found no association between occupational EMF exposure and female breast cancer. Several studies have reported an increased risk of breast cancer among men employed in EMF-related occupations. However, the 1994 study of electrical workers in Canada and France reported no such association [6].

Several large-scale studies are now under way in the United States and in other countries to see if women living in homes with higher EMF exposures have an increased risk of developing breast cancer. The reason for the recent interest in EMF and breast cancer has less to do with epidemiology than with biology-laboratory evidence concerning the role of EMF and melatonin in the development and suppression of breast cancer.

3.6 Cancer Rates and Increased Use of Electricity

Not necessarily although use of electricity has increased greatly over the years (right), EMF exposures have probably not increased in the same way. Changes in the way that buildings are wired and in the way electrical appliances are made have in some cases resulted in lower magnetic field levels. Rates for various types of cancer have shown both increases and decreases through the years. For example, mortality rates (deaths) for the two most common cancers in children have decreased because of better treatment. Incidence rates (numbers of new cases), however, have tended to increase for unknown reasons. Reliable data on incidence rates only became available beginning in the early 1970s.) Incidence rates can reflect changes in exposures to various environmental agents, and they are also affected by changes in how cancers are diagnosed and reported **[8]**.

The effect of a major cancer risk factor, like smoking, is evident in the historic lung cancer rates. The possible effect of EMF would be mixed with those of many other factors having small or moderate risks to certain segments of the population. The individual contribution of these factors would be difficult to separate in the overall cancer rates.

3.7 Other Kind of Health Effects

Several Epidemiologic studies have looked for EMF effects on pregnancy outcomes and general health. Various EMF sources have been studied for possible association with miscarriage risk: power lines and substations, electric blankets and heated water beds, electric cable ceiling heat, and computer monitors or video display terminals (VDT). Some studies have correlated EMF exposure with higher than expected miscarriage rates; others have found no such correlation. Epidemiologic studies have revealed no evidence of an association between EMF exposure and birth defects in humans.

Several studies looked at the overall health of high-voltage electrical workers, and a few looked at the incidence of suicide or depression in people living near transmission lines. Results of these studies have been mixed. Some studies have also investigated the possibility that certain sensitive individuals may experience allergic-type reactions to EMF, known as "electrosensitivity."

One preliminary report released in 1994 has suggested a possible link between occupational EMF exposure and increased incidence of Alzheimer's disease. This study also found a higher incidence of Alzheimer's disease among tailors and dressmakers. At the time this booklet was produced, the research related to Alzbeimer's had not been peer-reviewed or published.

3.8 Biological Studies

If exposure is sufficiently intense, radiowaves can cause biological effects. Possible injuries include cataracts, skin hums, deep burns, heat exhaustion and heat stroke. Most, if not all, of the known biological effects from exposure to high-power radiofrequency sources are due to heating. The effects of this heating range from behavioural changes to eye damage (cataracts). Except possibly within a few feet of the antennas themselves, the power produced by cellular phone and PCS base station antennas is too low to cause heating.

There have been scattered reports of effects that do not appear to be due to heating, the so-called non-thermal effects. None of these effects have been independently replicated and none have any obvious connections to human health risks.

3.9 Effects of EMF Reported in Laboratory Studies

Several kinds of biological effects have been reported in studies of electric and/or magnetic fields. A biological effect is a measurable change in some biological factor. It may or may not have any bearing on health. Overall, effects attributed to EMF have been small and difficult to reproduce. Very specific laboratory conditions are usually needed for effects of EMF to be detected. It is not known how EMF actually causes these effects. Laboratory studies to date have not answered questions about possible human health effects. These studies are, however, providing clues about how EMF interacts with basic biological processes. The cell membrane may be an important site of interaction with induced currents from EMF. Keep in mind that some of these effects are within the "normal" range of variation. A biological response to a particular stimulus does not necessarily result in a negative health effect [9].

3.10 Effects of EMF on the Hormone Melatonin

Melatonin is a hormone produced mainly at night by the pineal, a small gland in the brain. One reason scientists are interested in melatonin is that it could help explain results of some EMF epidemiological studies. Melatonin has been reported to slow the growth of some cancer cells, including breast cancer cells, in laboratory experiments. If power frequency EMF can affect melatonin in humans, this could be a mechanism to explain results of some EMF studies of breast cancer.

In the 1980s, scientists found that in rats exposed to 60-Hz electric fields, night time melatonin levels were reduced. Other studies have since reported that both AC and DC magnetic fields can also affect melatonin levels in rats and hamsters. These experiments are very delicate and depend on a combination of factors such as age of the animals and length of day. Melatonin levels were not affected in sheep raised for nearly a year in the EMF directly beneath a 500-kV transmission line. Experiments with baboons also showed no changes in melatonin. The Midwest Research Institute (MRI) has studied the effect of 60-Hz magnetic field exposure on human melatonin. In 1993

MRI reported that although subjects showed no effect on the average, those individuals with naturally lower levels of melatonin did show a small further decrease. However, in 1994 MRI reported that a second study, specifically designed to replicate the earlier results, found no such effect [6].

3.11 Cellular Phone Antennas and Human Health

The consensus of the scientific community is that the power from these base station antennas is far too low to produce health hazards as long as people are kept away from direct access to the antennas. There are some reasons to be concerned about human health effects from the handheld cellular and PCS phones them (although it is not certain that any risks to human health actually exist). These concerns exist because the antennas of these phones can deliver large amounts of radiofrequency energy to very small areas of the user's body. Base station antennas do not create such "hot spots", so the potential safety issues concerning the phones have no real applicability to the base station antennas. There are many technical differences between cell phones, PCS phones, and the types of "cell" phones used in different counties, but for evaluation of possible health hazards, the only distinction that matters is that they operate at slightly different frequencies. Humans may absorb the radiowaves from some base stations somewhat more than the radiowaves from other types of base stations. However, once the energy is absorbed the effects are the same. The radiowaves from some antennas particularly FM and VHF-TV broadcast antennas are absorbed more by individuals. This is more than the radiowaves from other sources (such as cellular phone or PCS base station antennas); but once the energy is absorbed the effects are basically the same. In addition, FM and TV antennas are 100 to 5000 times more powerful than base station antennas, but are mounted on much higher towers (typically 800 to 1200 ft).

Cellular and PCS phones and their base station antennas are radios, and produce radiofrequency (RF) radiation; that's how they work. This radiofrequency radiation is "non-ionising", and its biological effects are fundamentally different from the "ionising" radiation produced by x-ray machines.

3.12 Ionising and Non-Ionising Radiations

The electromagnetic spectrum in details is shown in figure 3.3 the interaction of biological material with an electromagnetic source depends on the frequency of the source. X-rays, radiowaves and "EMF" from power lines are all part of the electromagnetic spectrum, and the parts of the spectrum are characterised by their frequency.

Electric power in the US is at 60 Hz AM radio has a frequency of around 1 MHz, FM radio has a frequency of around 100 MHz, microwave ovens have a frequency of 2450 MHz, and X-rays have frequencies above one million MHz. Cellular phones operate at 860-900 MHz, and PCS phones operate at 1800-2200 MHz.

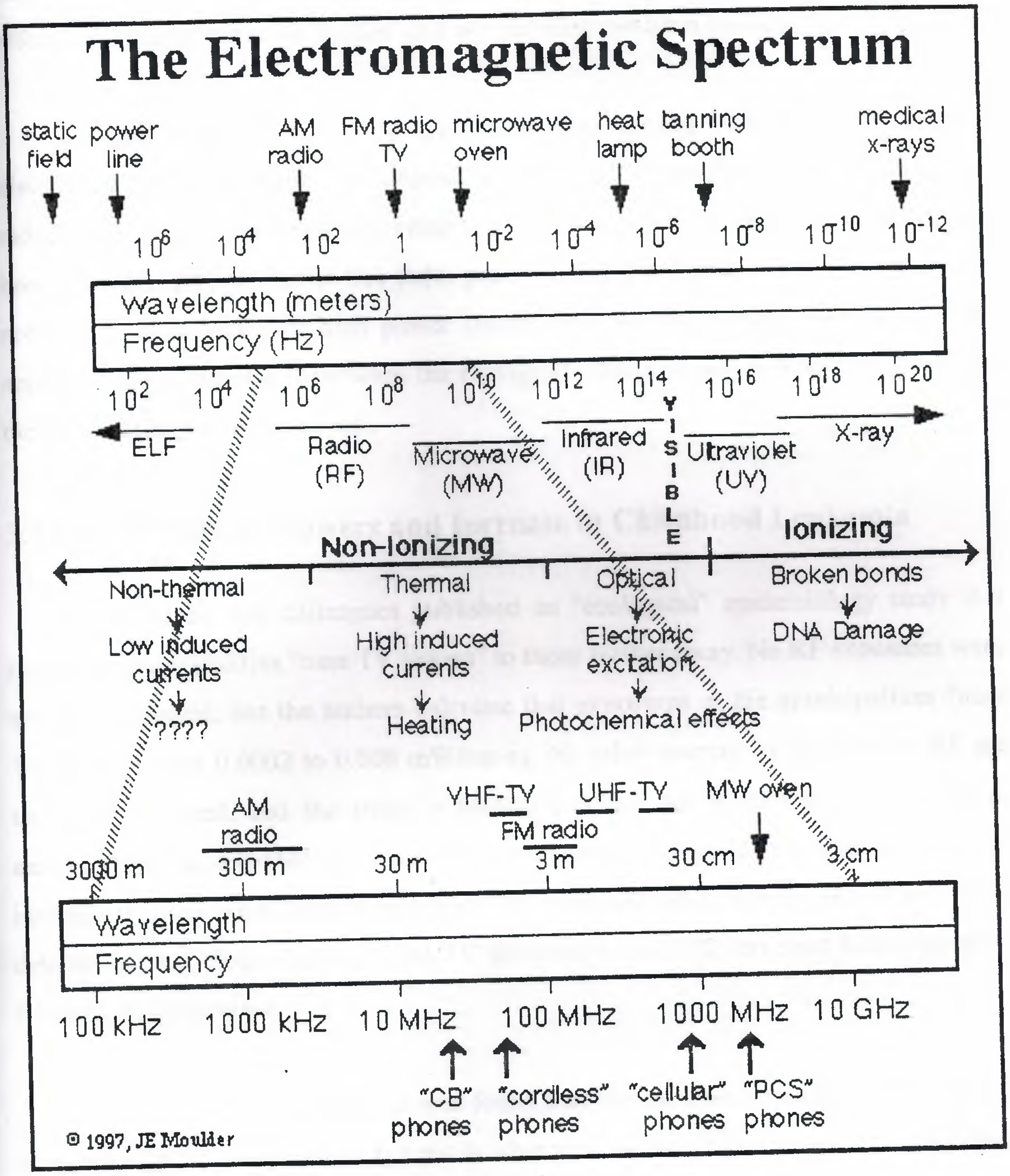

Figure 3.3

At the extremely high frequencies characteristic of X-rays, electromagnetic particles have sufficient energy to break chemical bonds (ionisation). This is how X-rays damage the genetic material of cells, potentially leading to cancer or birth defects. At lower frequencies, such as radiowaves, the energy of the particles is much too low to break chemical bonds. Thus radiowaves are "non-ionising". Because non-ionising radiation cannot break chemical bonds, there is no similarity between the biological effects of ionising radiation (x-rays) and non-ionising radiation (radiowaves).

