

ELECTROMAGNETIC RADIATION AND COMFORT IN THE WORKPLACE

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ABSTRACT

This paper describes research on the extremely low frequency (ELF) end of the electromagnetic spectrum from VDUs, because this is very close to the frequencies of the brain when it is concentrating. Our most recent experiments involve the use of an alpha oscillator which when stimulated with magnetic radiation from VDU's emits frequencies which peak around 12Hz. The oscillator neutralises ELF emissions from the VDU by resonance thus acting like a tuning fork. A recent experiment carried out at a Health Authority office building involved 100 people who were given either active or dummy devices over a period of two months. It was a double blind crossover experiment because neither the occupants of the building nor the researchers knew which devices were active and which ones were dummies until the end of the experiment. Each subject then answered 19 questions concerned with building sickness syndrome and ergonomic factors. Everyone answered the questionnaire three times, once at the beginning, once after the first experiment and once after the second experiment, having swapped over the active and dummy devices. The statistical analysis of the results showed that there was a highly significant effect in the reduction of building sickness symptoms by a third when using the alpha oscillator, thus leaving scope for a further reduction of nearly 70% due to other factors than radiation.

KEYWORDS

Electromagnetic radiation, VDU's, biological effects, building sickness syndrome, alpha oscillator.

INTRODUCTION

The energy of the sun interacts with the earth's magnetic field. Solar winds are composed of high energy atomic particles which travel through space towards the earth creating a magnetosphere around the earth. The sun also emits large amounts of ionising radiations such as x-rays and the magnetosphere shields the earth from these rays by absorbing or diverting them around the earth. The sun itself is not constant in its activity but conducts an eleven year sunspot cycle during which solar storms are common at periods of high activity resulting in solar flares. These energise the solar wind to high levels of activity which result in magnetic field disturbances and ultimately magnetic storms. The magnetosphere does not rotate but remains fixed in space therefore any location on the surface of the earth has a constantly changing magnetic field. It is the rise and fall of this field which relates to biological rhythms. This interaction not only results in the production of ionising radiation but also electromagnetic radiation over a wide band of frequencies but those of particular interest here are in the extra low frequency (ELF) range between 0-100 Hz and in the very low frequency (VLF) range between 100-1000 Hz. The ELF cover a range of frequencies which are similar to those of the brain.

For over a century there has been an increasing use of electricity for lighting, power and communications. People have become exposed to more intense electromagnetic fields according to the work reviewed by Becker (1990) and this has significant effects on the body. During the last twenty years there has been a rapid increase in the use of visual display units (VDU) and since 1990 mobile phones. Electromagnetic fields have become therefore, much more prominent and variable in the home, at school as well as in the workplace. The question is whether the increasing array of electromagnetic fields around us affect our behaviour and ultimately our work performance. Evidence as yet is not conclusive but does suggest that we need a coordinated research effort as this is an aspect of the environment about which we know a lot less than other factors such as air quality, lighting (albeit a form of electromagnetic radiation) and sound. Clearly one can play safe by minimising the emission of electromagnetic radiation from equipment; by locating oneself at least five metres away from equipment; by introducing some interference device between the equipment and the person to cancel out the effects. However, these procedures do not mean that we should avoid trying to understand more about the nature and effect of electromagnetic radiation on people.

The super-conducting quantum interference detector (SQUID) is a magnetometer which was developed in 1970 and can be used to measure the magnetic field (magnetoencephalogram) produced by the brain. The flow of electrical currents in the brain produces a magnetic field which has a strength in the order of 15fT (femtoTesla). All living things possess a magnetic field and this interacts with the external magnetic field. According to Becker (1990) the magnetic field around our brain reflects what is happening in the brain. The earth's magnetic field has a low intensity but we are increasingly using equipment emitting much higher values. Does this matter to living organisms?

Becker (1990) has shown that there is a relationship between the earth's geomagnetic field and human behaviour. Using epidemiological methods he found there was a significant relationship between the rate of admission of patients with severe mental illnesses and the occurrence of major magnetic storms.

It is well established that animals have the ability to sense and derive directional information from the earth's magnetic field. The work of Baker (1988), shows that the sense of direction can be disturbed by placing a magnet on a person's forehead for fifteen minutes. It appears that a *magnetic organ* is present in most life forms and it is closely connected to the brain.

