THE ELECTROMAGNETIC COMPATIBILITY AND ELECTROMAGNETIC FIELD IMPLICATIONS FOR WIND FARMING IN AUSTRALIA

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This document is a detailed briefing paper discussing the electromagnetic compatibility (EMC) and electromagnetic fields (EMF) implications of wind farming in Australia. This paper was prepared as background information for the preparation of a fact sheet for dissemination to the general public. As a result this document, any related documents (listed below) and the fact sheet itself attempts to be as non-technical as possible and sometimes goes to great pains to explain what may appear to be quite obvious to someone intimately involved in either wind energy or specific environmental issues.

However, as is often the case, such attempts may unintentionally oversimplify the issue or present information in a distorted way. We may also have made errors or omissions in the preparation of this document. Please do not hesitate to forward any suggested changes or additions to this document to Grant Flynn at Sustainable Energy Australia (Grant@SustainableEnergyAustralia.com.au).

Where possible footnotes have been provided within the text to allow the reader to consult the source article directly.

This document should be read in conjunction with the following sub-documents;

- None

This document has also been distilled into a very brief fact sheet of just 2 pages which can also be downloaded from the AusWEA: Australian Wind Energy Association web site at www.auswea.com.au.

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SOURCES OF INFORMATION

- Musselroe Wind Farm EMI Study Document TSG-042-TR-001 Hydro Tasmania Telecommunications Services Group 6 June 2002
- Heemskirk Wind Farm Development Proposal and Environmental Management Plan Hydro Tasmania January 2003 (http://www.dpiwe.tas.gov.au/inter.nsf/Attachments/SSKA-J3397/$FILE/Heemskirk_proj_summ.pdf)
- The Australian Radiation Protection and Nuclear Safety Authority http://www.arpansa.gov.au/eme_pubs.htm
- The Australian Communications Authority http://www.aca.gov.au/
- Softwright Engineering USA http://www.softwright.com/faq/engineering/Fresnel%20Zone%20Clearance.html

SUMMARY

What is Electromagnetic Radiation (EMR)?

Electromagnetic radiation (EMR) can best be described as waves of electric and magnetic energy moving together through space. EMR is emitted by natural sources like the Sun, the Earth and the ionosphere. Radiofrequency EMR (RF EMR) is emitted by artificial sources such as mobile phones, broadcast towers, radar facilities, remote controls and electrical and electronic equipment.

The ability of EMR to propagate through space can be impaired when it is absorbed by different materials. For example microwaves of particular frequencies are absorbed by water molecules, which is how a microwave oven heats food. Likewise ultraviolet radiation is absorbed by the ozone layer in the atmosphere (in the stratosphere) thereby protecting us from this harmful radiation.

EMR and Telecommunications

It is possible to communicate between two remote locations if a wanted (e.g. audio) signal is used to modulate a radio frequency electromagnetic wave. There are a variety of modulation and demodulation principles, however two important ones are Amplitude Modulation (AM) and Frequency Modulation (FM). In telecommunications these RF EMR waves – the modulated carrier wave - are generated and propagated at the speed of light making them very useful in our modern society.

The range and reception quality of the signals depend, among other factors, upon their frequency. Their frequency affects how the RF EMR is propagated through space and how they are absorbed, reflected or refracted as they travel through space. There are three main classes of propagation of RF EMR waves – ground waves, direct waves or sky waves. The principle propagation method used in telecommunication is through direct waves of RF EMR (though the others are used in specific circumstances). Ground waves are quickly absorbed by the earth and sky waves are problematic so networks of repeater stations, relaying their signals using direct wave propagation, have been established for reliable long range communication. Of course in the last few decades orbiting communications satellites have increasingly been used for this purpose. These networks can use ultra short wavelengths (i.e. super high frequencies) in the microwave band.

Telecommunications in these higher frequencies can either be point to point (e.g. in data communication links) or point to area (e.g. for a television or radio broadcast to a region). A wide range of different frequencies and propagation techniques are used for each of these broad categories.

Unfortunately some devices can generate unwanted RF waves (e.g. electrical switches and spark ignition systems). These unwanted RF waves combined with the natural background of RF EMR create a noisy background in which our desired signal must be detected. All these unwanted RF waves, together with the wanted signal, enter the receiver via its antenna and impair reception. Effective telecommunications relies on obtaining a sufficiently strong signal in an environment of as little noise as possible (i.e. a strong signal to noise ratio).

Radio interference is generated wherever electric currents are suddenly switched on or off resulting in rapid current changes or pulses. The interference pulses exhibit irregular and sometimes bizarre waveforms which correspond to a spectrum of EMR frequencies and so have a disturbing effect in all frequency ranges.

An appropriate antenna can dramatically improve the signal to noise ratio by being of an appropriate length for the wanted signal and inappropriate for other frequencies. An antenna can also be made directional through a variety of techniques. On a transmitting antenna directionality serves to increase the signal strength in a particular direction (toward a receiver) and in a receiving antenna it will reduce the amount of unwanted noise received from sources other than the signal transmitter.

Is Radio Frequency EMR Safe?

Radio frequency electromagnetic radiation (RF EMR) is non-ionising radiation and so is not able to directly impart enough energy to a molecule or atom to break chemical bonds or remove electrons. In contrast, ionising radiation (e.g. X-Rays) can strip electrons from atoms and molecules, which produces molecular changes that can lead to damage in biological tissue. Each type of radiation interacts differently with the human body.

It has been known for many years that high levels of RF EMR can heat biological tissue and potentially cause tissue damage. However, studies have shown that environmental levels of RF EMR routinely encountered by the public are far below the levels needed to produce significant heating and increased body temperature.

At relatively low level of exposure to RF EMR, the evidence for production of harmful biological effects is ambiguous and unproven. Although there have been studies reporting a range of biological effects at low levels, there has been no determination that such effects might indicate a human health hazard, even with regard to long-term exposure[i].

What is Electromagnetic Compatibility (EMC)?

Electromagnetic compatibility (EMC) is an electrical system's ability to remain completely neutral in the vicinity of other systems. In other words it does not interfere with other systems while at the same time being in its self proof against any interference which other systems generate.

Potential Wind Farm EMC Issues and How to Overcome Them?

Telecommunication systems often use high points in the landscape for their antenna. These same locations are prospective sites for wind energy because of the increased wind speeds at elevated locations. Telecommunications systems, regardless of their purpose, are very important in our modern lifestyles. Consequently there is sometimes concern that the wind energy development may have an adverse impact upon a telecommunication system.

A diverse range of telecommunications services may be located on or near a proposed wind energy site including radio and television broadcasters, mobile telephone cell base stations, data links and emergency service radio masts. Furthermore these various services use a wide range of different frequencies, propagation techniques and antennae.

There is potential for a wind turbine to directly obstruct a signal or to reflect or refract a signal thereby causing interference to normal telecommunications (called passive interference). There is also potential for the wind turbine generator itself to produce interfering RF EMR waves (called active interference). The power line that provides the interconnection between the wind farm and the existing electricity grid also has the potential to cause passive or active interference.

In general the effects of wind turbine generators on electromagnetic waves will be relatively limited. The tower and blades are relatively slim and curved. Consequently they tend to disperse rather than obstruct or reflect waves. Typically blades are made from glass reinforced plastic (GRP), which is essentially transparent to electromagnetic waves. While the impact of a modern wind turbine might be very slight, it is not completely eliminated. However for all the potential impacts, a means of mitigation, avoidance or remedy can be found. Interference can be minimised or eliminated through a combination of special technical solutions and appropriate turbine siting.

It is not always obvious whether a wind farm proposal will have an impact on telecommunications systems. If the telecommunications tower is within sight of the proposed wind farm site, it becomes relatively obvious that the issue needs to be carefully considered. However even when these structures are not present, there is potential for impact. The Australian Communications Authority is responsible for licensing of the spectrum and maintaining a database of communications link locations. This makes it possible for the developer to conduct an audit of communication services that may potentially by impacted upon by the proposed development.

Telecommunications towers are not a contra-indicator of wind turbine generators. In some cases the two are compatible and can cohabitate. For example the Thursday Island Wind Farm (far north Queensland) is in close proximity to a microwave tower, radio masts and an airways corporation satellite tracking station and yet causes no interference.

In regard to passive interference avoidance of interference with a point to point link is usually a matter of appropriate turbine siting to avoid the link and its first Fresnel zone. Sometimes it is cost effective to install more directional antennae so as to narrow the link's beam. For point to area telecommunications (e.g. radio and television broadcasts or two-way radio communications) it is sometimes a little more difficult to avoid some minor interference because of the variety of possible receiver locations.

Generally any interference to mobile radio services is negligible. If interference did become apparent it is likely to be local to the wind farm area (i.e. close to or within the wind farm site). The interference level will depend on where the mobile unit is located and can be overcome by moving the mobile unit a short distance (just as you would to avoid any other structure).

Interference to television signals in the wind farm area can be caused either by reflection or obstruction from the turbine blades, called backward and forward scatter. As the blades of modern wind turbine generators are generally constructed from glass reinforced plastic and contain no significant metallic components, the possibility of any significant interference to television signals is minimised. However in cases where there is close proximity of the turbines to the houses in the immediate area it cannot be discounted completely.

In these circumstances it is recommended that testing be carried out prior to construction of any towers, typically for signal strength and picture quality, so that a baseline can be formed. If interference becomes apparent after the wind farm is constructed, the area can be re-tested and the results compared to the baseline. This work is often conducted as a part of an initial site survey which helps to determine whether residents are likely to experience interference.

At the planning stage the most common mitigation strategy is to alter the wind turbine generator location where possible so that it is away from the line of site to the broadcast transmitter.