Power lines produce no significant non-ionising radiation, they produce electric and magnetic fields. In contrast to non-ionising radiation, these fields do not radiate energy into space, and they cease to exist when power is turned off. It is not clear how, or even whether, power line fields produce biological effects; but if they do, it is not in the same way that high power radiowaves produce biological effects. There appears to be no similarity between the biological effects of power line "EMF" and the biological effects of radiowaves.

3.13 TV Broadcast Towers and Increase in Childhood Leukemia

Hocking and colleagues published an "ecological" epidemiology study that compares municipalities "near TV towers" to those further away. No RF exposures were actually measured, but the authors calculate that exposures in the municipalities "near TV towers" were 0.0002 to 0.008 mW/cm-sq. No other sources of exposure to RF are taken into account, and the study is based on only a single metropolitan area. The authors report an elevated incidence of total leukemia and childhood leukemia, but no increase in total brain tumour incidence or childhood brain tumour incidence. More detailed epidemiology studies of FM/TV antennas in the U.K. have not found evidence for a cancer connection

In a research at 1998 it was found that the increased childhood leukemia in one area near the TV antennas, but not in other similar areas near the same TV antennas; and they found no significant correlation between RF exposure and the rate of childhood leukemia. They also found that much of the "excess childhood leukemia" reported by Hocking et al occurred before high-power 24-hour TV broadcasting had started. This replication study, plus the failure to find any effect in the larger UK studies, suggests that correlation reported by Hocking et al was an artefact [7].

RF exposure is associated with mutations, birth defect, and cancer. This review is based largely on what the author admits to be "non-peer-reviewed sources", most of which are stated to be "incomplete" and to lack "reliable dose estimates". The author further states "no systematic effort to include negative reports is made; thus this review has a positive reporting bias".

3.14 RF Exposure from Base Stations

Dr. Henry Lai (Department of Bioengineering, University of Washington, Seattle) has claimed at meetings that "low intensity" RF radiation has effects on the nervous system of rats. Dr. Lai has further claimed at meetings that there are published studies showing that RF radiation can produce "health effects" at "very low field" intensities.

Dr. Lai's own research has no obvious relevance to the safety of cell phone base stations since most of his studies were conducted with RF radiation intensities far above those that would be encountered near base stations. In general, Dr. Lai's studies were done with at a power density of 1 mW/cm-sq and an SAR of 0.6 W/kg. This RF radiation intensity is over 100 times greater than that would be encountered in publicly-accessible areas near FCC-compliant base stations, and substantially exceeds the SAR limit that forms the basis of the FCC and ANSI safety guidelines for public exposure.

The statistical significance of the "effects" reported in two other studies are also open to question, as the effects reported are very small and appear in only some experiments. Several of the studies use RF radiation intensities that substantially exceed anything that would be found in public areas near a FCC-compliant base station.

Although the public's principle health concern about cell phone and PCS base station antennas appears to be the possibility of a cancer connection, other health related issues come up periodically. Particularly common are questions about interference with heart pacemakers **[6]**.

3.15 Effects on Medical Devices

There is no evidence that cellular phone or PCS base station antennas will interfere with cardiac pacemakers or other implanted medical devices as long as exposure levels are kept within the ANSI standard for uncontrolled exposure. It is possible that PCS phones themselves might interfere with pacemakers if the antenna is placed directly over the pacemaker. This problem is reported to occur with only some types of PCS phones and some types of pacemakers [6]

3.16 Effects on Nervous System

There are anecdotal reports that cell phones cause headaches, and there have been no serious epidemiological studies of the issue, and there are no real biophysical or physiological bases for expecting a connection [6].

3.17 Physiological Changes in People

An experiment on volunteers using a 2 W GSM cell phone for 35 minutes showed a 5-10 mm Hg rise in blood pressure. The study is small and was not blinded, and a rise in blood pressure of this magnitude has no known health consequences. Meanwhile it was reported that cell phones could alter the electrical activity of the brain. However, the effect may be an artefact caused by RF interference with the EEG leads. In 1999, another experiment reported that exposure of human volunteers to cell phone RE radiation might decrease reaction times.

3.18 Risk of Cancer Due to Radiowaves Exposure

Even at high levels of exposure, there is no substantial evidence that radiowaves can either cause or contribute to cancer. Although research in this area has been extensive, there is no replicated laboratory or epidemiological evidence that radiowaves at the power levels associated with public exposure to radiowaves from cellular phone and PCS base station antennas are associated with cancer.

There are two recent laboratory reports that RF exposure might produce cancer, or cancer-related injuries in animals. Both studies use RF levels far above those found in publicly accessible area near base station antennas, and neither study has been replicated. The epidemiological studies of RF show no consistent association with total cancer, or with any specific type of cancer.

3.19 Miscarriages or Birth Defects

Exposure to levels of radiowaves sufficient to cause whole body heating can cause miscarriages or birth defects. The power produced by cellular phone and PCS base station antennas is far too low to cause such heating. There is no laboratory or epidemiological evidence at all that radiowaves at the power levels associated with public exposure to radiowaves from cellular phone and PCS base station antennas are associated with miscarriages or birth defects.

3.20 Comparison of Modulated and Continuous Wave Radiation

It has been suggested that amplitude-modulated (AM) RF radiation might have different effects than continuous-wave (CW, unmodulated) RF radiation. This could be important, since cell and PCS phones and base stations produce a modulated signal, and much of the research has been done with unmodulated RF sources. This issue had been reviewed and concluded that:

"The literature relevant to the possible biological effects of AM radiofrequency radiation consists of scattered observations using a wide variety of experimental models and exposure parameters... Several studies have reported findings consistent with effects on the nervous system and cancer-related biological processes. However, the methods and exposure parameters vary widely, and no independent replications of the positive finds have been reported. The results available today fail to support the existence of well-defined modulation-specific bioeffects from exposure to radiofrequency radiation."

4. Health Risks & EMF

The scientific evidence suggesting that EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed [6].

The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real-life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other fat tor or common source of error could explain these findings. However, no consistent explanation other than exposure to EMF has been identified.

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 EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to EMF, but it cannot completely discount the epidemiological findings [6].

The NIEHS (National Institute of Environmental Health Sciences and National Institutes of health) in USA concludes that EMF exposure cannot be recognised as entirely safe because of weak scientific evidence that exposure my pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. This is described in greater detail in the section, Recommended Actions. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern [9].

4.1 Scientific Evidences

4.1.1 Background on the Limitations of Epidemiology Studies

Epidemiological studies are used to investigate the associations between health effects and exposure to a presumed disease agent. A well-designed and conducted epidemiological study involves several steps including identification of a study population, definition of the exposure to be studied, choice of the type of study to conduct (e.g. cohort study versus case-control study) and description of the period over which the exposure is relevant. All of these factors influence the quality of a study and the limits that must be placed on interpretation of a study's findings.

In carefully controlled laboratory and clinical investigations, study subjects are typically assigned to a treatment or exposure regimen. In epidemiological investigations, the inability to randomly assign exposures means that investigators must design their study so that the individuals who develop the disease of interest (cases) resemble the individuals who are disease-free (controls) in all aspects except for exposure; this is intended to limit possible bias. Bias due to improper selection of cases and controls is introduced if exposure is related to characteristics that would make cases more or less likely to be sampled than controls, or once sampled, to participate [12].

In the Nordic countries, comprehensive national population registries are generally used for selecting controls. If all persons are listed in these population registries and participation rates are high, bias doe to selection of improper controls is unlikely even if exposure is related to participation. In countries such as the United States where population registries do not exist, other methods must be used to study rare diseases like leukemia for which existing cohort studies are inadequate. These methods lead to difficulties in identifying, contacting and recruiting controls that match the cases in all aspects other than exposure. For example, controls are sometimes identified through stratified random sampling of individual telephone numbers (random-digit dialling). Random-digit dialling may not properly identify controls of low socioeconomic status that do not have telephones; this could bias the results found in studies of childhood leukemias **[12]**.

Epidemiological studies have used various methods for estimating past EMF exposure to provide scientific evidence concerning the possibility of health effects from exposure to EMF. Residential exposures to EMF have been conducted in five basic ways: wire codes that are essentially based upon distance to major structures used for delivering electrical energy (eg. high tension power lines and transformers) ; calculated magnetic fields that are based upon a theoretical calculation of the magnetic field emitted by certain types of power lines using historical electrical loads on those lines; spot measurements that generally give a single, instantaneous measurement of the magnitude of the magnetic field in one or more spots in a residence; average measured fields that are essentially spot measurements taken repeatedly every few seconds for 24 hours and averaged over time; and personal average measured fields where the subject wears a monitor and measurements are taken repeatedly every few seconds for 48 hours and averaged over time.