The pineal gland* is a tiny pine-cone shaped structure in the centre of the head and is what has become known as our biological clock, since it regulates our pattern of sleeping and waking. It secretes the hormone melatonin so that any environmental factors which affect this secretion consequently affect our psychic pattern of behaviour. Disturbances in the bio-cycle pattern can produce stress which in turn can decrease the effectiveness of the immune system. Various factors in the environment can affect the immune system but once it is decreased then effectively the defence system of the body is lowered and one becomes more susceptible to other factors.

Wolpaw (1987) measured the levels of neurohormones in the spinal fluid of monkeys that had been exposed to electromagnetic fields for three weeks. He found that the levels of serotonin and dopamine were significantly depressed immediately following exposure but only the dopamine returned to normal levels whilst the serotonin levels remained much reduced for several months. Neurohormones affect behaviour. For example, in the case of serotonin it has been established that continued depressed levels of this hormone increases the possibility of suicide (*Lancet* 24 October, 1987).

The link between ELF and the mind is not understood. The brain has been conceived as a hard wired system and the overall level of consciousness is regulated by alternating *and* direct current flows. According to Becker (1990) there appears to be a roughly linear relationship between the extent of consciousness loss and the amount of electric current applied. Becker superimposed a 1-10 Hz frequency on the DC current and this produced a significant loss of consciousness. ELF frequencies alone have no effect, and the same strength of DC current produced much less loss of consciousness but the two acting together produced a much greater effect. Above 10 Hz the enhancement decreases linearly with the rise in frequency. At 20 to 30 Hz the effect is not apparent. Becker (1990) speculates that the interface between the analogue and digital systems may be involved in some of the higher nervous functions such as memory, logic, creativity or even more fundamentally, it may be the home of the mind.

Silk (1998) and Lam (1996), describes research work in California using MRI scans from 40 people. It was found that certain parts of the brain are particularly sensitive to external magnetic fields, in particular the temporal lobes and their sub-cortical components amygdala and the hippocampus where the tissues are prone to what is called *kindling* by which the tissues display electrical impulses over time as they are repeatedly exposed to minute electrical currents.

Chronic-fatigue Syndrome

Fatigue may be produced by a variety of conditions ranging from physical exertion to minor virus infections but in the office environment, lethargy has often been a principal symptom of building sickness syndrome as shown in many independent studies over the last twenty years. Becker (1990) reports that in 1982 a new syndrome symptomised by severe fatigue, sore throat, tender lymph nodes, mild fever, inability to concentrate, depression and mental confusion became prevalent. Other studies were carried out by Strauss (1988).

* Descartes (1596-1650) believed that the human being was a combination of body (matter) and mind which he thought of as a thinking substance. Body existed and could be measured, but the mind was sensed and willed. Descartes believed that the link between the two was the pineal gland through which the mind influenced parts of the brain.

It is also evident from our own work that some people are more sensitive than others to environmental factors. We have received many letters from individuals that have had to leave their jobs, re-locate and radically change their pattern of working because they are certain that working with computers for many hours a day affect them. The chronic-fatigue studies in the USA found that patients in general improved when they were away from sources of electromagnetic radiation. Anecdotal evidence, epidemiological studies and conclusions from experiments on animals concerning human use, are still viewed as suspect by natural scientists. However the implication is clear. We need to understand more about electromagnetic radiation.

Television, Personal Computers Video Display Units and Mobile Phones

Televisions and computers are broad band radiating sources which emit a wide spectrum of frequencies from 20Hz - 200 MHz . Pictures on the screen are made up of separate lines each being constantly generated from left to right. There is also a fly-back circuit that returns the line of sweep to the left side of the screen at the end of each line. Flyback circuits operate in the VLF range generally at about 17 kHz. The electromagnetic radiation is generated from the circuits within the equipment. The radiation pattern from a computer is similar to that from television but people are sitting much closer to the screen in the former case.

Youbicier - Simo (1997), reports the effect of VDUs and mobile telephones on chicken hatching patterns. Embryo mortality rates exposed to these electromagnetic sources increased from around 15% to about 60% with significant reductions in the hormonal and immune responses as well as body weight. Using an alpha oscillator it was possible to restore these levels of responses although the embryo mortality still remained some 10% above the control levels. Hyland (1999) reports work of the Avignon Teaching Hospital in France which shows that VDUs have an effect on the brain using EEG measurements as the source of data.

Hyland (1999) reports on several studies which have placed an alpha oscillator on a VDU. Most of the experiments involve testing a number of subjects with and without the alpha oscillator. Research at the University of Luton used mood tests and found that by using an alpha oscillator people were more relaxed, less tense and more alert. This result is supported by previous work undertaken by Smith (1981), Johansson (1984), Zavala (1984).