Once the wind farm is in operation the possible mitigation techniques include;

- the installation of a better quality antennae or more directional antenna,
- directing the antenna toward an alternative broadcast transmitter,
- installation of an amplifier,
- relocation of the antennae to achieve better signal to noise ratio,
- installation of a terrestrial digital set top box for digital TV,
- installation of satellite or cable TV, or
- if a wide area is affected then the construction of a new repeater station may be considered.

For active interference the main services of concern are those employing amplitude modulation (broadcast AM radio and television for example), however other services may also be affected. This type of interference is minimised by ensuring that the generators and their associated equipment comply with relevant electromagnetic compatibility standards.

Under the EMC regulatory arrangements a product must be shown to comply before it can be supplied in Australia. These rules apply equally to wind turbine generators and their components.

Interconnection power lines are the same as any other power line in the local network. Generally the distance between the interconnection power line and any dwellings will mean that residences should not be significantly affected by any active interference. They will be at sufficient distance from the line easement for this effect to be negligible.

The Australian Communications Authority web site provides details of a variety of television signal interference patterns and ways to overcome these problems (http://www.aca.gov.au/radcomm/publications/better_tv_radio/index.html).

What are Electromagnetic Fields (EMF)?

There is a general perception amongst many in the community that there are health risks resulting from exposure to electromagnetic fields (EMF) from power lines, magnetic fields in particular, and an increased risk of contracting cancer.

All alternating electric currents generate electric and magnetic fields, collectively known as EMFs (sometimes, incorrectly referred to as electromagnetic radiation). Power lines are a highly visible source of these fields, but any electrical device is capable of producing them. Australians are exposed to these fields, to varying extents, throughout their lives.

Electric field strength depends on the voltage and they are present in any live wire whether an electrical appliance is being used or not. Magnetic field strength is proportional to the current and these fields are created around the lead and the appliance but only when it is operating. These fields emanate from the wires delivering electricity to our homes and all devices which use electricity in the home.

Electric fields can be easily shielded but shielding of magnetic fields is technically difficult and very expensive. Buried power lines generate lower magnetic fields than overhead power lines because of their design (not because the earth eliminates the field). In general the easiest way to reduce exposure to magnetic fields is to increase the distance from the source.

The scientific evidence does not firmly establish that exposure to 50 Hz electric and magnetic fields found around the home, the office or near power lines are a hazard to human health. The scientific research done so far shows that if any risk exists, it is small (excluding of course the risk of electric shock) and would be associated with prolonged exposure.

WHAT ARE THE ELECTROMAGNETIC FIELD IMPLICATIONS OF WIND FARMING?

There are four potential sources of EMF associated with wind farming. These are:

- the grid interconnection power line;
- the wind turbine generators;
- any electrical transformers; and
- the underground collector network cabling.

The interconnection with the existing grid is usually made above ground and is no different from any other power line used within the network. The EMF levels are comparable to typical household appliances, i.e. negligible.

The electrical generator windings are close together and surrounded by conductive metal housing so the electromagnetic fields are effectively zero.

The switchyard transformer, which will carry the entire output of the wind farm, is generally located in a central part of the switchyard and the protective fencing means it is not possible for members of the public to come close enough to be exposed to appreciable EMF.

The collector network, which connects the various wind turbine generators of a wind farm, operates at typical distribution voltages and is buried at least 750 mm below ground level. Because of the closeness of the phase conductors within the cables and the screening of the cables, the electromagnetic fields are balanced out to be effectively zero.

The electromagnetic fields associated with generation and export of electricity from a wind farm does not pose a significant threat to public health. Consequently no serious or adverse EMF or interference issues are anticipated from a wind farm.

MAIN DOCUMENT

What is Electro-Magnetic Compatibility (EMC)?

Electromagnetic compatibility is an electrical system's ability to remain completely neutral in the vicinity of other systems. In other words it does not interfere with other systems while at the same time being in its self proof against any interference which other systems generate.

A basic knowledge of radio engineering is required to understand the processes concerned in interference and suppression and the following section provides a brief introduction to these fundamental principles of telecommunications.

Fundamentals of Telecommunications

What is Electromagnetic Radiation (EMR)?

Electromagnetic radiation (EMR) can best be described as waves of electric and magnetic energy moving together through space. EMR is emitted by natural sources like the Sun, the Earth and the ionosphere. Radiofrequency EMR is emitted by artificial sources such as mobile phone base stations, broadcast towers, radar facilities, remote controls and electrical and electronic equipment.

In contrast to acoustic waves that require a medium (such as air or water) through which to propagate, EMR is able to propagate through free space. When the electromagnetic wave encounters a conductive material (all materials are conductive to some extent) a voltage may be induced and currents may flow.

EMR is used in many aspects of modern society such as in telecommunications (radio and TV signal are transmitted by electromagnetic radiation) and in medical imaging (X-Rays are a form of electromagnetic radiation). The ability of EMR to propagate through space can be impaired when it is absorbed by different materials. For example microwaves of particular frequencies are absorbed by water molecules, which is how a microwave oven heats food. Likewise ultraviolet radiation is absorbed by the ozone in the stratospheric layer of the atmosphere thereby protecting us from this harmful radiation.

Oscillation

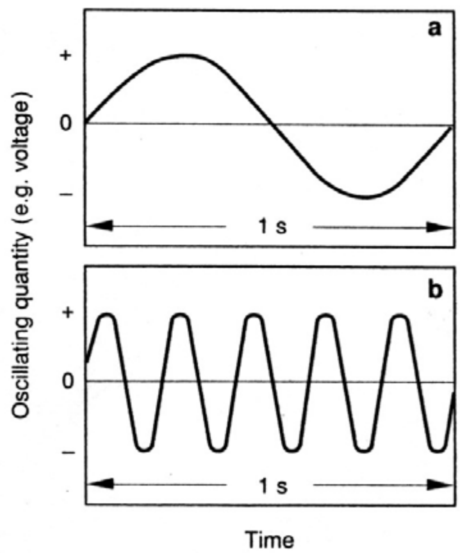
Oscillations are changes of state recurring at regular intervals in time such as by a clock pendulum, the strings on a violin and by the voltages in the electric power mains.

The shape of the oscillation (or its waveform) can differ but a common shape is the sinusoidal waveform (see the figure overleaf).

If an oscillation is propagated in a medium (e.g. water, air, etc) it is referred to as a wave. For example the vibration of a violin string leads to oscillations of the air which are audible as sound waves. A similar process takes place in electrical engineering. For example an alternating current used in the public power supply system oscillates at 50 cycles per second.

FREQUENCY

Frequency is defined as the number of oscillations which take place in one second. The unit of frequency is Hertz (Hz).



The effects generated by various frequencies are best understood using an acoustics analogy. Considering the vibrating string of a violin again, the higher the frequency the higher the pitch and vice versa. The frequency range that is audible to the human ear extends to about 20,000 Hz. The frequencies commonly used in electrical engineering cover a considerably wider range (in excess of 30,000 MHz).

At higher frequencies (several kHz) the waves generated by an alternating source are radiated by any conductors which are attached to the source and are free to propagate in space. This is how Marconi transmitted information over distances using the first wireless telegraphy system in 1897. This served as the basis for the development of the complete field of radio telecommunications using electromagnetic waves.

WAVELENGTH

Wavelength denotes the distance between two successive points of a periodic wave in the direction of propagation, in which the oscillation has the same phase. For instance between to adjacent wave troughs (see the figure overleaf). Wavelength is given in metres.

The relationship between wavelength, velocity of propagation and frequency is given by;

$$\lambda = \frac{c}{f}$$

where;

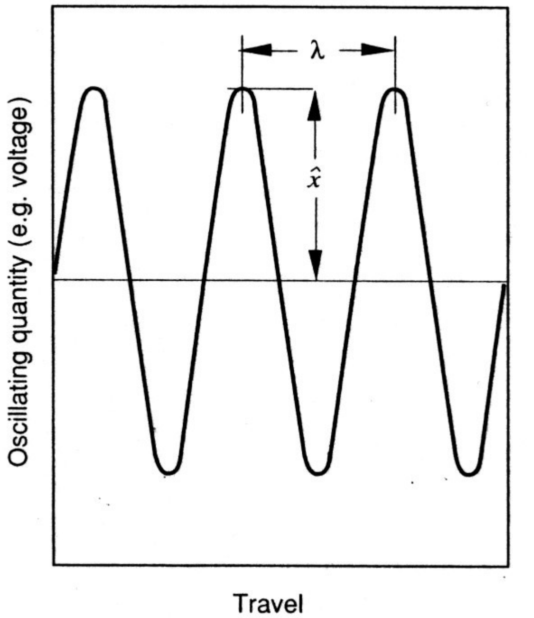
λ .... is the wavelength in metres,

c....................... is the propagation velocity in metres per second

.... (for electromagnetic waves the speed of light –

.... about 300,000,000 ms^{-1}), and

f .... is the frequency in Hz.



The table below shows the most important frequency ranges used in telecommunications.

Frequency Range	Common Usage	Frequency f	Wavelength λ
Long Wave LW	Radio Broadcast	0.1 to 0.3 MHz	10,000 to 1,000m
Medium Wave MW	Radio Broadcast	0.3 to 3.0 MHz	1,000 to 100 m
Short Wave SW	Radio Broadcast	3.0 to 30.0 MHz	100 to 10 m
Ultra Short Waves (VHF) Very High Frequencies		30 to 300 MHz	10 to 1 m
VHF Band 1	TV Broadcast	41 to 68 MHz	
VHF Band 2	FM Radio	87.5 to 100 MHz	
VHF Band 3	TV Broadcast	174 to 223 MHz	
Decimetre Waves (UHF) Ultra High Frequencies		300 to 3,000 MHz	1 to 0.1 m
UHF Band 4	TV Broadcast	470 to 582 MHz	
UHF Band 5	TV Broadcast	610 to 960 MHz	
Centimetre Waves (SHF) Super High Frequencies	Radio Relay	3 to 30 GHz	0.1 to 0.01 m

AMPLITUDE

Amplitude denotes the magnitude (intensity) of an oscillation (shown as *x* in the figure above). For example in acoustics, where the amplitude of the oscillation determines its loudness, as the amplitude of the wave increases the loudness of the sound is perceived to increase.