The validity of individual exposure assessment methods has been examined and each has its limitations. Wire codes and calculated fields have the advantage of remaining fairly consistent over time making them more likely to be correctly determined during the time of cancer onset. However, their main disadvantage over measured fields is a lack of consideration of all possible sources of exposure, in particular fields from in-home appliances and ground currents. The relationship of wire codes to direct magnetic field measurements has been examined; the reliability of wire codes as a quantitative measure of magnetic field exposure is variable.

4.2 Childhood Cancers

The hypothesis generated by the seminal study used wire codes to evaluate residential exposures in children. Four additional epidemiological studies in which wire codes were used to assess exposure to EMF are of sufficient quality to be used in the evaluation of a causal association between the risk of childhood leukemia and exposure to magnetic fields. Two of the studies reported an association, and two studies reported no association with the risk for childhood leukemia. A trend of increasing risk with wire codes classification implying increased fields was observed in the two positive studies. All of these studies, including the seminal study, could have been affected by the types of biases described earlier including exposure bias, control selection, and confounding from other risk factors. In addition, the seminal study and the four subsequent studies differed in their groupings of leukemias ranging from evaluating all types of leukemias to evaluating only acute lymphoblastic leukemia, the most common form of the disease in children. The most recent U.S. study is the largest of the four subsequent studies for evaluating EMF exposure. Even though this study shows a negative association when comparing codes with leukemia risks, when combined with the remaining studies in a meta-analysis (a form of statistical analysis in which like studies are combined to get a single answer), the results indicate a marginal association for the highest exposure group versus the lowest exposure groups [3]. Removal of any of the three remaining studies diminishes this association substantially. After removal of the one follow-up study with the most severe design limitations, the association is no longer present. Another study was not included in the meta-analysis due to study limitations; this study showed no effect of wire codes.

Four epidemiological studies assessed exposure using calculated fields; all four studies were conducted in Nordic countries. Three of the studies observed an increased leukemia risk in one or more exposure group although only one achieved statistical significance. All four studies were population-based, with minimal potential for selection bias both in terms of control selection and participation rates. The main limitations of all four studies are the small number of cases overall and the small number of cases and controls in the high exposure group. The general trend of these studies provides marginal support for a small, increased risk.

Four studies in which spot measurements were used to assess exposure to magnetic fields are clearly of greater quality than the remaining studies. Two of these studies observed increased risks of marginal significance in one or more exposure groups and the other two showed no risk. Overall, spot measurements do not show an appreciable excess risk for leukemia when the four studies are combined.

Four studies used 24-hour measured magnetic fields to assess exposure. The studies examined three different classifications of childhood leukemias: acute lymphocytic leukemia, acute leukemia and leukemia including nonlymphocytic leukemia. The results of three of the studies showed an increased risk for children in higher exposure class(es); in two studies there were no statistically significant differences, in the largest study only one experimental category out of many was statistically significant, and depending on the grouping, the fourth study achieved statistical significance [2]. The data reported for the largest study suggest an exposure-response relationship that the original authors did not consider important. The pattern of dose versus response in this study was considerably different from the pattern in the other two studies with multiple dose groups. The results of these studies, when combined, provide weak evidence for an association between exposure based on 24-hour measured magnetic fields and a small, increased incidence of childhood leukemia.

One study assessed exposure using 48-hour personal monitors that measured both magnetic fields and electric fields. Analyses were done for all childhood leukemias and separately for acute lymphocytic leukemia. The general trend in the data indicated a negative association for both magnetic fields (current or predicted two years prior to diagnosis) and electric fields. No statistically significant positive associations were observed. This study, using personal exposure meters, does not support an association between EMF exposure and childhood leukaemia [3].

Several of the same studies described earlier also looked at electrical appliance use and the risk of childhood leukemia. The results do not fit a coherent pattern. None of the individual epidemiological studies provides convincing evidence linking magnetic field exposure with childhood leukemia. Hence, in making an assessment, one must rely upon the evaluation of the data as a whole using expert judgment and the meta-analyses as a guide. The pattern of response, for some methods of measuring exposure, suggests a weak association between increasing exposure and increasing risk. The small number of cases in these studies makes it impossible to firmly demonstrate this association. This level of evidence, while weak, is still sufficient to warrant limited concern.

Two other childhood cancers have been sufficiently studied to warrant comment. Two early studies observed an increased risk of brain cancers using wire codes as the exposure measure. Later studies using wire codes, calculated fields and measured fields failed to support this finding [3]. The association between exposure to EMF and childhood lymphomas was considered in several epidemiological investigations. In all studies, the number of cases of lymphoma in the high exposure groups was too small for any reliable inference to be drawn. In general, these data do not support the concern that exposure to magnetic fields may increase the risk of brain cancers or lymphomas in children.

4.3 Adult Cancers

Epidemiological reports of diseases associated with occupational exposure to EMF preceded concerns about residential exposure. Reports of various health problems in high-voltage substations in the former USSR initially focused attention on electric fields. Initial studies in the United States led to over 100 epidemiological investigations of workplace exposure to EMF and various diseases. The early studies were based on workers in jobs assumed to entail exposure, and more recent studies used measured fields.

Recent studies evaluating the association between exposure to magnetic fields and chronic lymphocytic leukemia show mixed results. The two studies in the United States reported no association, but one used death certificates to identify the cases (chronic lymphocytic leukemia has a rather long survival time that can confound the diagnosis of the cases). On of the remaining studies indicated increased risk, which did not achieve statistical significance, and the two Scandinavian studies showed significantly elevated risks in one or more exposure groups. Both of the Scandinavian studies had consistently increasing risks with increasing exposure. Each of the e studies has its limitations and the limitations are different across studies, as are the designs and exposure assessment methods. Taken together, the studies provide weak evidence for an association between occupational exposure to magnetic fields and chronic lymphocytic leukemia.

The risks of adult cancer based on residential exposure to EMF have been evaluated in a number of studies. Risks of leukemia from residential exposures were evaluated in several recent studies [4]. The calculated field studies showed mixed results for the different sub-types of leukemia studied and for change in the definition of the exposure category. Specifically, when chronic Iymphocytic leukemias was examined separately (this was done in only two of the tudies) , the results were inconsistent with one study showing no increased risk and with the other showing fairly consistent dose-response with increasing cumulative exposure. The remaining studies, using wire codes and measured fields, demonstrated no increased risk. These data e inadequate for evaluating the association between exposure to EMF and leukemias. Specifically, for chronic lymphocytic leukemia, which demonstrated a weak association in the occupational studies, there are mixed results for adults in the residential studies.

The risk for leukemia associated with use of electrical appliances was also considered in two studies. These studies resulted in inconsistent findings and generally do not support an association between appliance use and increased leukemia risk [4].

Limited data are available on risks of male and female breast cancer associated with residential exposure to EMF. A small, non-significant association between use of electric blankets and the risk for breast cancer was observed in one, large U.S. study but not in another. Both found no evidence for an association with duration of exposure. Three studies, using exposure measured by calculated fields, identified no association between exposure to magnetic fields and the risk of breast cancer. These same scientists also looked at exposures to EMF and cancers of the central nervous system (such as brain cancers); no associations were found.

None of the associations between cancer and residential exposure to magnetic fields in adults were indicative of a positive association However, the specific adult cancer showing weak evidence of a positive association with occupational exposure to EMF, chronic lymphocytic leukemia, as inadequately studied in residential settings. It cannot, therefore, be conclude that there is no association.

4.4 Non-Cancer Findings in Humans

The relationship between spontaneous abortion and exposure to EMF has been considered in several studies. Recent occupation and residential studies were the focus of this assessment. In the first occupational study, no association was observed. In a second occupational study, a significant association was found with exposure to high EMF; however, the response rate was very poor, particularly among controls, which could have biased this result upward. Pregnancy loss was investigated in two residential cohort studies. In one study, an increased risk was observed in the highest exposure category but not in the intermediate category. In the other, no association was observed for any measure of exposure. In a carefully designed prospective study in the United States, no association was reported between measured fields (including personal exposure monitoring) and intrauterine growth, birth weight or gestational age [5].

Low birth weight, intrauterine growth retardation, preterm birth and congenital anomalies arising from the father's exposure were not associated with occupational exposures to EMF. The risk for congenital anomalies in relation to the mother's use of heated waterbeds and electric blankets around the time of conception was evaluated in three studies; no association was observed for heated waterbeds in any study, and inconsistent results were reported for electric blanket use.

The association between occupational exposure to EMF and Alzheimer's disease was considered in five studies. All five studies showed increases in one or more exposure groups with four studies showing statistically significant increases and one showing non-statistically significant increases. All of these studies suffer from design limitations that make it inappropriate to use them for addressing a causal association between EMF exposure and Alzheimer's disease. Two of these are based on diagnoses from death certificates (Alzheimer's disease is not consistently noted on death certificates). Two studies used different groups of cases and controls; some of the control groups included persons with other types of dementia, and proxy information was used to define the exposure of cases. The one remaining study was evaluated using data for twins and also suffered many limitations. These data are inadequate for interpreting the possibility of an association.

The association between exposure to magnetic fields and amyotrophic lateral sclerosis was assessed in three studies. One study showed an increased risk in the highest exposure group and the other two studies were negative. Adequate adjustment could not be made for known risk factors making these studies difficult to interpret. Suicide and depression were studied in three occupational epidemiological studies. These studies do not support an association with EMF exposure.

Two occupational studies assessed possible adverse cardiovascular outcomes that may result from exposure to magnetic fields. In the first study, a significant decrease in risk using a broadly defined cardiovascular grouping was observed. In the second, data from five utilities were examined. This study was motivated a priori by a biological hypothesis based on the results of human clinical studies on heart rate variability for increased numbers of deaths due to arrhythmia and acute myocardial infarct. Significant, exposure-dependent associations were reported. Lacking additional epidemiological studies to collaborate these results, these data are inconclusive regarding an association between cardiovascular disease and exposure to EMF.

Human clinical studies of EMF exposures were carried out mainly through three major research initiatives. These include a long series of studies of utility workers begun in the 1960s in the former USSR, human laboratory research conducted in the 1970s in Germany and the human laboratory research program started in 1982 at the Midwest Research Institute in the United States. Dedicated facilities for human exposure testing were designed and constructed in Australia, Canada, England, France, Germany, New Zealand, the Russian Federation and the United States. Research with human volunteers is currently under way in many of these facilities **[8]**.