Hyland (1999) goes on to describe further work carried out at the Tecnosphere Research Centre, at Sampigny in association with the Cochin Hospital in Paris in which VDU workers at several French and Swiss companies were tested using a Stroop colour word test for assessing the degree of stress. By using the alpha oscillator peoples concentration was improved, especially for individuals who were more stressed. There were also improvements in speed and alertness reactions as well as a significant improvement in stress resistance.

Freude et al (1998) shows that electromagnetic fields emitted by mobile phones influence slow brain potentials which represent some stage of information processing but no conclusions were reached regarding health and well-being.

The Powerline Debate

Discussions about electromagnetic effects on people is difficult, because it is an area very much neglected when we take our first biology lessons at school. We are all introduced to the effect of a magnet on iron filings but this not related to our everyday life in terms of the human body. One

example which exposes the difficulty and ignorance that we have about the subject is the powerline debate which has been going on for over twenty years.

In the nineteen seventies Becker (1990) published the first epidemiological study that showed a significant relationship between people living near powerlines and suicide. Wertheimer (1979) carried out a further epidemiological study and discovered that 60 Hz magnetic field with strengths of only 3 milligauss was statistically significant in relation to childhood cancers. This field strength is many times smaller than the earth's normal magnetic field strength (0.35 - 0.70 Gauss) and is far below the average strength of 100 milligauss at a distance of about 15 metres from a standard transmission line. The New York State Department of Health, Powerlines Project, started in the 1980's and established that 20% of childhood cancers appeared to be produced by an exposure to 3 milligauss power frequency magnetic fields. Becker (1988) analysed the report that resulted from this study. The present view in the USA is that care should be taken when planning buildings near powerlines, in spite of a study by the National Cancer Institute in 1997 ruling out a link between powerlines and leukaemia.

Contrast this with the present situation in the UK when in one week there appear to have been conflicting evidence produced by two eminent authorities. Fews et al (1999) shows that electromagnetic fields around the powerlines generate corona ions and these charge atmospheric pollutants so that they stick to the skin of people living up to 200 metres away. The conclusion was that the electric component of the electromagnetic field poses a possible link in association between powerlines and childhood leukaemia.

One day later on December 3rd, 1999, the public were informed in the *Daily Mail* newspaper, that the UK Childhood Cancer Study, under the leadership of Sir Richard Doll, had concluded that there was no extra risk of developing cancer triggered by magnetic fields from the electricity supply grid system. (Day 1999).

Of course this may not be as conflicting as first appears. Firstly, there is a distinction between electric and magnetic field effects, and secondly the emphasis in these studies has been on cancer, but the work by Fews et al, may indicate that there are health aspects other than cancer which may be important. All of this work, in the USA and the UK, illustrates the problem of studying electromagnetic fields. There appears to be conflicting evidence especially when one is trying to define causal relationships between electromagnetic fields and something specific like cancer. There seems to be less conflict as regards the fact that there *is some effect on health* and that this is only likely to be the case for those people who have a more hyper-sensitive reaction to electromagnetic fields. Work at the Brakespeare Hospital (Monro 1999) shows that people with food allergies are often those who are also very sensitive to electromagnetic fields. When it comes to studying the effects from computers and mobile phones there will be a similar range of argument. One thing is certain, we need to understand much more about the impact of electromagnetic fields in designing the workplace environment.

The work of Savitz (1988) and Tomenius (1986) confirmed the earlier work of Wertheimer (1989). Smith (1989) gives a highly referenced account of the work on the powerline problem in America, the UK and other countries

Electromagnetic Radiation and VDUs

Goldhaber (1988) in the USA found that women who use VDU's for more than 20 hours a week had more than twice as many miscarriages as women doing other types of office work. A survey was

carried out among 1583 pregnant women and showed that the risk of early or late miscarriages increased approximately 80% for all women who worked on VDUs for more than 20 hours a week.

An extensive source of references on VDUs are given in Bentham (1995, 1996) who describes evidence from another twenty-three studies in Canada, Denmark, UK, Finland, Sweden, Japan, Poland as well as the USA and she concludes that the results show that unsuccessful pregnancies among VDU users are on an average of around 75% more common than for non-users. In other words VDU's increase the risk, but like most environmental issues, there are a number of confounding factors which can cause a particular outcome.

Clearly VDUs can give rise to problems in a number of ways for people who are using them continuously. They can cause various muscle aches, repetitive strain injury, sore eyes, skin complaints as well as the possible effects of electromagnetic radiation. VDUs emit extremely low frequency radiation (15 - 60 Hz), very low frequencies (up to 20 kHz), radio frequencies (100 RHz up to 300MHz), microwaves,(300 MHz - 20 GHz) and to complete the non-ionising radiation range, infrared and ultraviolet radiation. VDUs also emit soft x-rays in the ionising radiation range. The spectrum for mobile phones is similar.