HIGH FREQUENCY WAVES

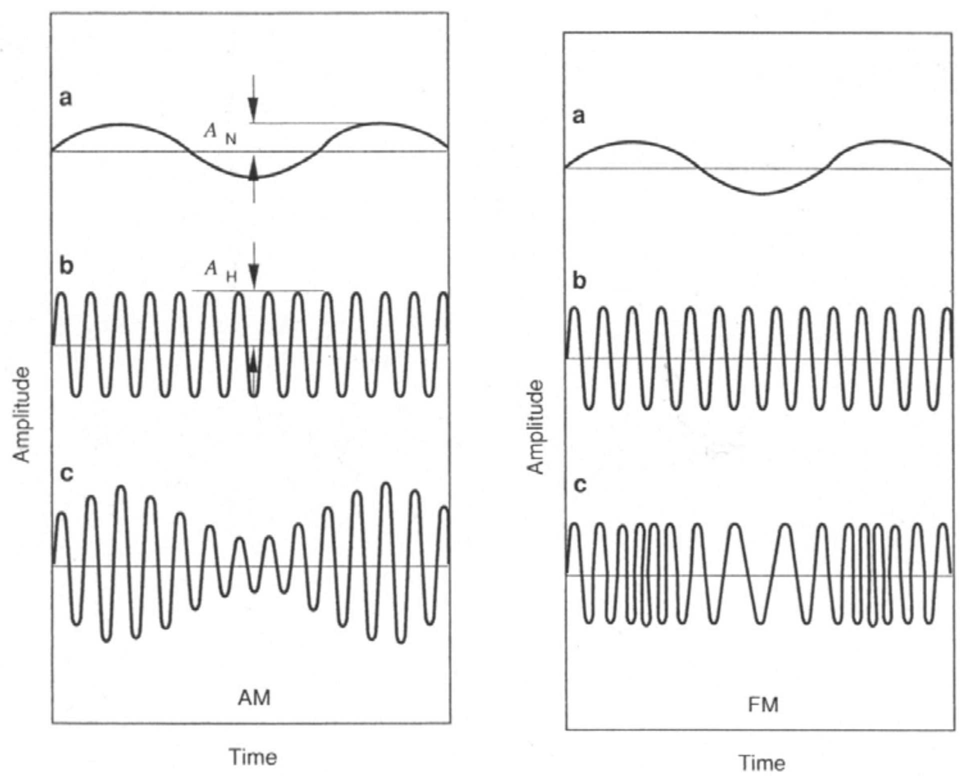
It is possible to communicate between two remote locations if a wanted (e.g. audio) signal is used to modulate a high frequency (HF) wave. In telecommunications these HF waves – the carrier wave - are generated and propagated at the speed of light. Their range and reception depend, among other factors, upon their wavelength (or frequency). Long waves have intercontinental ranges whereas centimetre waves have ranges not much beyond that of unrestricted vision.

HF waves are purposely generated by a variety of telecommunications equipment such as radio and television transmitters, radio telephones, etc. However some devices can generate unwanted HF waves (e.g. electrical switches and spark ignition systems). The main components of HF telecommunications transmitters are oscillating (or tuned) circuits comprising of a combination of capacitors and coils. They are able to modulate electromagnetic waves in a narrow, sharply defined frequency range to which a receiver must be tuned in order to pick up the desired transmission.

In contrast to the HF frequency of a telecommunications transmission the audio frequencies of a broadcast which we wish to transmit are quite low (up to about 20kHz). The low frequency (LF) audio frequencies (air oscillations) are picked up by microphones and converted into electrical oscillations. These electrical oscillations can then be imposed on the carrier such that the carrier is modulated with the low frequency audio oscillations.

The modulated carrier wave is transmitted by the transmitter's antenna and picked up by the receiver's antenna where the process is reversed and the HF carrier is demodulated and the resulting LF electrical oscillations are converted into acoustic oscillations by means of a loudspeaker.

There are a variety of modulation and demodulation principles however two important ones are Amplitude Modulation (AM) and Frequency Modulation (FM).



AMPLITUDE MODULATION

In the AM process the amplitude of the carrier wave is varied in accordance with the low Frequency audio oscillation. The frequency of the carrier wave remains constant. AM is used in the Short, Medium and Long wave frequency ranges.

FREQUENCY MODULATION

In the FM process the frequency of the carrier wave is changed in accordance with the low frequency audio oscillation within very narrow and well defined limits. The amplitude of the carrier wave remains unchanged. FM is used in FM radio broadcast as well as television broadcasting.

PROPAGATION

Depending upon their wavelength (or frequency) waves propagate in different ways. Ground waves follow the curvature of the earth, sky waves refract through the ionosphere and straight line waves propagate directly to the receiver. Long waves tend to propagate only as ground waves and are able to propagate over very large distances and even through deep water. One of the few uses of very long waves is the Omega Navigation System that has a network of eight 450m high antennae around the world (one is in Gippsland, Victoria). Because of the nature of the propagation this network is able to provide very accurate (<1m) navigation signals to submerged submarines (GPS signals cannot penetrate the water and would necessitate the submarine surfacing).

Medium and Short waves are able to reflect off the ionosphere and so are able to propagate using all three principles. Ultra short waves such as Very High Frequency (VHF) and Ultra High Frequency (UHF) tend to propagate only in a straight line (i.e. direct waves).

Typically HF waves will propagate in all directions from the antenna. However directional antenna can be used to increase the power level of the signal in a particular direction or directions. In contrast to sound waves, electromagnetic waves do not need a medium in which to propagate and so are able to propagate in free space (sound waves cannot).

Electromagnetic waves are changes of the electrical and magnetic state of space. Consequently if the wave encounters any form of conductor (e.g. an antenna) the electrical and magnetic state in the vicinity of the conductor as well as the conductor itself will change and voltages and currents are generated.

The area of space that can be influenced by the transmitter (i.e. its effective range) is called the transmitter's electromagnetic field – measured in Volts per metre (or Vm^{-1}). This field's strength decreases as the distance from the transmitter's antenna increases – depending heavily upon the wavelength.

Telecommunication facilities generally fall into two broad categories – point to point communication (line of site links) or point to area communication (broadcast).

LONG WAVES

AM long waves are propagated in the form of ground waves along the surface of the earth. Regardless of the time of day they can be received over long distances (600km and more). Atmospheric or local disturbances (e.g. from engines, motor vehicles, trams, etc) have a serious affect on this frequency range.

MEDIUM WAVES

AM medium waves propagate partly as ground waves and to some extent as sky waves refracted through the ionosphere (about 400km above the earth's surface). Because the height and refractivity of the ionosphere changes according to atmospheric conditions and solar activity, evening and night time reception is usually better than day time. Sometimes the ground and sky waves can interact to either amplify or attenuate each other, causing fluctuations at the receiver (called fading).

SHORT WAVES

AM short waves are absorbed by the earth's surface and only sky waves can be received over longer distances. Again fluctuations in the ionosphere mean reception conditions can vary considerably and there are certain zones in which reception is totally impossible.

ULTRA SHORT WAVES

FM ultra-short waves propagate practically in a straight line. Ground waves are quickly absorbed by the earth's surface and the waves are unable to refract through the ionosphere. Consequently the range is not much more than the range of unrestricted vision (hence the term "line-of-sight"). This is why it is often impossible to receive a relatively close FM transmitter in mountainous or hilly regions; the signal simply cannot reach behind the mountains or hills. In such cases "fill-in" transmitters can be used to repeat the signal into the areas not able to receive the signal directly.

Buildings and high ground can sometimes refract or reflect ultra short waves which can lead to "ghost" images appearing on the TV screen. In this case reflected waves are received at the antenna in addition to those coming directly from the transmitter. The reflected waves do not take a direct route and so are slightly behind the direct waves from the transmitter leading to a second, usually weaker, picture on the screen. Such reflections occur in valleys where the waves reflect from the valley slopes or in urban areas where the waves reflect of large buildings.

Generally reception can be impaired due to the effects of conductors located in the transmitter's radiation field. Such conductors include steel girders, pylons and plumbing lines. Wooded or low lying areas and neighbouring houses can also lead to poor reception.

RADIO INTERFERENCE

Radio interference is generally understood to include all unwanted HF waves which together with the wanted signal enter the receiver via its antenna and which impair reception. This also applies to combined transmitter/receivers.

Radio interference impairs reception acoustically or even makes it impossible due to crackling, clicking, pattering, howling and hissing noises. On a TV screen dots, strips and lines can appear and in extreme cases the picture rolls (pulls out of synchronism) so that reception becomes totally impossible.

Interference waves can be caused by such things as spark plugs and ignition distributors in spark engines. Interference waves can be propagated in a variety of ways either via lines and conductors directly connected to the source of the interference or independently of the lines and conductors (i.e. through radiation). The propagation path chosen by the interference waves depends upon their frequency.

CAUSE OF INTERFERENCE

Radio interference is generated wherever electric currents are suddenly switched on or off. For instance when a switch is actuated (or in the commutation of an electric machine), rapid current changes (pulses) can result in interference. Among other things the level of interference depends upon the slope of the pulse rise and the pulse amplitude. The disturbance is particularly serious in the case of very rapid, high amplitude current change pulses with a steep leading edge.