A large number of clinical end-points were evaluated in these laboratories. Several effects reported at high exposures warrant little concern as health dangers such as hair standing on end in very strong electric fields and flickering visual sensations in very strong magnetic fields. However, a number of measurements potentially linked to health effects have been studied. The central nervous system was one of the first areas investigated as a potential site of interaction with EMF. Studies of changes in brain wave patterns (electroencephalography) during waking hours were generally negative showing little or no effect of EMF, especially in the range of power-line frequencies. Several studies showed decreased sleep and reduced sleep efficiency during EMF exposure. These studies all had deficiencies (e.g. disturbance of subjects by drawing blood and incomplete adaptation of study subjects to the laboratory environment) making them inconclusive. Changes in human pulse as a function of exposure to EMF fall into two categories: changes in the number of beats per minute (pulse rate) and changes in the variability of the electro-chemical signals going to the heart (heart-rate variability). Two research groups examined changes in pulse rate following exposure to EMF. All five clinical studies from the same laboratory showed a decrease in pulse rate in at least one exposure group; however, all exposures represented rather large, combined electric and magnetic fields (6 to 12 kV/m and 10 to 30 T, respectively). The remaining study was a field trial under a high-tension power line and no effect was observed. The biological mechanism is unknown, and the general effect is very small making it unlikely that this is a health risk at lower doses.

Few laboratories studied the effects of EMF on the immune system. Three studies investigated effects of EMF exposure on the immune system and all were negative. Finally, there have been a number of case reports of mood changes and hypersensitivity thought attributable to EMF exposure (manifested as physiological reactions, disturbed sleep, fatigue, headaches, loss of concentration, dizziness, eye strain and skin problems). These symptoms generally seem to be intermittent and difficult to study clinically. Several carefully designed studies were performed to evaluate the response of persons with these symptoms to EMF. In general, these studies were negative with the exception of one that reported an increased incidence of skin rashes in persons exposed to high ambient electric fields (>31 V/m) relative to control fields (< 10 V/m). These data are insufficient to support an association between EMF and hypersensitivity **[6]**.

4.5 Animal Cancer Data

Animal carcinogenicity studies are routinely used to identify environmental agents that may increase cancer risk in humans. Many areas of biological investigation are more efficiently studied in animal models than in human beings, because the agent can be studied invasively and under carefully controlled environmental conditions. The use of animal models in studying effects of EMF exposure is limited by two problems: extrapolation of experimental findings across species and extrapolation of laboratory exposure patterns to environmental exposure patterns. Animal carcinogenic studies of EMF were done at levels of exposure generally much higher and having greater uniformity in frequency and intensity than would appear in environmental settings. These experimental conditions were chosen to maximise the ability of a researcher to detect an effect, if one exists, for a clearly defined exposure **[9]**.

The laboratory data in animal models are inadequate to conclude that exposure to EMF alters the rate or pattern of cancer. There are some sporadic findings (including increased cancers) with no clear interpretation; however, it is noteworthy that these data provide no support for the reported epidemiological findings of increased risk for leukemia from EMF exposure.

Only a few lifetime bioassay studies have been performed for EMF exposure. These studies exposed large groups of animals generally for periods of up to two years at magnetic field intensities considerably higher than elevated residential exposures. No consistent effects of EMF exposure on cancer rates in bioassay animals were found. The most comprehensive study conducted through the National Toxicology Program used four exposure groups (control, 2, 200 and 1000 T continuous exposure for 18.5 hours per day and 1000 T intermittent exposure) and four gender/species groups. There were no exposure-related clinical findings for rats or mice. The two-year study found no evidence of carcinogenicity in female rats and male or female mice at any exposure level and equivocal evidence for carcinogenicity in male rats based upon an increased incidence of thyroid gland C-cell tumours.

A similar study was conducted in female rats where exposure to 60 Hz linearly polarized magnetic fields (control, 2, 20, 200 and 2000 μT continuous exposure) began in utero two days before birth and continued for 20 hours per day for two years. No consistent, exposure-related clinical findings or evidence of carcinogenic activity from 60 Hz magnetic fields were reported. In another study male and female rats were exposed to control, 500 or 5000 μT 50 Hz magnetic fields for 22.6 hours per day for two years. No differences in cancer rates between field-exposed and sham-exposed animals were found [7].

Epidemiological findings have suggested a possible association between magnetic field exposure and breast cancer in men or women. In addition, a hypothesis was proposed that magnetic field exposure might lower nocturnal melatonin levels that could increase risk for breast cancer. Animal studies using chemically induced mammary cancer followed by magnetic field promotion of carcinogenesis were undertaken to test whether mammary cancer was affected by EMF exposure.

Following an initial report that magnetic fields promoted mammary tumour development in rodents, a comprehensive series of studies on EMF exposure and mammary tumour initiation and promotion in the rodent model was conducted. In these studies, female Sprague-Dawley rats were used and cancer was initiated by intragastric administration of four weekly doses of dimethylbenz anthracene (DMBA) followed by promotion with 50 Hz magnetic fields, 24 hours per day for 13 weeks. One of the early studies in this series, where the data were subsequently examined histologically, provided evidence that magnetic fields of low flux density (100 μT) promoted fit, increased growth and size of mammary tumours but did not affect tumour incidence. The same laboratory repeated this work, and in additional studies testing different magnetic flux densities, examined the question of whether a dose-response relationship exists with field intensity. Over the range of 10 to 100 μT magnetic fields (50 Hz), a higher (not statistically significant) number of total tumours was found in the field-exposed groups. Magnetic field exposure was not associated with more tumours per tumour-bearing animal. Effects on tumour latency and size were not consistent across the studies [6].

The National Toxicology Program conducted similar studies. Animals were exposed to magnetic fields at both European frequency (50 Hz, 100 or 500 μT) and American frequency (60 Hz, 100 μT) 18.5 hours per day, seven days per week for 13 weeks following intragastric administration of four weekly doses of, DMBA as the initiator. There was no difference in size or incidence of mammary, gland tumours between control and exposed groups. However, the tumour incidence was high in all groups, and sensitivity was reduced for detecting a promoting effect of magnetic fields. The study was repeated at a lower dose of DMBA. Tumour incidence, latency and size, total number of tumours and number of tumours per tumour-bearing animal were not affected by magnetic field exposure; in the exposure groups there were slightly fewer total mammary neoplasms statistically significant than in controls. A 26-week study, where animals received a single initiating dose of DMBA, gave similar results there were significantly fewer tumours for the two exposed groups. However, the tumour incidence was high in all groups, and sensitivity was reduced for detecting promoting effects of magnetic fields. This collection of studies provides strong evidence of no effect of magnetic fields on the promotional development of mammary cancer [9].

Based upon some evidence from occupational and residential studies suggesting an increased risk for brain cancer with EMF exposure, several animal studies examined this question. Rodent models are relatively insensitive to the induction of brain cancer by chemicals, and as such, caution should be used in interpreting the findings from studies with EMF exposure. The lifetime studies in rodents demonstrated no effect of magnetic field exposure on brain cancer. In the large initiation/promotion leukemia study in female mice, discussed earlier), sections of the brain were prepared and reviewed for primary proliferative lesions. No evidence of an effect of magnetic field exposure on primary brain tumours was found.

4.6 Non-Cancer Health Effects in Experimental Animals

A number of non-cancer end-points were investigated for possible adverse effects of EMF exposure. In general, the experimental models used to study interactions with EMF have been guided by methods and end-points that were developed to assay the effects of other physical and chemical agents such as drugs. chemicals and ionising radiation.

The effects of EMF exposure on the immune system were investigated in multiple animal models including baboons and rodents, and there is no consistent evidence in experimental animals for effects from EMF exposure. Reports of effects in baboons were not confirmed when the study was repeated. Some studies had methodological difficulties making interpretation of the findings difficult. Other studies found no or inconsistent effects of EMF exposure on immune system indices and function.

Seven studies examined standard measurements of haematological and clinical chemistry indices following EMF exposure; several included a limited number of animals and were of short duration. These studies provide no evidence that exposure to EMF affects haematological or clinical chemistry parameters in rodents.

A variety of animal models including non-human primates, pigeons and rodents were exposed to high intensity electric or magnetic fields to study the behaviour and physiology of the nervous system. Detection of electric fields by animals is a well-established phenomenon, and the sensitivity thresholds for animals appear to be similar.

Various neuro-behavioural responses including avoidance and aversion and learning and performance were tested for effects from exposure to EMF. The data from studies including baboons and rodents suggest that exposure to strong electric fields can be perceived, but there is no evidence that these fields are harmful at environmental intensities. The addition of a magnetic field to the electric field appears to modulate the acute behavioural response of animals to perceptible electric fields.

Relatively little evidence is available for evaluating whether exposure to electric fields can affect performance of learned behaviour. The studies in baboons suggest that any effects are minimal. In contrast, exposure to magnetic fields was associated with several effects: adverse, beneficial or absent depending upon the task being performed and the timing of the magnetic field exposure. Studies in non-human primates with combined exposure to electric fields and magnetic fields detected no impact on operant performance.

Epidemiological studies have addressed the question of whether EMF exposure affects reproduction and development. Studies using avian species were conducted, but their relevance to mammalian systems is not clear. Studies examining teratogenic and reproductive end-points were also done in mammalian systems. An extensive evaluation of magnetic field exposure (control, 2, 200 and 1000 μT continuous exposure and 1000 μT intermittent exposure) on fetal development and reproductive toxicity in the rodent was conducted. There was no evidence of any maternal or fetal toxicity or malformation. A further study examined multi-generational reproductive toxicity using a continuous breeding experiment. The results suggested no evidence of altered reproductive performance or developmental toxicity in the rat [4].