The interference pulses exhibit irregular and sometimes bizarre shapes which correspond to a spectrum of frequencies. As a result the interference waves generated can have a disturbing effect in all frequency ranges.

The effect can be compared to the field of acoustics. When an aircraft breaks the sound barrier there is a sharp detonation which triggers all oscillatory objects in the vicinity (e.g. windows and metal parts). The result is a clattering noise.

To reduce radio interference we need to attempt to eliminate, smooth or slow the current rise.

PROPAGATION OF INTERFERENCE

Interference can reach the receiver through;

- Direct coupling
- Capacitive coupling
- Inductive coupling, or
- Radiation

Direct coupling usually occurs when an interfering source and the receiver are both connected to the same power supply (e.g. vehicle ignition system and car radio).

Capacitive and inductive coupling can occur when the receiver is located inside the interference sources short range field without wires.

Separation of the circuits of both the receiver and interference source by an insulator (e.g. air) can result in a dielectric effect and a capacitive link between the two circuits. While the capacitive effect of the separation is a block to direct currents, it is a conductor for the HF waves. Generally the closer the wires are together the greater the capacitance and so the higher conduction of the interference waves. Hence one way to reduce capacitive coupling is to increase the separating distance between the wires.

Alternating currents in a conductor induce a magnetic field which can then be induced into nearby conductors. This leads to an inductive (magnetic) link between the two circuits. Again the closer the wires are the greater the inductive link and the greater the conduction of the interference waves and separation of the circuits is a way to reduce interference.

Inductive coupling occurs with high interference currents and capacitive coupling tends to dominate in the case of high interference voltages.

Radiation of interference occurs when the lines and conductors connected to the interference source act as a transmitter and radiate HF waves. Frequencies above 30MHz are mainly propagated by means of radiation and are most effectively propagated when connected to metal parts which are one quarter wavelength long or multiples thereof.

Measures taken to prevent the propagation of inference must be implemented as near as possible to the source of the interference, otherwise metallic parts which are connected to the source will pass on the interference or radiate it.

SIGNAL TO NOISE RATIO

Reception quality depends upon whether the electromagnetic field strength (signal strength) is considerably greater than that of the field generated by the interference source (noise field intensity). This means that the so-called signal-to-noise ratio should be as high as possible.

A receiver operating in the vicinity of an interference source picks up not only the wanted HF waves from the transmitter to which it is tuned but also the unwanted HF interference waves from the interference source. Normally it is impossible for the receiver to separate the wanted signal from the interference since they both have the same frequency. Good reception is possible though provided that at the point of reception the field strength of the wanted transmitter is considerably above that of the interference. For sound broadcast reception the signal-to-noise ration should be 100:1 and for TV it should be at least 50:1.

The signal strength depends upon the transmitter output power, the distance between the transmitter and receiver and the propagation conditions. For example even a very powerful transmitter will only produce a weak signal at the point of reception if the field strength is weakened by unfavourable topographic features.

The ability of the receiver to detect the signal will also depend upon the antenna used by the receiver. Suitably designed antennae will help achieve optimum signal to noise ratio. The interference level must also be reduced at the receiver's antenna. On the one hand the energy of the interference waves must be reduced at the source and on the other the effects of the interference circuit on the receiver must be reduced to a minimum by decoupling the interference circuit from the receiver circuit.

ANTENNAE AND RECEIVERS

The correct antenna dimensions and antenna location can increase the signal voltage at the receiver input. This improves the signal to noise ratio - a decisive factor for reception quality. Receiver design also influences the reception quality.

In many cases the selection of the correct receiving antenna and locating it appropriately can reduce the expenditure required for interference suppression. An antenna is exposed to all the electromagnetic fields that radiate through space. Just because we do not wish to receive the radiation from a particular transmitter does not mean that it suddenly disappears. We simply design an antenna so that it (along with the receiver circuit) is tuned to the frequency we desire so as to increase the signal strength.

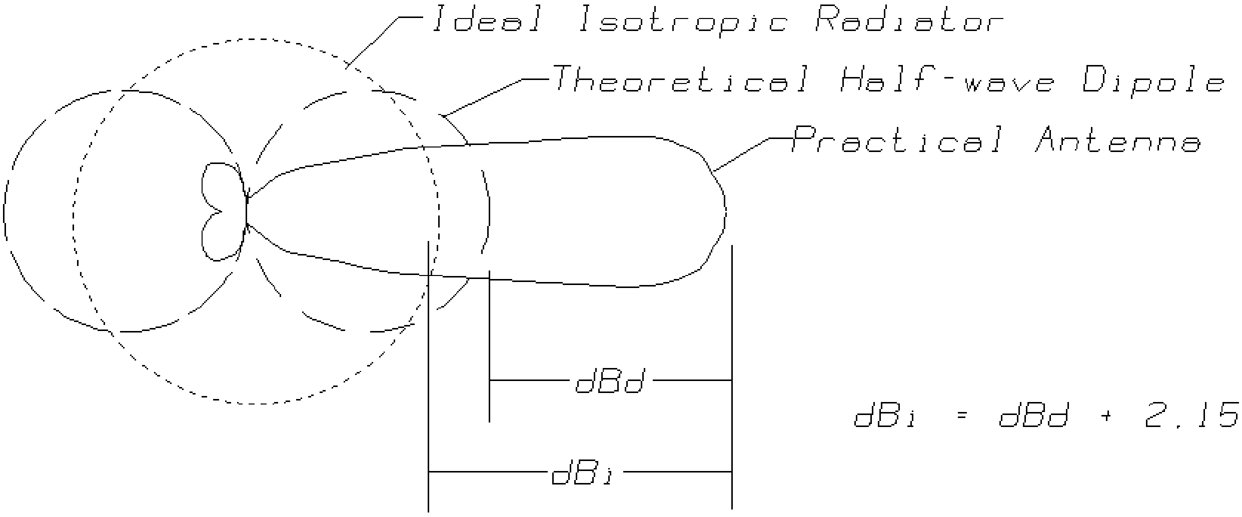
The antenna's received power mainly depends upon the correct antenna length. An antenna's optimum "electrical length" results when its physical length is one quarter of the wavelength to be received. For FM signals the wavelength is the middle of the spectrum of modulation (i.e. the carrier frequency). For example a 94 MHz signal is best received by a 79 cm antenna. Antenna length is affected by its location inside the magnetic and electrical fields of surrounding objects as well as the coaxial cable joining it to the receiver and so the mechanical length of the antenna may need to be longer (eg for 94 MHz it becomes about 98 cm).

The antenna needs to be installed so that it is as far away as possible from interference sources, protrudes as far as possible above interference field in its vicinity and as near as possible to the receiver to reduce the length of the lead. Antenna leads can be screened to reduce the effect of interference, by connecting the antenna lead screen and the receiver housing to ground. Metal screening around the receiver is also important for interference suppression as it reduces the influence of waves from sources other than the receiving antenna.

Telecommunication facilities generally fall into two broad categories – point to point communication (line of site links) or point to area communication (broadcast). Clearly in point to point communications it is desirable to increase as much as is possible the level of radiation directed toward the receiver station and to reduce it in all other directions. Such directing of the radiated energy can be achieved through the transmitter antenna (as well as the frequency spectrum used). Even in point to area communications some directing of the energy may be desirable where the broadcast audience is located in only one general direction.

It is equally desirable to direct the receiving antenna toward the source transmitter thereby reducing the amount of radiation received from spurious or interfering sources (i.e. increasing the signal to noise ratio).

There are a variety of techniques to provide directionality to an antenna but for longer waves it is most often achieved by using multiple dipoles that are able to change the isotropic radiation pattern into the desired radiation pattern. For very short waves the radiation pattern is achieved through the use of apertures (usually circular) to direct the radiation in the desired direction.



FRESNEL ZONES

The key area of potential interference is called the first Fresnel zone (pronounced *'fre-nel'* the "s" is silent). This is the area around the visual line-of-sight that radio waves spread out into after they leave the antenna. This area must be clear or signal strength will weaken.

A Fresnel zone is one of a (theoretically infinite) number of concentric ellipsoids of revolution which define volumes in the radiation pattern of a (usually) circular aperture. Fresnel zones result from diffraction by the circular aperture. The cross section of the first Fresnel zone is circular and centred on the line of sight between the two antennas. Subsequent Fresnel zones are annular in cross section, and concentric with the first. Odd-numbered Fresnel zones have relatively intense field strengths, whereas even numbered Fresnel zones are nulls. The concept of Fresnel zones may also be used to analyse interference by obstacles near the path of a radio beam.

The line of sight shows simply the direct path between the two antennas. The Fresnel zone is a theoretical "envelope" around the line of sight that has several important implications. The most common use of Fresnel zone information on a profile plot is to check for obstructions that penetrate the zone. While line of sight is important, it may not always be adequate. Even though the path has clear line of sight, if obstructions (such as terrain, vegetation, buildings, etc.) penetrate the Fresnel zone, there will be signal attenuation.

The formula to calculate the N^{th} Fresnel zone is;

$$F_N = \sqrt{\frac{N \times \lambda \times D_1 \times D_2}{D_1 + D_2}}$$

where

λ .... is wavelength
D_1 .... is the distance from one endpoint
D_2 .... is the distance from the opposite endpoint

The calculated value represents a perpendicular distance from the direct line of sight line. The combination of these points along the path can be viewed as the Fresnel zone plot. Typically the first Fresnel zone (N=1) is used to determine obstruction loss. Anytime the path clearance between the terrain and the line of sight path is less than $0.5F_1$ (half of the first Fresnel zone distance), some knife edge diffraction loss will occur. The amount of loss depends on the amount of penetration by the obstacle.