One hypothesis that magnetic fields acting through the retina as a sensitive receptor reduce melatonin levels. It was thought that this depression might act as a risk factor for cancer. Studies examining effects of EMF exposure on circulating melatonin levels were conducted in a variety of mammalian species. Overall, the experimental evidence is lacking in consistency and quality across the studies. The data in rodents is weak, but suggests that when effects do occur, the result is a decrease in melatonin concentration. There is no evidence for EMF effects on melatonin in sheep and baboons. These findings parallel those reported from clinical investigations in humans and population studies.

Long-term exposure to electric fields decreases melatonin concentrations slightly in rats; the biological significance of this effect is not understood. In a series of studies of acute magnetic field exposure in hamsters, a suppression of pineal and plasma melatonin levels reported in the earliest study was not replicated in later studies. Studies in rats with different magnetic field exposures, field intensities and times of exposure relative to the dark cycle have not shown consistent effects of magnetic fields on melatonin levels. Some laboratories reported that long-term exposure to magnetic fields in rats can reduce nocturnal pineal or blood concentrations of melatonin, but other laboratories did not find similar results. Interpretation of the findings from this large data set is complicated by variability across studies in confounding factors such as species, strain, gender, co-exposure to chemicals, field characteristics and measured outcomes. Long-term studies of EMF exposure in lambs and baboons showed no effects on melatonin levels.

4.7 Studies of Cellular Effects of EMF

The number of cellular components, processes and systems that can possibly be affected by EMF is large. Historically, testing of potentially toxic substances has relied on the use of carefully controlled in vitro experimental systems. In an attempt to identify potentially carcinogenic or toxic effects of an agent, these studies have typically exposed cells to the agent over a range of doses including levels above those encountered in the environment. Measurements are then made of cellular end-points as a means to detect alterations in processes such as differentiation, proliferation, gene expression and signal transudation pathways. This toxicological approach was applied to EMF in general through exposure of cultured cells over a range of dosef5. Because nothing is known about the potential mechanistic action of EMF on biological end-points, careful consideration must be given to the range over which the experimental doses of EMF is varied. The extrapolation of observed effects to lower field intensities may be inappropriate as EMF may have different mechanistic actions over different patterns of field intensity. Likewise, the actual agents responsible for the EMF "dose" to which individuals are exposed are not clear. Environmental EMF exposure is complex being composed of not only pure 60 Hz electric fields and magnetic fields, but also possibly transients (intermittent spikes and changes in the frequency of the field) and harmonics (multiples of the pure 60 Hz exposure: 120,180,240, etc.) [5].

The breadth of in vitro data on EMF produced over the last two decades is enormous. Many of these investigations were done using unique experimental protocols in single laboratories. A major focus was research that targeted examination of in vitro effects that might clarify potential mechanistic actions of EMF in order to explain reported epidemiological associations with magnetic fields. Because of the noted complexity of EMF exposures, efforts were also made to standardise the exposure systems used in these studies to allow for comparability of findings across laboratories. Through oversight by the DOE, on-site quality assurance evaluations were made of laboratories funded by this program. In addition, four regional EMF exposure facilities were established and made available for use by investigators.

Considerable progress was made in the area of in vitro research on EMF. Many of these studies of EMF exposure focused on end-points commonly associated with cancer. Convincing evidence for causing effects is only available for magnetic flux densities greater than 100 μT or internal electric field strengths greater than approximately 1 mV/m. To date, there is no generally accepted biophysical mechanism by which actions of lower intensity EMF exposures, including those reported to be of concern in epidemiological studies, might be explained [8].

Given the concern about whether EMF exposure is carcinogenic, considerable effort was undertaken to investigate whether EMF exposures can damage DNA or induce mutations. It has been generally believed that the energy associated with EMF is not sufficient to cause direct damage to DNA; however, it has been postulated that indirect effects might be possible by EMF altering processes within cells that could subsequently lead to changes in DNA structure. Overall, there was considerable variability in experimental design and methodology used in these studies resulting in no conclusive evidence that genotoxic effects result from EMF exposures. [9]

Studies also examined the potential cytogenetic effects of power-frequency sine wave or pulsed magnetic fields using model systems of human cells isolated directly from peripheral blood and amniotic fluid or cultured human lymphocytes and leukemia cells. Overall, the studies varied considerably, and in general, there is no evidence of chromosomal damage even when cells were exposed to relatively strong magnetic fields. Chromosomal aberrations were reported in one study using pulsed magnetic fields; however, the exposures tested were within the range of exposures reported in other studies to have no effect.

4.8 Biophysical Theory

The physics governing the interactions of EMF with matter were elucidated over a century ago and succinctly stated in the Maxwell equations. Years of successful application of these principles for practical advances have left little doubt about our ability to understand and predict electromagnetic biophysical phenomena when details of the system and fields are completely described. Given the complexity, dynamics and organisation in living organisms, it is difficult to apply this knowledge. Living organisms function through the use of biochemical and electrical signals carefully controlled by the organism' s structure. Early attempts to explain the biological effects of

EMF focused on simple application of electromagnetic theory to calculate the forces on biological molecules and the energies transferred to them by weak EMF. The extremely small magnitude of these interactions led many investigators to conclude that they would not occur at normally encountered field strengths. This has not fundamentally changed; calculations still strongly suggest that the small electric fields and magnetic fields associated with EMF in environmental settings cannot be expected to supply, by themselves, the energies necessary for chemical changes **[9]**.

The complexity and structure of biological systems make uniform application of these findings difficult. For example, even very small fields might act as control signals to modify processes that depend on metabolically supplied energy. This would be analogous to extremely weak radio signals, such as those transmitted over thousands of miles, that control locally supplied energy or power a loud-speaker or a large-screen television set. The exact nature of biological signal processing systems and their susceptibility to control by time-varying EMF is of continuing interest. Biological systems contain complex feedback loops and amplification sequences in which very small changes at one point may ultimately lead to very large changes further along the communication chain. In considering EMF changes on the nature of biological signals, it is essential to recognise that all aspects of a field (frequency, amplitude and pattern) may be involved. These considerations make definitive statements based upon biophysical theory difficult to apply to living organisms.

Several mechanisms for explaining EMF effects on biological systems have been proposed. One set of theories predicts effects of EMF on chemical reactions due to resonances that depend on complex interactions between constant and oscillating magnetic fields. There is limited experimental support for these theories; the validity of the assumptions used in the theories has been questioned.

Modification of the transfer of electrons from one molecule to another has also been suggested as a theoretical mechanism for the effects of EMF. However, the energies involved in electron binding are many orders of magnitude larger than those contained in weak, externally applied electric fields or magnetic fields making these theories difficult to accept. It is also possible that EMF could interact with magnetic particles in human cells. However, work with this theory would suggest that such effects can occur only with large magnetic fields are not applicable to the normal human environment; these conclusions may be premature.

Magnetic fields are capable of altering specific types (eg. radical pair formation) of chemical reactions. Potential effects of EMF have been predicted by analytical work. Such reaction effects have been shown for strong fields, but there are few studies of the effects in biological systems with moderate to low field intensities. Biochemical and biomechanical processes are generally dynamic. It has been suggested that rather than causing changes in the usual state of the system, EMF may induce slight changes in the frequency of events that trigger other processes, especially for effects on chemicals that associate within cells and between cells and their environments. Both theoretical and biological studies exist that support this suggestion. However, there is open debate about whether this phenomenon is applicable for EMF exposures that are generally found in the human environment [10].

All of the theories for biological effects of EMF suffer from a lack of detailed, quantitative knowledge about the processes to be modelled. Nevertheless, theoretical models are useful, even in the absence of critical data, because they can indicate what data are needed, suggest previously uncontemplated experiments, suggest bounds on risks under defined situations and provide nonlinear methods of analysis of critical data based upon presumed mechanisms. The current biophysical theories for EMF would suggest little possibility for biological effects below exposures of 100 μT. However, considering the complexity of biological systems and the limitations required by the assumptions used to mathematically model these theories, this finding has to be viewed with caution.

5. Mandatory Human Exposure Standards

There is a regulatory framework to limit exposure of the general public to radiofrequency electromagnetic radiation from radiocommunications and telecommunications transmitters. The framework includes introduction of a mandatory standard which establishes exposure limits in various prescribed circumstances. The framework also includes compliance arrangements for manufacturers and importers of specified radiocommunications and telecommunications devices to the marketplace and also licensed owners or operators of radiocommunication facilities [11].

The regulatory framework has been developed in recognition of the considerable community interest in the possibility of adverse health effects associated with the use of radiocommunications equipment such as mobile telephones, and the siting of mobile towers and other installations utilising radio frequencies. It is intended to support and complement other initiatives, for example activities of the EME Health Issues Committee, to address the possibility of adverse health effects from exposure to radiofrequency electromagnetic energy.

Standards are mandate to have the effect of setting limits to human exposure to radiofrequency electromagnetic radiation (RF EMR) from radiocommunications transmitters or receivers. Regulations are being developed internationally although different countries may use different legislative or administrative mechanisms to achieve the required exposure limitations.

Making the human exposure standard mandatory together with the accompanying compliance requirements will affect the operation of a wide range of radiocommunications and telecommunications devices and services.

These standard specifies the limits of exposure of all or part of the human body to electromagnetic fields in the frequency range 3 kHz to 300 GHz and is applicable wherever people may be exposed to RF electromagnetic helds, in the course of their work (occupational exposure) and the incidental exposure of the general public.

The mechanisms for implementing compliance with the human exposure limits follow a dual approach to technical regulation encompassing applying the mandatory standard to radiocommunications licences and at point of supply to the market for specified devices [12].

Compliance with the mandatory standard is required by manufacturers and importers of devices fitted, or intended to be fitted, with an integral antenna and intended to be used in close proximity to the body. Compliance arrangements with the human exposure standard are consistent with the Electromagnetic Compatibility (EMC) framework, the Radiocommunications Standards, Compliance and Labelling framework and the telecommunications framework, all of which are based on industry s-declaration of conformity with mandatory standards and are currently the subject of a process of harmonisation. The framework requires manufacturers, importers and agents to:

Make a declaration that their product complies with applicable standards; Create and maintain a compliance folder of documentation supporting their claim; and Label devices.

Two categories of compliance requirements are applied to devices with, or intended to be fitted with, integral antennas and which are intended to be used in close proximity to the human body.