Profiles are often drawn with the first Fresnel zone (N=1) and a ratio of 0.5 to provide a quick visual inspection of possible problems caused by obstructions penetrating that zone. Some engineers plot a ratio of 0.6 of the first Fresnel zone to add a bit of headroom for the path design.

Another important use of Fresnel zone information is to check paths (particularly microwave paths) for possible reflection points.

Fresnel Zones are an area of concern for 2.4 GHz wireless systems. Although 2.4 GHz signals pass rather well through walls, they have a tough time passing through trees. The main difference is the water content in each. Walls are very dry whereas trees contain high levels of moisture. Radio waves in the 2.4 GHz band are absorbed by water quite well. This is why microwaves -- which also use the 2.4GHz band -- cook food. Water absorbs the waves, and the heat from the energy imparted cooks the food.

The Fresnel zone formula shown above is the set of points where the distance from the transmitter to the Fresnel zone, then to the receiver, is longer than the direct path from the transmitter to the receiver. For even numbered Fresnel zones (N=2, 4, etc.), the difference between the direct path and the indirect path defined by the Fresnel zone distance, is a multiple of one-half wavelength. If the geometry of the path is such that an even numbered Fresnel zone happens to be tangential to a good reflecting surface (e.g. a lake, a highway, a smooth desert area, depending on what wavelength is involved), signal cancellation will occur due to interference between the direct and indirect (reflected) signal paths.

Planners can set the Fresnel zone to even numbered values when plotting a profile to see if any potential areas of destructive signal reflection are present on the path.

IS RADIOFREQUENCY EMR DANGEROUS?

Radiofrequency EMR is non-ionising radiation. This means that it is not able to directly impart enough energy to a molecule or atom to break chemical bonds or remove electrons. In contrast, ionising radiation such as X-rays can strip electrons from atoms and molecules, which produces molecular changes that can lead to damage in biological tissue.

It is important that the terms *ionising* and *non-ionising* not be confused when discussing the biological effects of radiofrequency EMR. This is because each type of radiation interacts differently with the human body.

A biological effect occurs when a change can be measured in a biological system after the introduction of some type of stimuli. However, a biological effect, in and of itself, does not necessarily suggest the existence of a biological hazard. A biological effect only becomes a biological hazard when it causes impairment to the health of the individual or his or her offspring.

It has been known for many years that exposure to sufficiently high levels of radio frequency electromagnetic radiation (RF EMR) can heat biological tissue and potentially cause tissue damage. This is because the human body is unable to cope with the excessive heat generated during exposure to very high RF EMR levels. However, studies have shown that environmental levels of RF EMR routinely encountered by the public are far below the levels needed to produce significant heating and increased body temperature.

At relatively low level of exposure to RF EMR (that is, field intensities lower than those that would produce measurable heating), the evidence for production of harmful biological effects is ambiguous and unproven. Although there have been studies reporting a range of biological effects at low levels, there has been no determination that such effects might indicate a human health hazard, even with regard to long-term exposure.

REGULATIONS LIMITING PUBLIC EXPOSURE TO RADIOFREQUENCY EMR

To protect the Australian public from the heating effects of radiofrequency EMR, especially with the increasing use of mobile telecommunications, the ACA has introduced new electromagnetic radiation (EMR) human health exposure regulations for radio communications installations and portable transmitting equipment. The regulations are set out in the Radio Communications (Electromagnetic Radiation—Human Exposure) Standard 2001 (as amended from time to time).

The new regulations (latest amendment in March 2003) make mandatory the EMR limits set out in a standard developed by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). ARPANSA is the government agency responsible for radiation advice.

The regulations cover all portable transmitters designed for use close to the human body, including hand held two-way radios, walkie-talkies and remote controlled toys as well as radio communications installations, such as broadcast towers and amateur radio stations. The new regulations extend the previous arrangements which only covered mobile phone handsets and base stations.

The new regulations were developed, through appropriate consultations, in response to community concerns about possible health effects associated with the use of radio communications equipment and the siting of radio communications transmitter infrastructure.

These regulations will support and complement other initiatives of the ACA to address the possible health effects of exposure to EMR, without unnecessarily compromising the benefits that radio communications technology has brought to modern living.

ARE MOBILE PHONES SAFE?

The weight of national and international scientific opinion is that there is no substantiated evidence that using a mobile phone causes harmful health effects. The ACA liaises with Commonwealth health agencies to monitor new research and to date, although subtle biological effects caused by radiation emitted from mobile phones have been reported in some laboratory studies, there remains no evidence that these effects may lead to adverse health outcomes.

Rather than setting emission limits, the standard specifies exposure limits to regulate the rate at which a mobile phone user absorbs energy from the handset. This is known as the specific absorption rate (SAR). The SAR limit for all mobile, cordless and satellite phone handsets for sale in Australia is 1.6 watts per kilogram of tissue. This limit set by the ACA is considered well within international guidelines developed by the International Commission on Non-Ionizing Radiation Protection. They are based on a careful analysis of all scientific literature (both thermal and non-thermal effects) and offer protection against all identified hazards of radiofrequency energy with large safety margins.

There are differences in SAR levels between different mobile phone models. The SAR published by the manufacturer is the result of tests conducted at worst case scenario and the energy you absorb from your phone cannot exceed that level.

In practice, the energy you absorb will vary and in many instances will be much less that the published SAR. This is because the phone only uses as much energy as is needed to communicate with a base station, the closer the less energy used.

Potential Wind Farm EMC Issues and How to Overcome Them?

Telecommunication systems often use high points in the landscape for their transmitting and receiving antenna. These same locations are prospective sites for wind energy because of the increased wind speeds at elevated locations. Telecommunications systems, regardless of their purpose, are very important in our modern lifestyles. Consequently there is sometimes concern that the wind energy development may have an adverse impact upon the telecommunication system.

A diverse range of telecommunications services may located on or near a proposed wind energy site including radio and television broadcasters, mobile telephone cell base stations, data links for national utilities, educational facilities or government departments and emergency services such as ambulance and coastguard. Furthermore these various services may use a wide range of different frequencies, propagation techniques and antennae.

There is potential for a wind turbine to directly obstruct a signal or to reflect or refract a signal, thereby causing interference to normal telecommunications. There is also potential for the wind turbine generator itself to produce interfering electromagnetic waves which may couple with nearby receiving circuits (either directly or through radiation of the waves).

The power line that provides the interconnection between the wind farm and the existing electricity grid also has the potential to have differing effects on communications services, depending on the frequency of service and the location of the transmission line with respect to the service. Generally, the effect can be classified as either obstruction or reflection, and the result of both of these is to degrade the signal at the receiver and decrease the performance and reliability of the service.

If steel towers are used in the power line (e.g. Stobie Poles in SA), they will provide the potential to obstruct and/or reflect radio transmissions. This situation is less common and the effects are generally less severe than obstruction or reflection due to the wind turbine generators themselves. This is mainly because of the lower height of the power lines compared to the wind turbine generators.

In general the effects of wind turbine generators on electromagnetic waves will be relatively limited. The tower and blades are slim and curved and consequently will disperse rather than obstruct or reflect waves. Typically blades are made from glass reinforced plastic (GRP), which is essentially transparent to electromagnetic waves and there is no impact. However the location, size and design of the turbines may be important depending upon the location and nature of the telecommunication facility.

Generally those most likely to be affected are those which operate at Super High Frequencies, where they rely on line of sight between the transmitter and receiver. Any obstruction in the path may cause interference and signal degradation.

It is not always obvious that a wind farm proposal will have an impact on telecommunications systems. If the telecommunications tower is within sight of the proposed wind farm it is relatively obvious, however even when these structures are not present there is potential for impact. Consequently wind farm developers should contact the Australian Communications Authority which is responsible for licensing of the spectrum as well as maintaining a database of where communications links are located.

The developer may need to conduct an audit of communication services identified as being potentially impacted by the development, before and after wind farm construction. Any demonstrable loss in standards of communication caused by the wind farm can be overcome by the wind farm developer through the upgrading of existing facilities or installation of new facilities as required.

For all electromagnetic effects mentioned above, a means of mitigation, avoidance or remedy can be found to minimise or eliminate the interference through a combination of special technical solutions and appropriate turbine siting. These may include specific location of particular turbines, choice of wind turbine generator type, tower design or specific blade material. Relocating, adjusting or enhancing existing communications installations may also be an option for reducing potential for interference. For domestic receptors it may be possible to enhance reception by upgrading the quality of the existing antennae or receiver or by installing a repeater station to boost the signal transmission.

Telecommunications towers are not a contra-indicator of wind turbine generators. In some cases the two are compatible and can cohabitate. For example the Thursday Island Wind Farm (far north Queensland) is in close proximity to a microwave tower, radio masts and an airways corporation satellite tracking station and yet causes no interference.

Thursday Island Wind Farm

PASSIVE ELECTRO-MAGNETIC INTERFERENCE MECHANISMS OF WIND TURBINES

A wind farm will have differing effects on radio services, depending on the type and frequency of service and the location of the wind farm with respect to the service. There are two main classes of effect, being obstruction and reflection. Both of these act to degrade the signal at the receiver and decrease the performance and reliability of the service.

Obstruction interference relates to the situation where the wind farm breaks the path of a radio transmission between transmitter and receiver, causing the power received from the transmitter to be reduced below what would normally be received (Fig. 1a overleaf).

Reflection interference (also known as multi-path loss) relates to the situation where the wind farm is not directly in the path of the radio service, but causes a reflection of the transmitted signal which is out-of-phase to the main beam (Fig. 1b overleaf). When combined at the receiver, the main and reflected beams subtract so that the received power is reduced below that which would normally be received.