. Category A applies to devices that meet the non-evaluation criteria of the mandatory standard. These devices by their very nature and by being of such low power cannot exceed the base limits of the standard. The Declaration of Conformity (s-declaration) is the only documentation required for this group of devices.

. Category B applies to devices, which require evaluation according to the mandatory standard. Manufacturers and importers of this group of devices are required to make a Declaration of Conformity based on test reports as well as any other requirements that may deem necessary to confirm compliance.

Compliance is also required of operators and Users of all transmitters presently licensed under the Radiocommunications Act including those used for telecommunications and broadcasting transmitters, both commercial and public. In general, two categories of compliance apply to licensing conditions:

- Category 1 applies to devices whose installed performance under normal operating conditions is likely to be well within the limits imposed by the mandatory standard for the general public.

- Category 2 applies to high power devices eg broadcast transmitters, the installed performance of which may approach the limits of the mandatory standard unless certain provisions are put in place. Under this category, the installation must be assessed by an approved assessment body and a Declaration of Conformity and test reports must be held by the licensee.

In regard to multiple transmitter sites, the proposes to follow a similar approach to that adopted by the Federal Communications Commission (USA). Licensees on a site with multiple transmitters will be required to share the responsibility of bringing the emission from all transmitters into compliance with the limits of the human exposure standard **[12]**.

In an area accessible to the general public, compliance with non occupational human exposure limits in the standard is likely to be a shared responsibility, and the subject of negotiation, between licensees.

5.1 Regulating Human Exposure to Electromagnetic Radiation)

Electromagnetic radiation (EMR), also known as electromagnetic energy (EME), has always been with us in the form of visible light as well as from the energy emitted from all living organisms. Radiofrequency (RF) EMR has been with us since the advent of radio more than a 100 years ago

The heating properties of RF energy, including its potential impact on human health have been known for quite some decades. Fundamental research into biological and health effects of RF exposure began in the late 1940's and this research has demonstrated a relationship between the intensity and duration of exposure and the subsequent reaction or non-reaction of biological systems. From this research, an exposure limit has been established, beyond which it is well known and undisputed that heating of biological tissue will occur and that, below 1 MHz, induced RF currents can lead to electrostimulation effects. This knowledge has been used by international standards making bodies to develop standards or guidelines, which set limits, based on a "doseresponse" rate for exposure and which also have large built-in safety factors. **[12]**

The advent of mobile telephony in the mid to late 1980's has brought the possible health effects of EMR, beyond the known heating effects, under closer scrutiny from the public, the media and the scientific and medical community. Therefore, the dilemma for public policy makers goes far beyond the physical and medical science of the issue.

Mobile telephony is increasing the use of RF EMR and providing far greater ease of access. This, along with the visual impact of some mobile phone base stations, has created an environment of increasing anxiety regarding any possible health hazards. This has created a situation in which significant portions of the public perceive greater risks from such exposure than does the scientific community. The challenge is to develop public policy with appropriate regulations that will provide protection for the public from the known acute effects of RF EMR while taking account of the public concern about the uncertainty in the science on other possible adverse effects of EMR [12].

5.2 International Situation

The regulation of RF exposure is consistent with the current body of international scientific opinion that radiofrequency devices that operate in accordance with recognised human exposure standards will not pose a health risk.

USA

The Federal Communications Commission (FCC) in the United States of America has adopted the National Council on Radiation Protection and Measurement (NCRP) recommended exposure limits for field strength and power density for transmitters operating at frequencies from 300 kHz to 100 GHz. In addition, the FCC has adopted the American National Standards Institute (ANSI) and Institute of Electrical and Electronics Engineers (IEEE) guidelines for specific absorption rate (SAR) limits for certain devices operating within close proximity to the body. The SAR limits for portable and mobile devices became effective on 7 August 1996. The limits for field strength and power density came into effect on 1 September 1997.

Japan

The Ministry of Posts and Telecommunications (MPT) in Japan released Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields in April 1997. The MPT now proposes to make these Guidelines into Rules or compulsory standards. As of May 1998, the MPT advised that they would target specific radiocommunications transmitters as well as those which can be measured by SAR measurement technology. The guidelines for SAR measurement are currently voluntary but will become mandatory when SAR measurement technology is established as an international standard.

Japan is also considering exempting specified classes of transmitters, which would normally comply, with the levels of emissions imposed by the Guidelines. This exemption would take into consideration the form of installation and equivalent isotropically radiated power.

The MPT will apply rules to new transmitters. Existing transmitters will be given a transition period.

European Union

Regulatory measures have also been considered in the European Union. The European Commission announced a draft Council recommendation on 22 June 1998 to limit exposure of the general public to electromagnetic fields in recognition of the potential for electric shocks, skin burns and effects on the central nervous and cardiovascular systems. This recommendation is based on the ICNIRP Guidelines. The EU framework recommended basic restrictions and reference levels to ensure consistency of public health protection throughout the EU. This proposal considered only thermal effects.

The EU has left it to Member States to provide detailed rules on how the recommendation will apply in practice. Countries such as Austria, Bulgaria, Croatia, Germany and Switzerland have different forms of EMR regulations, or proposed regulation [12].

5.3 Consultation

The development of a regulatory framework for EMR in Australia has been assisted by the firm relationships developed between the ACA and the communications industry in the development of previous standards regulatory frameworks, such as for EMC. However, industry views are just one of the considerations that have been taken into account. Community concern about health effects from radiocommunications transmitters, and opposition to the siting of mobile phone towers has been a powerful determinant in the ACA's decision to implement these regulations. The ACA firmly believes that practicable options to resolve this issue can only be obtained through participation of all stakeholders in the processes of identification, examination and evaluation.

Frequency Range	Designation	Type of Device or Service
3 - 30 kHz	VLF (very low frequency)	navigation beacons
30 - 300 kHz	LF (low frequency)	LF broadcast and long range radio
300 - 3000 kHz	MF (medium frequency)	AM radio, radio navigation, ship to shore
3 - 30 MHz	HF (high frequency)	CB radio, amateurs, HF radio communications and broadcast eg. Radio Australia
30 - 300 MHz	VHF (very high frequency)	FM radio, VHF TV, emergency services, amateurs
300 - 3000 MHz	UHF (ultra high frequency)	UHF TV, paging, mobile phones, amateurs
3 -30 GHz	SHF (super high frequency)	microwaves, satellite communications, radar, pt. to pt. microwave
30 - 300 GHz	EHF (extremely high frequency)	radar, radio, astronomy, short link microwave

5.1 Standard For Limits of Exposure to Radiofrequency Fields

Guidelines and standards are being developed by standards making bodies internationally to set limits, with adequate safety factors, for human exposure to radiofrequency electromagnetic energy. These standards developed by a Standards technical committee, specifies the limits of exposure of all or part of the human body to electromagnetic held in the frequency range 3 kHz to 300 GHz. The Standards committee has taken into account the international standards work [12].

The standard has application to the radiofrequency EMR from all devices that produce and radiate radiofrequency fields either deliberately or incidentally during their operation. The limits of this standard are designed to be applied wherever people may be exposed to radiofrequency electromagnetic fields - in the course of their work (occupational exposure) or where there may be incidental exposure of the general public. This standard does not apply to patients exposed to radiofrequency radiation for medical diagnosis or treatment.

The basic parameter used in setting the limits in the standard was the lowest RF exposure level, confirmed by independent laboratory studies that caused adverse biological effects to the animal subjects of those laboratory studies. An adverse effect was considered to be where the animals altered their performance and changed their behaviours consistent with the characteristics of thermal stress. This effect was found to occur at an elevation in temperature of the whole body of 10C during the exposure. For exposures in the frequency range above about 10 MHz, this occurred with absorption of RF energy in the body equivalent to a whole body average SAR (Specific Absorption Rate) of 4 W/kg. (SAR is a measure of the time rate at which radiofrequency electromagnetic energy is imparted to an element of mass of a biological body.)

Safety factors have been superimposed on the basic limit. For occupational exposure, a safety factor of 10 has been applied to the basic limit, giving a SAR of 0.4 W/kg. For general public exposure, a factor of 50 was applied to the basic limit giving a SAR of 0.08 W/kg. The additional safety factor for the general public was included on the basis that the general public could not be expected to take any precautions to avoid this exposure and to take account of the infirm, the very young and the elderly. With respect to non-uniform exposure, as might be expected from mobile phones, where whole body averages are not appropriate, the provisions are based on the spatial peak SAR of 8 W/kg (for aware users) modified by a further safety factor of 5 (ie. 1.6 W/kg) for the general public (non-aware users) [11].

There are also other limits in the standard which, for frequencies below 1 MHz, are based on limiting induced RF currents which can lead to direct electrostimulation effects. In developing the standard, both thermal and non-thermal effects are considered, however, evaluation of international scientific literature failed to establish any reasonable nonthermal basis on which to base an exposure standard.

5.4 Measurement Methods (Field Strength)

Radiofrequency Radiation: Principles and Methods of Measurement - 300 kHz to 100 GHz) was developed in 1988 by specifying techniques and instrumentation for the measurement of potentially hazardous electromagnetic fields in both the near field and far field of electromagnetic sources in the stated frequency range. As standardised test and measurement methods will be needed to operate the compliance framework, it may also be consider mandating the techniques and test methods to demonstrate compliance with the field strength levels.

5.5 Mandatory Health and Safety Standards and the Legislative Process

Standards are made to protect the health and safety of persons who may be exposed to emissions from radiocommunications transmitters. Standards made are consisting of requirements, which are necessary or convenient for: "Protecting the health or safety of persons whom: Operate radiocommunications transmitters or radiocommunications receivers; or Work on radiocommunications transmitters or radiocommunications receivers; or Use services supplied by means of radiocommunications transmitters or radiocommunications receivers; or Are reasonably likely to be affected by the operation of radiocommunications transmitters or radiocommunications receivers."

The mandatory standard has two parts.

1. It specifies the fundamental restrictions ie. the SAR limits, or where appropriate, the levels of exposure expressed in electric field strength, magnetic field strength and power flux density that have been derived from the SAR limits.