Most actual interference problems associated with wind farms emanate from turbines which have had metallic or carbon fibre blades. Interference is caused by the rotating action of the blades presenting a large conductive area which causes the obstruction or reflection. The use of fibreglass/epoxy or plastic blades (i.e. those with no metallic content) in modern wind turbine generators reduces the likelihood of interference caused by the blades, however the risk is not completely eliminated. To some extent the steel towers also potentially obstruct and/or reflect radio transmissions.

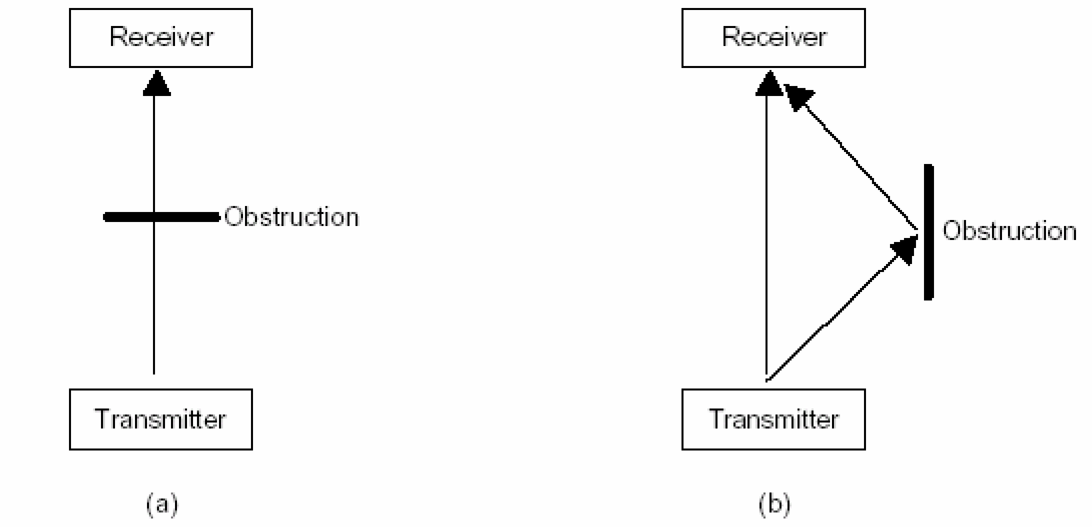


Figure 1. (a) Obstruction, and (b) Reflection Interference.

ACTIVE ELECTRO-MAGNETIC INTERFERENCE MECHANISMS OF WIND TURBINES

As well as being a passive obstruction to or reflector of radio signals the electrical generators and any electrical switching components mounted within the turbines can be a source of radiated electromagnetic radiation. It is possible for this spurious radiated power to be received by radio receivers and cause interference. (Please note that this section is not a discussion of the potential direct health impacts of electromagnetic radiation. That aspect of wind farming is discussed elsewhere in this paper under the heading of electromagnetic radiation.)

The transmission line can also be a source of radiated electromagnetic radiation. It is possible for this spurious radiated power to be received by radio receivers and cause interference.

The main services of concern are those employing amplitude modulation (broadcast AM radio and television for example), however other services may also be affected. This type of interference would be minimised by ensuring that the generators comply with relevant Australian, Federal Communications Commission (FCC – USA) and/or European electromagnetic compatibility standards.

Under the EMC regulatory arrangements compliance labels must be applied to a product before it can be supplied in Australia. Suppliers must obtain permission from the Australian Communications Authority to be able to use compliance marks and they must show compliance with the relevant foreign or Australian standards.[1]

[1] From http:///ww.aca.gov.au

Such rules apply to wind turbine generators and their components and there is no special treatment of their equipment.

Generally the distance between the interconnection power line and any dwellings will mean that residences should not be significantly affected, as they will be at sufficient distance from the line easement for this effect to be negligible.

FIXED POINT-TO-POINT/MULTIPOINT RADIO LINKS

In general, point-to-point and point-to-multipoint radio links operate at frequencies above 100 MHz and require line-of-sight conditions for reliable communications. These types of services may be affected by both obstruction and multi-path loss. As frequency increases the signal degradation typically becomes more severe.

Reflection interference on a fixed point to point radio path, while unlikely, could be mitigated by the installation of more directional antennas.

In terms of locating a wind turbine near a communications link, a turbine within the first Fresnel zone may be acceptable, particularly if it is a solitary obstacle and has a width less than 0.3 times the radius of the zone. However every case needs to be considered on its particular circumstances. Potential effects can be calculated from information about the signal, the local conditions and the turbine design and location.

MOBILE RADIO SERVICES

These same obstruction and reflection factors also have the potential to affect mobile (two-way) radio services. These services usually operate as a transceiver located on a central high point communicating to remote mobile units in vehicles, and hand-held units.

Generally any interference to these services would be negligible. If interference did become apparent it would be local to the wind farm area depending on where the mobile unit is located and can be overcome by moving the mobile unit a short distance (e.g. move from behind the tower).

TELEVISION SERVICES

Television signals, in general, are also subject to the same obstruction and reflection losses as the other forms of radio transmissions. Due to the visual nature of the reception, any degradation of the signal presents itself very obviously in a number of ways including 'snow' and 'ghost images'.

Interference to television signals in the area can be caused either by reflection or obstruction from the turbine blades, called backward and forward scatter (Figs. 2 and 3 overleaf). In the backward scatter region the television transmitter signal is reflected by the blades of the wind turbines and arrives at the receiver with a different phase and amplitude to the main signal. This type of interference usually manifests itself in the form of a periodically fluctuating “ghost image”. Amplification installed on the receiver in this case would not be expected to improve the image. The course of action required would be to install a more directional antenna at the receiver.

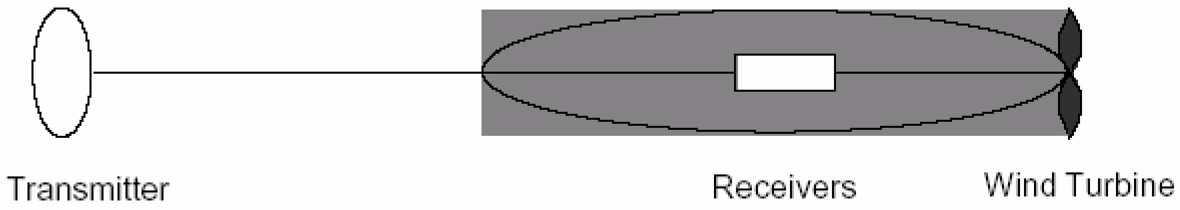


Figure 2. Backward scatter interference of television signals from a wind turbine.

Forward scatter interference occurs when the wind turbine directly impedes the direct path from the transmitter to the receiver. This effectively casts a radio shadow over the receiver. It would be expected that such an installation would cause fluctuations in the picture's intensity rather than the "ghosting" caused by backwards scatter.

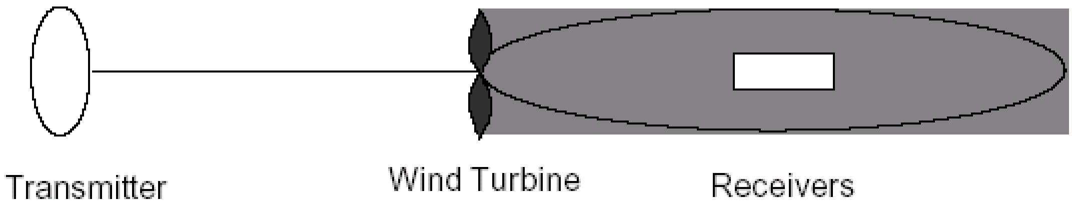


Figure 3. Forward scatter interference of television signals from a wind turbine.

As the blades of modern wind turbine generators are generally constructed from fibreglass/epoxy and contain no significant metallic components, the possibility of any significant interference to television signals is minimised. However in cases where there is close proximity of the turbines to the houses in the immediate area it cannot be discounted completely.

It is recommended that testing be carried out prior to construction of any towers, typically for signal strength and picture quality, so that a baseline can be formed. If interference becomes apparent after the wind farm is constructed, the area can be re-tested and the results compared to the baseline. This work is often conducted as a part of a site survey which helps to determine whether residents receiving from the local repeater would experience interference.

At the planning stage the most common mitigation strategy is to move the WTG location so that it is away from the line of site to the broadcast transmitter.

Once the wind farm is in operation the possible mitigation techniques include;

- the installation of a better quality antennae or more directional antenna,
- directing the antenna toward an alternative broadcast transmitter,
- installation of an amplifier,
- relocation of the antennae to achieve better signal to noise ratio,
- installation of a terrestrial digital set top box for digital TV,
- installation of satellite or cable TV, or
- if a wide area is affected then the construction of a new repeater station may be considered.

The Australian Communications Authority web site provides details of a variety of television signal interference patterns and ways to overcome these problems (http://www.aca.gov.au/radcomm/publications/better_tv_radio/index.html).

The Electromagnetic Field Controversy and Possible Adverse Health Effects[2]

There is a general perception amongst many in the community that there are health risks resulting from exposure to electromagnetic fields (EMF) from power lines. All alternating electric currents generate electric and magnetic fields, collectively known as EMF (sometimes, incorrectly referred to as electromagnetic radiation).

Electric and Magnetic Fields

Electricity generates both electric and magnetic fields. These fields reverse direction 50 times every second and are referred to as extremely low frequency (ELF) fields. The electric field is proportional to the voltage (which can be considered as the pressure with which electricity is pushed through the wires) so the strength of the electric field depends on the voltage. Typically 240 V is used for households). The electric field is present in any live wire whether an electrical appliance is being used or not.

Magnetic fields are produced by electric currents. The magnetic field is proportional to the current, i.e. to the amount of electricity flowing through the wires. The direction of the current, and therefore that of the magnetic field, changes 50 times per second (or at 50 Hz). When an electrical appliance is turned off, there is no magnetic field - a magnetic field is created around the lead and the appliance when it is operating.

It is these fields which have given rise to concerns over a possible association with childhood cancer.

Sources of EMF

These fields emanate from the wires delivering electricity to our homes and all devices which use electricity in the home. Many people are concerned about the alleged link between exposure to magnetic fields, in particular, and an increased risk of contracting cancer. These concerns are raised when stories appear in the media in which the words radiation and cancer are emphasized, especially when children are also involved.

Electric fields can be easily shielded, but the shielding of magnetic fields is technically difficult and therefore very expensive. Buried power lines generate lower magnetic fields than overhead power lines because of their design, not because the earth eliminates the field. The easiest way to reduce exposure to magnetic fields is to increase the distance from the source, particularly for fields generated by appliances.

Power lines include transmission lines (mounted on large steel towers) and distribution lines (mounted on concrete or wood poles placed along the road reserve). Transmission lines generate both strong electric fields and strong magnetic fields. Distribution lines generate weak electric fields, but can generate strong magnetic fields.

[2] From a fact sheet published by the Australian Radiation Protection and Nuclear Safety Agency's (ARPANSA) and available on their website

HEALTH EFFECTS OF EMF

Human studies have consistently shown that there is no evidence that prolonged exposure to weak electric fields (such as those found in the home or in most workplaces), results in adverse health effects. Whether chronic exposure to weak magnetic fields is equally harmless remains an open question. There is no evidence that these fields cause immediate, permanent harm.

Several types of studies are done to determine whether there is a health hazard from 50 Hz magnetic fields.

In cellular studies, cells are exposed to magnetic fields and then examined to see whether changes occur to their normal growth pattern. These experiments demonstrate that these fields do not bring about the changes in cells normally associated with the start of cancer.

Animal studies on rats and mice have not shown that magnetic fields increase the risk of cancer. Studies have not convincingly demonstrated that magnetic fields reduce or alter melatonin levels in humans. Melatonin is thought by some to be a natural cancer suppressor.

Laboratory studies on animals and cell cultures have shown that weak magnetic fields can have effects on several biological processes. For example, they may alter hormone and enzyme levels and the rate of movement of some chemicals through living tissue. By themselves, these changes do not appear to constitute a health hazard. We do not know if, in the long term, they may have an effect on the incidence of cancer or other adverse health effects.

Another way to find out whether EMF affects human health is to conduct relevant studies on human populations. While most studies have produced inconclusive results or no increased cancer incidence in laboratory animals following exposure to EMF, a few studies have indicated weak evidence of an association with childhood leukaemia from modern epidemiological studies. These studies compare the exposure to magnetic fields of people who have cancer and other diseases with similar people who do not have these diseases.

HUMAN EPIDEMIOLOGY STUDIES

To determine if there is a health risk from some, as yet, unknown cause, science uses the discipline called epidemiology. Epidemiology is the study of occurrence and distribution of disease in the population (or community). The first major benefit to mankind from this science came in 1855 when John Snow, a British physician, observed that death rates from cholera were particularly high in areas of London which were supplied with drinking water which had been extracted from the Thames River at points adjacent to sewage outfalls. He proposed that cholera was transmitted by an unknown agent through sewage. This discovery eventually led to proper treatment of sewage.

To do this type of study for EMF and cancer, two groups of people need to be compared: one group which has, in the past, been exposed to EMF while another group (the control group) has not. Because everyone in the community has been exposed, to some extent, to these fields, the exposed group is usually made up of people who live near to power lines, while the non-exposed group live further away. An observation is then made as to whether there are more cancers in the exposed group than in the non-exposed group. While this sounds simple it is not and that is why the controversy remains.

EPIDEMIOLOGY

The epidemiology of cancer is difficult for the following reasons:

- There is a long latency period (delay) of 5 to 20 years or more between exposure and onset of the disease. Cancer usually occurs in old age because of the long latency period.
- Cancer is found amongst people who have not been exposed to the causative agent because the disease is naturally occurring. For this reason carcinogenic (cancer causing) agents are often given a relative risk ratio. Cigarette smokers for example have 10 to 30 times the risk (relative risk ratio) of contracting lung cancer as do non smokers.
- Not everyone who is exposed will get a cancer. Cancer incidence is relatively rare, except amongst the elderly.
- There are many factors which can increase the risk of cancer. For example; poverty, cigarette smoking, alcohol consumption, occupation, sex, race, lifestyle and age.
- The cause of most cancers is not known. The occurrence of cancer in an exposed group seems to be a random process. Not all cigarette smokers get lung cancer and perhaps that is why people continue to smoke despite the warnings. They are playing a lottery with their lives.

For the above reasons, to do an epidemiological study between an exposed and non exposed group for a possible cancer risk factor, one needs to meet the following criteria:

- A large number of people must be included in the study (not everyone exposed gets a cancer).
- The two groups must be matched in every respect except exposure to the agent under test (there are many risk factors for cancer).
- The two groups must be monitored for a long time (long latency period for cancer).

Since cancer incidence is random, a statistical (mathematical) analysis of the results must be performed. This analysis will result in a relative risk factor (see above).

There are several ways in which these studies can be performed. Because of the time and cost savings involved, a retrospective cohort (group of associates) study is the most common method for EMF exposure. In this type of study a group of people who have been exposed to the agent under test and a similar group who have not been exposed are compared. One might choose electrical linesman and compare them with their next door neighbour, for example. This type of study is fraught with pitfalls, such as:

- The exposed group have not had their exposure, to the agent under test, measured. It is assumed because of their occupation or proximity (say to powerlines) that they are more exposed than the control group.
- It is difficult to find a control group which has the same mix of characteristics so that confounding (confusing) factors do not interfere with the result.

EMF EPIDEMIOLOGICAL STUDY RESULTS

The results of all EMF studies to date have indicated either no association or a weak association with adverse health effects. Those studies which do indicate an increased risk of health effects claim a relative risk ratio of 2 to 3. That is as a result of exposure to power line electromagnetic fields the risk of contracting a cancer is two to three time the risk for a non exposed person. Because of the small risk ratios found (most epidemiologists consider a single study with a relative risk ratio less than 3 as not significant) there is room for debate about whether a health hazard exists at all.

At this point it is necessary to discuss the meaning of the word “association” as it is used in epidemiology. Association does not mean causation. The fact that the air temperature rises when the cock crows is an association. We know that it is the rising of the sun that causes the temperature to rise, not the cock crowing. To pass from association to causation the results of these studies should meet most, if not all, of the following criteria:

- The risk ratio should be high, usually 5 or greater.
- The studies should consistently demonstrate an association.
- There should be an association between the exposure and a specific disease. The association should not refer to cancer in general but a specific cancer; e.g. leukaemia and brain cancer together is acceptable but not leukaemia in one study and brain cancer in another.
- There should be a demonstrable dose effect. A dose effect means that as you increase exposure to EMF the number of cancers increases.

- There is a biological mechanism by which the agent under test can cause the associated disease; e.g. cholera is caused by a bacterium, lung cancer is caused by the chemical carcinogens in tobacco tar.

To date all of the epidemiological studies on exposure to EMF do not meet these criteria. The evidence is either weak or absent. In particular:

- The relative risk ratio for those studies which do show an association is usually less than 3.
- The studies are inconsistent. Many studies show no effect.
- The health effects vary. Some studies show an increase in brain cancer while others show an increase in leukaemia.
- No dose effect has been demonstrated.
- No biological mechanism is known for induction of cancer from exposure to EMF's.

It is for these reasons that the majority of scientists, and Australian radiation health authorities in particular, do not regard chronic exposure to 50 Hz electric and magnetic fields at the levels commonly found in the environment as a proven health risk. Moreover, the evidence we have is inconclusive and does not allow health authorities to decide whether there is a specific magnetic field level above which chronic exposure is dangerous or compromises human health.

Some authorities advocate a policy of minimizing exposure wherever possible, providing this can be achieved at reasonably modest cost. Since this is essentially a question of judgement, such decisions are best left to the individual. Simple steps to reduce exposure are:

- using an electric blanket to warm the bed and switching it off before climbing in will virtually eliminate what could be a significant exposure;
- locating bedrooms towards the rear of the house reduces dramatically the exposure due to distribution lines in front of the house;
- moving a bed away from an external wall which has an electric hot water service on the other side will also reduce exposures;
- a distance of about 50 cm between a video screen and the user usually results in an exposure not very different from those found elsewhere in the environment.

AUSTRALIAN EXPOSURE GUIDELINES

There are currently no Australian standards regulating exposure to these fields. The National Health and Medical Research Council has issued Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields. These guidelines are aimed at preventing immediate health effects resulting from exposure to these fields. The recommended magnetic field exposure limit for members of the public (24 hour exposure) is 0.1 millitesla (1,000 mG - milligauss) and for occupational exposure (whole working day) is 0.5 millitesla (5,000 mG)[3].

The NHMRC notes that "although there are limitations in the epidemiological studies that suggest an increased incidence of cancer among children and adults exposed to 50/60 Hz fields, the data cannot be dismissed. Additional study will be required before these data can serve as a basis for risk assessment". In other words, because the research data do not indicate an exposure level at which a cancer risk exists (assuming that such a risk exists at any level); it is simply not possible to determine an exposure limit below which that risk would disappear. Hence, the above NHMRC limits do not apply to the avoidance of cancer risk resulting from chronic exposure to 50 Hz magnetic fields.