2. It also contains methodologies for assessing compliance with the both SAR limits and field strength levels. The mandatory standard initially applies to specified devices only, with application extending to cover more types of devices over time. The

first devices to be subject to the mandatory standard are mobile phones and mobile phone base stations.

A standard becomes an apparatus licence condition, which specifies that an apparatus licence is subject to a condition that any radiocommunications device operated under the licence must comply with all the standards applicable to it. If an apparatus licensee operates a radiocommunications device under the licence that breaches the mandatory standard, they may be subject to penalties for possessing or causing a radio emission from a non-standard device, and for breach of licence conditions. In addition, once a standard is mandated, a person must not supply a device that does not comply with the standard, where the standard is applicable to that device. [13]

Radiocommunications devices that are subject to a class licence may also be subject to the mandatory standard where the standard is applicable. The may be also guidelines in relation to the mandatory standard. These guidelines may indicate that if a device meets certain specifications and is operated in a certain way, then the licensee is entitled to assume that it complies with the mandatory standard, and is not required to have it tested [13].

The mandatory standard also requires labelling of specified devices to indicate whether the device meets the requirements of the standard. The notice requires manufacturers, importers and agents to meet certain requirements before the label can be applied, such as testing and making a declaration of compliance. The notice also places requirements on them that must be met after the label has been applied, such as record keeping requirements. The sale of a device without such a label, or without meeting the requirements is an offence. With respect to such requirements regarding fencing and signage, there are conditions on transmitters covered by an Apparatus Licence.

5.6 Other Powers

The power to make standards is usually subject to public consultation requirements. However, in cases of urgency, health and safety standards interalia may be made without complying with these requirements. There may also be declare that the operation or supply, or the possession for the purpose of operation or supply, of a radiocommunications transmitter or radiocommunications receiver is prohibited for the reasons set out in the declaration [12].

5.7 Implementation

The mandatory standard is to limit human exposure to EMR from radiocommunications devices. The mechanisms for implementing compliance with the mandatory standard follow the dual approach to technical regulation, which encompasses applying the mandatory standard:

To radiocommunications licences; and at point of supply to the market for specified devices. This means that some devices will be subject to the mandatory standard in their manufacture as well as by licence conditions on their Use. As a general rule, the use of standards imposes a condition on the supplier (manufacturer, importer or agent) to ensure that the product complies with limitations on radiofrequency emissions at the first point of supply to the market. Licensing, on the other hand, places conditions on the Users of specified devices or equipment throughout their period of Use, and could have a wider application, for example relating to how the device is Used, where and in what circumstances [14].

The operation of all radiocommunications devices is subject to conditions of a licence. This licence may be a class licence, spectrum licence or an apparatus licence. People are generally not permitted to operate an unlicensed radiocommunications device without reasonable excuse or in the circumstances of emergency operation.

5.8 Compliance at First Point of Supply - General Principles

Persons who manufacture or import devices fitted, or intended to be fitted, with an integral antenna and intended to be Used in close proximity to the human body must indicate compliance with the mandatory standard by labelling their devices prior to placing the device on the market. Labelling requirements are specified which mandates the standard. When fully implemented, this will apply to such devices as:

· Cordless telephones;
. Mobile telephones;
· Handheld or portable amateur and CB equipment;
· Low Interference Potential Devices (LIPD's):
o remote control models;
o tag detectors;
o radar guns;
o remote control Units.

Compliance arrangements with the mandatory human exposure standard have been harmonised with those for the EMC, Telecommunications and Radiocommunications Standards, Compliance and Labelling frameworks which are all based on industry s-declaration and require manufacturers, importers and agents to: Make a declaration that their product complies with applicable standards; Create and maintain a compliance folder of documentation that supports their claim; and Label devices.

For devices already covered under existing standards, manufacturers, importers and agents are not required to compile a separate Compliance Folder of documentation attesting to compliance with the human exposure standard but will include this documentation in the existing Compliance Folder.

Manufacturers and importers are held responsible for devices whose performance in relation to human exposure to RF emissions is dependent on installation.

This is because the radiation characteristics of the installed device, and hence the likelihood of exceeding the limits of the standard, is in part dependent on the type of antenna and its installation eg. height above the ground, public access to site. For example, land mobile transmitters can be provided to the market without antennas because the antenna can be sourced from other specialised suppliers. In addition, the type of the antenna is dependent on the applications of the transmitter eg. point-to-point, point-to-multipoint, mobile [13].

This principle also applies to manufacturers of mobile phones who will not be held responsible for compliance after point of sale if the device is modified or has any attachments. However, suppliers within Australia who import or act as agents for the manufacturer could be held responsible for the compliance of the device should they make any modifications to the originally compliant device that would make the device non-compliant. It is an offence to knowingly operate, supply or use a non-standard device.

Two levels of compliance requirements are applied to devices with, or intended to be fitted with, integral antennas and which are intended to be used in close proximity to the human body.

. Category A applies to devices that meet the non-evaluation criteria of the mandatory standard. These devices by their very nature and by being of such low power cannot exceed the base limits of the standard. The cordless phone is an example of a device in this category. The Declaration of Conformity (s-declaration) is the only documentation required for this group of devices. However, there may be instances where manufacturers or importers may be required to supply proof of the low power characteristics of the device.

· Category B applies to devices, which require evaluation according to the mandatory standard. manufacturers and importers of this group of devices are required to make a Declaration of Conformity based on test reports as well as any other requirements that may deem necessary to confirm compliance. Devices included in this category include:

- o mobile phones;
- o baby monitors;
- o radio control models.

All radiocommunications devices subject to mandatory standards are currently required to be labelled to indicate compliance, as well as providing an identification of the supplier. Presently, the "C-Tick" Mark attests to compliance with applicable standards for most radiocommunications devices however, mobile phones are required to be labelled with the "A-Tick".

Finally, compliance with the mandatory human exposure standard by the manufacturers and importers of specified devices will be enforced through the currently operating system of random audits of Compliance Folders as well as through complaint investigations.

The exposure limits in the following tables, gathered from various sources, were derived from well-established, severe biological effects (such as tissue heating and nerve stimulation) data. This information is not meant to present "SAFE" vs. "UNSAFE" levels when it comes to the much lower exposure thresholds studied in the epidemiological literature (with respect to cancer, melatonin suppression, and other biological effects).

6. CONCLUSIONS AND RECOMMENDATIONS

Assessment of EMF-related health effects, an international panel of 30 scientists met in June 1998 to review and evaluate the weight of the EMF scientific evidence. Using criteria developed by the International Agency for Research on Cancer, none of the Working Group considered the evidence strong enough to label EMF exposure as a "probable human carcinogen." This decision was based largely on "limited evidence of an increased risk for childhood leukemias with residential exposure and an increased occurrence of CLL (chronic lymphocytic leukemia) associated with occupational exposure.

It is also concluded that EMF exposure cannot be recognised as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures.

Several groups have attempted to determine the risk of childhood leukemia in the general population under the unproven assumption that EMF is truly causing this disease. If this assumption were correct, these calculations generally suggest, on average, that between 5% and 15% of childhood leukemias could be caused by exposures to EMF with confidence intervals including 0%. This would make the lifetime risk of childhood leukemia attributable to EMF (again, conditional on the risk being real) between 2.5 to 7.5 per 100,000 people. On a yearly basis, this conditional risk is approximately 15 times less than the lifetime risk or 2 to 6 additional cases per million children per year.

Regulatory action on any environmental exposure can be multifaceted and proceed by any of a number of options. In general, if regulatory action is to be taken the types of controls can be broken down into restrictions placed on the production of the hazard and those placed on individuals who might come in contact with the hazard. In the case of EMF, there are several issues that complicate any regulatory action.

Regulatory actions prompted by this review of EMF are not the purview. The Interagency Committee (IAC, described earlier) has been involved in all aspects of both our research program and the process of reviewing these data. The agencies that compose the IAC employ experts who have greater experience and knowledge concerning mitigation of EMF exposure. However, it is important that the strength of the evidence reported here be placed in a context that is clear to the regulatory authorities. Therefore, it is provided the following suggestions that are intended to give scope for future regulatory actions.

It is suggested that the level and strength of evidence supporting EMF exposure as a human health hazard are insufficient to warrant aggressive regulatory actions; thus, we do not recommend actions such as stringent standards on electric appliances and a national program to bury all transmission and distribution lines. Instead, the evidence suggests passive measures such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. It is suggested that the power industry continue its current practice of siting power lines to reduce exposures and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards. We also encourage technologies that lower exposures from neighbourhood distribution lines provided that they do not increase other risks such as those from accidental electrocution or fire.

In summary, it is believed that there is weak evidence for possible health effects from EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged.

The research centres are committed to the support of hypothesis-driven research on any environmental exposure that is of concern for human beings. Exposure to EMF is no different. These exposures warrant continued monitoring because EMF exposure is ubiquitous and the use of electromagnetic technology is growing in our society.

The characteristics of EMF and their possible interactions with biological systems have been investigated for several decades. Building upon the knowledge base developed, meritorious research on EMF through carefully designed, hypothesis-driven studies should continue for areas warranting fundamental study including leukemia. Certain areas of research, however, warrant noting.

There are several epidemiological studies of EMF exposures and childhood leukemia underway that may help clarify this issue. Any new epidemiological studies of EMF exposure are not warranted unless, in some unique manner, the studies differ from existing ones and can test new hypotheses. Very little is known about the mechanisms and causes of childhood leukemias and chronic lymphocytic leukemia in adults. Many agencies, including the National Institutes of Health, have ongoing programs in these areas aimed at improving our understanding of these diseases. As risk factors are identified, we strongly recommend re-analysis of the existing EMF epidemiology data to determine if these risk factors reduce or strengthen the reported findings of concern expressed in this document. Where currently available studies cannot adequately address newly discovered risk factors, it is encouraged new studies.

The Mobile phone and the supporting base stations are still a very new subject to scientific research and discussion. The antenna together with circuit elements inside the handset mainly transmits the RF power from a phone. The antenna is usually a metal helix or a metal rod a few centimetres long extending from the top of the phone. At 2.2 cm from the antenna (The distance at which calculations made) the maximum values of the electric field are calculated to be about 100 V/m for a 2W, 900 MHz phone and about 200 V/m for a 1 W, 1800 MHz phone and the maximum magnetic field is calculated to be about 1μT for the both phones.

The rate at which the energy is absorbed by a particular mass of tissue m, is $m\sigma E^2/\rho$ where σ and ρ are respectively, the conductivity and the density of the tissue and E is the rms value of the electric field. The quantity $m\sigma E^2/\rho$ is called the specific energy absorption rate or SAR and is measured in watts per kilogram (W/Kg). It varies from point to point in the body both because the electric field changes with position and because the conductivity is different for different types of tissue.

At 900 MHz when the $\sigma = 1$ S/m and $\rho = 1$ mKg/m^3 then for 1 W/Kg SAR the required electric field intensity is 30 V/m. At 1800 MHz this value is 25 V/m.

Looking at the figures above shows that for both type of the phones the maximum intensity is about 200 W/m^2 and that is ¼ of the intensity of the sun's radiation in a clear summer day. However it should not be forgotten that the SAR produced by a particular value of electric field is somewhat larger in children than in adults because their tissue normally contains a larger number of ions and so has higher conductivity.

So it is highly recommended that to keep the children as much as possible away from the mobile phones. Additionally as there is no definite research result for the psychological effects of the Mobile phones on the nervous system using them over the specific time period time defined by the manufacturers could be harmful.

The interaction of humans with EMF is complicated and will undoubtedly continue to be an area of public concern. The World Health Organisation through its own international program on EMF will review this field in the year 2003.

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Glossary

The descriptions below are intended to help the reader understand the text; they are not necessarily definitive scientific terms, for which the reader is advised to consult specialist sources.

Words in bold are defined separately.

Analogue	The original cellular technology used in the transmission of speech by Vodafone and Cellnet since 1985, operating as an analogue system at 900 MHz. Typically accessed by high powered phones installed in cars.
AM	Amplitude modulation.
Action potential	Voltage produced across a nerve cell membrane by a stimulus. It arises from the entry of sodium ions across the cell membrane, which results in membrane depolarisation.
Antenna	Device designed to radiate or receive electromagnetic energy.
APC	Adaptive Power Control. System used to control mobile phones and base stations in order to ensure that the radiated power does not exceed the minimum consistent with high quality communication. The system effectively operates to reduce average radiated powers.
Base station	Facility providing transmission and reception for radio systems. For macrocells, the infrastructure comprises either roof- or mast-mounted antennas and an equipment cabinet or container. For smaller microcells and picocells, the antennas and other equipment may be housed in a single unit.
Case–control study	An investigation into the extent to which a group of persons with a specific disease (the cases) and comparable people who do not have the disease (the controls) differ with respect to exposure to putative risk factors.
CDMA	Code Division Multiple Access. System that encodes signals to a number of users, so that all of these users can simultaneously use a single, wide frequency band. Each user's handset decodes the information for that user, but cannot access information for any other user.
Cell and Cellular	A cell in the context of mobile phone technology is the area of geographical coverage from a radio base station. "Cellular" describes such systems, but is often used to distinguish the original analogue systems from the later digital **PCN** systems, although the latter themselves have cells.
Chromosomes	Rod-shaped bodies found in the **nucleus** of cells in the body. They contain the genes or hereditary material. Human beings possess 23 pairs.
Cohort study	An investigation into the extent to which a group of individuals (the cohort) about whom certain exposure information is collected, and the ascertainment of the occurrence of diseases at later times. For each individual, information on prior exposures can be related to subsequent disease experience.

CJD	Creutzfeldt-Jakob disease.
Confidence interval (CI)	An interval calculated from data when making inferences about an unknown parameter. In hypothetical repetitions of the study, the interval will include the parameter in question on a specified percentage of occasions (for example, 95% for a 95% confidence interval).
CW	Continuous wave.
Decibel (dB)	A measure of the increase or decrease in power at two points expressed in logarithmic form. Gain = $10 \log_{10}(P_2/P_1)$.
DECT	Digital Enhanced Cordless Telecommunications.
Digital	Technology introduced in the 1990s as a method of transmitting speech and data. Offers increased security, and technical advantages with low powered phones.
DNA	Deoxyribonucleic acid. The compound that controls the structure and function of cells and is the material of inheritance.
DTX	Discontinuous transmission. System regulating mobile phones to ensure that transmission occurs only during speech. The system has the effect of reducing the time of exposure to approximately half (assuming an equal conversation).
EEG	Electroencephalogram. Measurement of changing voltages associated with brain activity.
EIRP	Equivalent isotropically radiated power. This is the power that would have to be emitted in *all directions* to produce a particular intensity and so takes account of the transmitter power plus the characteristics of the antenna.
Electric field	Produces a force on a charged object. Measured in units of volts per metre.
Electromagnetic fields	The electric and magnetic fields associated with electromagnetic radiation.
Electromagnetic radiation	A wave of electric and magnetic energy that travels or *radiates* from a source.
EMF	Electromagnetic field.
ERP	"Evoked" or "Event-related" potential.
FDD	Frequency division duplex.
Frequency	The number of complete cycles of an electromagnetic wave in a second. Measured in units of **hertz (Hz)**.
Genes	Biological units of heredity. They are arranged along the length of **chromosomes**.
Gene expression	The realisation of genetic information encoded in **genes** to produce functional protein or **RNA**.
GSM	Global System for Mobile Communications or *Groupe Spéciale Mobile*. The international, pan-European operating standard for the new generation of digital cellular mobile communications. Enables mobile phones to be used across national boundaries. PCN operators work to the same standard but at different frequency allocations.
Hertz (Hz)	Unit of frequency. One cycle per second.

Risk	The probability or likelihood of injury, harm or damage occurring.
RNA	Ribonucleic acid.
SAR	Specific energy **absorption rate** .
Significance level	The probability of obtaining a result at least as extreme as that observed in the absence of a raised risk. A result that would arise less than 1 in 20 times in the absence of an underlying effect is often referred to a being "statistically significant".
Specific energy absorption rate	The rate at which energy is absorbed by unit mass of tissue in an electromagnetic field. Measured in units of watts per kilogram (W/kg).
Third Generation	The next evolution of mobile phone technology, based on **UMTS** and expected to result in widespread use of video phones and access to multimedia information.
TDD	Time Division Duplex.
TDMA	Time division multiple access. System that divides each frequency band into a number of time slots, each allocated to a single user. Allows several users to operate on the same frequency at the same time.
TETRA	Terrestrial enhanced trunk radio system.
Transcription	The synthesis of **RNA** from **DNA**.
UMTS	Universal Mobile Telecommunications System.
Wavelength	Distance between two successive points of a periodic wave in the direction of propagation, in which the oscillation has the same phase. Measured in units of metres.

Quantities and units used to characterise electromagnetic radiation

Quantity	Unit	Symbol
Frequency	hertz	Hz
Wavelength	metre	m
Electric field strength	volt per metre	V/m
Magnetic field strength*	ampere per metre	A/m
Magnetic field, B/Magnetic flux density*	tesla	T
Intensity/Power density	watt per square metre	W/m^2
Specific energy absorption rate (SAR)	watt per kilogram	W/kg

*A magnetic field strength of 1 A/m is equivalent to a magnetic field of $4\pi\ 10^{-7}$ T in non-magnetic media

Glossary

IMT - 2000	International Mobile Telecommunications - 2000. International name for **UMTS**.
Infrared radiation	**Electromagnetic radiation** capable of producing the sensation of heat and found between visible radiation and **radiofrequency radiation** in the electromagnetic spectrum.
Intensity	The power crossing unit area normal to the direction of wave propagation. Measured in units of watts per square metre (W/m^2). See also **power density**.
Ion	Electrically charged atom or group of atoms.
Ion channel (gate)	Protein that allows the passage of ions across a membrane, down a concentration gradient.
Ion pump	A protein pump that moves ions across a membrane against a concentration gradient.
Magnetic field B	Produces a force on a charged object moving at an angle to it. Measured in tesla (T). See also **magnetic flux density**.
Magnetic flux density	Produces a force on a charged object moving at an angle to it. Measured in tesla (T). See also **magnetic field B**.
Magnetite	Naturally occurring oxide of iron with magnetic properties
Microwave	Electromagnetic radiation of ultra high frequencies between 1 GHz and 300 GHz.
Molecule	Smallest portion of a substance that can exist by itself and retain the properties of the substance.
Mutation	Chemical change in the DNA in the nucleus of a cell. Mutations in sperm or egg cells, or their precursors, may lead to inherited effects in children. Mutations in body cells may lead to effects in the individual.
Neuron(e)	Nerve cell. Basic unit of the nervous system, specialised for the transmission of electrical impulses.
Nucleus	The controlling centre of higher cells. Contains the important material **DNA**.
Order of magnitude	Quantity given to the nearest power of ten. A factor of ten or so.
OFTEL	Office of Telecommunications.
PCN	Personal Communications Network. A mobile system principally directed towards the hand portable, domestic user market and operating with digital technology at 1.8 GHz. The two main UK operators are One 2 One and Orange.
Power density	The power crossing unit area normal to the direction of wave propagation. Measured in units of watts per square metre (W/m^2). See also **intensity**.
Radiofrequency radiation	Electromagnetic radiation used for telecommunications and found in the electromagnetic spectrum at longer wavelengths than **infrared radiation**.
Relative risk	The ratio of the disease rate in the group under study to that in a comparison group, with adjustment for confounding factors such as age, if necessary.
RF	**Radiofrequency radiation**.

Risk	The probability or likelihood of injury, harm or damage occurring.
RNA	Ribonucleic acid.
SAR	**Specific energy absorption rate**.
Significance level	The probability of obtaining a result at least as extreme as that observed in the absence of a raised risk. A result that would arise less than 1 in 20 times in the absence of an underlying effect is often referred to a being "statistically significant".
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Magnetic field, B/Magnetic flux density*	tesla	T
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Specific energy absorption rate (SAR)	watt per kilogram	W/kg

*A magnetic field strength of 1 A/m is equivalent to a magnetic field of $4\pi\ 10^{-7}$ T in non-magnetic media