RESIDENTIAL EXPOSURES

Exposure levels to EMFs around the home are in the range of 0.01 - 0.25 μT (microtesla = 0.1 - 2.5 mG). For homes near powerlines, these levels may be as high as .5 - 1 μT (5 - 10 mG). Immediately under the powerline, magnetic field levels of 6 - 10 μT (60 - 100 mG) may be found.

[3] The earth's magnetic field has a strength of about 50μT (500 mG). This figure is included to help the reader obtain a feel for what the units mean. The earth's magnetic field is not changing direction at 50 to 60 times per second and is therefore not comparable to power line fields as far as health effects are concerned. N.B. 10 milligauss = 1 microtesla.

WORKPLACE EXPOSURES

The widespread use of electricity means that in all workplaces, there will be levels of magnetic fields that would be considered "normal". However, there are also localized sources of magnetic fields in the workplace such as electrical substations in the basement, power cables in the walls or floor and distribution lines close to the building. The field levels close to these sources will be relatively high and may cause computer screens to shimmer, for example. These levels may exceed the NHMRC limit[4].

The only remedies currently available to reduce these fields, and the resultant exposure, is a combination of shielding and relocating the source (both very costly), or relocating the employees (also potentially costly). The general aim of any field reduction program is to minimize the exposure level for all staff. However, particular situations may require particular solutions and the local electricity supplier or the Electricity Suppliers Association of Australia should be consulted.

THE DOLL REPORT

The following conclusions are from a review of the research literature published in March 2001 by a committee chaired by Sir Richard Doll, for the National Radiological Protection Board in the UK.

> *"Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels [more than 0.4 μT] of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK. In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children."*
>
> -from ***ELF Electromagnetic Fields and the Risk of Cancer***,
> National Radiological Protection Board, 2001.

The inconclusive nature of this finding is due to the low relative risk and the lack of supporting evidence such as a biological mechanism or dose response curve, etc.

It should be noted that this review's conclusions are not new - previous reviews have drawn similar conclusions. The average level of 0.4 μT referred to in the conclusion to the Doll report is not an exposure limit or safe level. This exposure level was arbitrarily selected to distinguish "exposed" and "unexposed" participants in epidemiological studies.

More detailed studies, that include a determination of any relationship between exposure and risk, are required before an exposure limit relevant to avoiding a cancer risk, if it exists, can be determined.

THE POSSIBLE RISK

The Doll report says that there is a possible cancer risk from magnetic field exposure. In particular, it is possible that a child exposed to prolonged and higher-than-normal magnetic fields might develop leukaemia.

[4] The ARPANSA laboratory offers a magnetic field meter for hire which can be used to measure exposure to such fields. The cost is $30.00 (including GST) for use over a few days, plus $6.00 p&p to anywhere in Australia (2002).

On average, there will be about 270 new cases of acute lymphatic leukaemia every two years amongst the 3.9 million children in Australia (1997 data). On the basis of UK experience, 0.4% or 16,000 of them will be exposed to magnetic field levels greater than 0.4 μT (this would be an overestimate, given that the population density is much lower in Australia compared to the UK). If the exposure to magnetic fields above 0.4 μT does actually cause leukaemia at the level indicated in the Doll report, then, on average, there would be one extra case in Australia every two years.

CONCLUSION

On balance, the scientific evidence does not indicate that exposure to 50 Hz EMF found around the home, the office or near power lines is a hazard to human health.

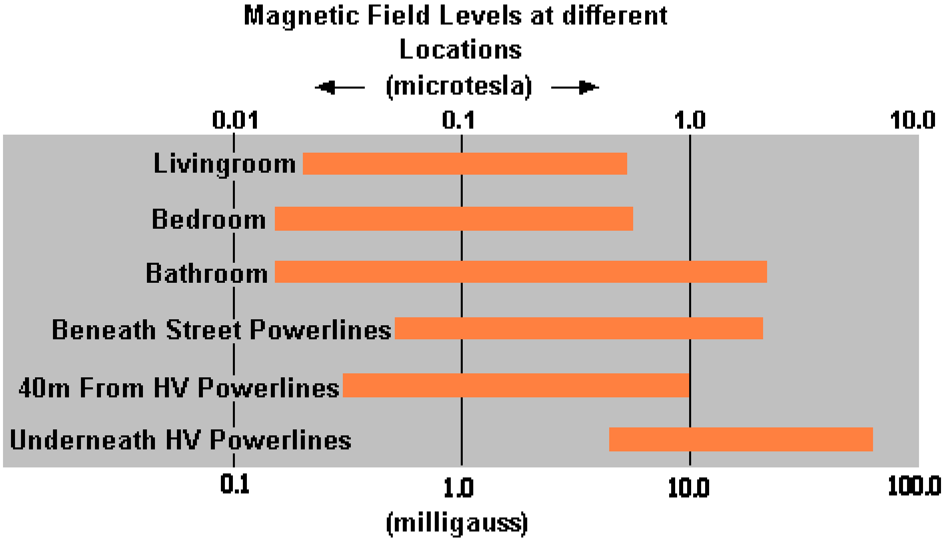
Household Exposure to EMF[5]

There are concerns that exposure to electric and magnetic fields may increase the risk of childhood leukaemia. Powerlines are a highly visible source of these fields, but any electrical device is capable of producing them. Australians are exposed to these fields, to varying extents, throughout their lives.

The scientific evidence does not firmly establish that exposure to 50 Hz electric and magnetic fields found around the home, the office or near power lines are a hazard to human health. The scientific research done so far shows that if any risk exists, it is small (excluding of course the risk of electric shock).

MEASUREMENT OF 50 HZ MAGNETIC FIELDS

The strength of magnetic fields are typically described in one of two distinct units, microtesla (μT) and milligauss (mG), where 1 μT = 10 mG. Magnetic fields within homes can vary greatly. The figure below shows a range of measurements of magnetic fields made around powerlines and in Australian homes.



Magnetic Field Levels

[5] From a fact sheet published by the Australian Radiation Protection and Nuclear Safety Agency's (ARPANSA) and available on their website

It is important to remember, however, that research suggests that if any health effects exist, they are associated with prolonged exposure. Measurements at one point in time do not accurately reflect prolonged exposure levels.

Reducing Exposures to Magnetic Fields

The magnitude of both electric and magnetic fields decrease rapidly with increasing distance from the source. The easiest way to reduce your exposure to these fields, if you wish to do so, may simply be to move areas where people spend a lot of time (for example, chairs, beds) away from electrical appliances and facilities by re-arranging room layouts.

Some electric blankets and underfloor heating installations are capable of producing relatively high exposure levels. However, more recent wiring designs utilise layouts where the magnetic fields from adjacent cables cancel each other, resulting in a minimal field. Electric blanket users, who are concerned about exposures, might preheat the bed and then switch the blanket off before they go to bed.

It is noteworthy that the Doll report did not relate proximity to high voltage powerlines and childhood leukaemia. Living further away from powerlines will not necessarily decrease magnetic field exposures in the home or reduce any possible risks associated with magnetic fields from electricity.

Conclusion

The scientific evidence does not firmly establish that exposure to 50 Hz electric and magnetic fields found around the home, the office or near power lines is a hazard to human health. In view of the epidemiological studies, however, the possibility remains that intense and prolonged exposures to magnetic fields may increase the risk of leukaemia in children.

If exposure to higher-than-normal magnetic fields does actually cause leukaemia at the level indicated in the Doll report, then, on average, there would be one extra case in Australia every two years. The evidence does not allow health authorities to decide whether there is a specific magnetic field level above which continuous exposure is dangerous or compromises human health.

What are the Electromagnetic Field Implications of Wind Farming?

There are four potential sources of electric and magnetic fields (EMF) associated with a wind farm proposal[6]. These are:

- the grid interconnection power line;
- the wind turbine generators;
- any electrical transformers; and
- the underground collector network cabling.

The interconnection with the existing grid is usually made above ground and typically it is at a voltages of between 22 and 132 kV – the same as those already used in distribution networks. In all cases these installations must adhere to or exceed prescribed electrical cabling standards. In other words they are no different from any other power line used within the network. In an assessment of EMF's from the transmission lines for the proposed Heemskirk Wind Farm by Hydro Tasmania the studies showed that at a distance of 30 m from the conductors EMF levels would be comparable to typical household appliances i.e. negligible.

The electrical generator windings are close together and surrounded by conductive metal housing so the electromagnetic fields are effectively zero. Furthermore, because the nacelle of the wind turbine generator is some 60 - 100 m above the ground, the electromagnetic field at ground level can be considered negligible.

The largest generator proposed so far in Australia is 3 MW, and so the electrical transformers at each wind turbine generator are not likely to be larger that 3 MVA. In such large machines these transformers are mounted within the turbine nacelle and so would have little (if any) effect at ground level. The switchyard transformer, which will carry the entire output of the wind farm, is generally located in a central part of the switchyard and so it is not possible for members of the public to come close to it due to the protective fencing.

The collector network that connects the various wind turbine generators of a wind farm will operate at voltages between 22 and 33 kV (the same as other distribution networks in the area). The electrical cabling used in the collector network will be buried at least 750 mm below ground level and the cable will be shielded (as well as steel armoured). Due to both the closeness of the phase conductors in cables and the screening of the cables, the electromagnetic fields are balanced out to be effectively zero.

The electromagnetic fields associated with generation and export of electricity from a wind farm does not pose a significant threat to public health. Consequently no serious or adverse EMF or interference issues are anticipated from a wind farm.

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[i] Australian Radiation Protection and Nuclear Safety Authority (ARPANSA)

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[6] http://www.dpiwe.tas.gov.au/inter.nsf/Attachments/SSKA-5J3397/$FILE/Heemskirk_proj_summ.pdf