The extremely low frequency emissions (ELF) result from the input electrical power and the vertical sweep circuits which put together emit electric and magnetic fields of up to 60 Hz frequency and associated harmonics. The major source of the magnetic field is the magnetic deflection coil. The human body is conductive to magnetic and electric fields hence there is the possibility of disturbance with the body's natural electromagnetic systems.

The International Telecommunications Union (ITU) recommend the following electromagnetic spectrum definitions as shown in Table 1.

Table 1
ITU ELECTROMAGNETIC SPECTRUM DEFINITIONS (Allen et al., 1994)

Band	Abbreviation	Frequency Range
Extremely low frequency	(ELF)	range 30-300 Hz*
Voice frequency	(VF)	range 300 - 3000 Hz
Very low frequency	(VLF)	range 3 - 30 kHz
Low frequency	(LF)	range 30-300 kHz
Mean frequency	(MF)	range 300-3000 kHz
High frequency	(HF)	range 3-30 MHz
Very high frequency	(VHF)	range 30-300 MHz
Ultra high frequency	(UHF)	range 300-3000 MHz
Super high frequency	(SHF)	range 3-30 GHz
Extra high frequency	(EHF)	greater than 30 GHz

* This will also include sub harmonics below 30 Hz and harmonics above 30Hz.

Biological Effects of ELF fields

Magnetic fields can pass through most materials and when they enter the human body they can induce small electric currents. Bentham (1995,1996) and Becker (1990) provide many references referring to the impact of these fields on protein synthesis, activity of enzymes, changes in the immune system and other effects. 'Add on screens' to VDUs can eliminate the static and alternating electric fields but they do not affect magnetic field components. In addition these screens usually

reduce glare and reflections from the screen. Bentham (1995-96) reviews evidence from surveys of VDU for VLF fields which give magnetic flux densities ranging from 69 - 1150 nT (screens with electric field strengths ranging from 1 - 165 Vm⁻¹.) For ELF fields the magnetic flux density ranges from 6 - 200 nT (0.05 - 10 Vm⁻¹).

The Swedish National Board for Technical Accreditation (SWEEDAC) pioneered and introduced the first ergonomic studies for VDU screens in 1990, known as NPR 11 (SEEDAC 1990). This limits the emissions of the VLF (25 nT, 2.5 Vm⁻¹) and ELF (250 nT, 25 Vm⁻¹) magnetic and electric fields measured at 50 cm from the VDU in three planes.

Graham (1990) found changes in the body's fundamental processes when people are exposed to low frequency magnetic fields which resulted in the slowing down of the heartbeat and reduced ability to concentrate. He concluded that lower frequencies may be more harmful than the higher ones. Adey (1988) states that cells in the body communicate with each other by passing signals and chemicals from one cell to the other and if there is interference with this process then the cells can behave in a cancerous way. Electromagnetic fields can be one source which can disrupt this inter cellular communication process. Some of his earlier work showed that cells exposed to 15 Hz resulted in a loss of calcium ions from body cells. Electromagnetic radiation plays a vital role in different parts of the cellular processes including the transmission of nerve impulses.

More recently the work of Sienkiewicz and his colleagues at the National Radiological Protection Board (1998a) reports on the effect of 50 Hz magnetic fields on a spatial learning task by mice. The magnetic field had a flux density of 0.75 nT and lasted for forty five minutes. The conclusion from these studies was that power frequency magnetic fields *may* affect the processing of spatial information in rodents. Other studies have identified that acute exposure to high field strengths can cause a transient and reversible affect on learning behaviour. Sienkiewicz (1998b) suggests that the behavioural changes reported for mice may have implications of effects in humans, but extrapolating data obtained with animals to humans is notoriously difficult. Behaviour changes noted so far are not large and do not appear to last but nevertheless there could be implications for people working with VDUs in their workplace over several hours. Research is needed to resolve these questions.

Sienkiewicz (1998c) gives a review about the biological effects of electromagnetic fields. Earlier reviews by the National Radiological Protection Board are referred to. Whilst acknowledging that there have been well established perceptual effects and a few subtle responses have been observed with low frequency electromagnetic fields, these effects remain small in magnitude, short in duration and are reversible.

Some recent work by Preece (1998) and his colleagues at the University of Bristol on the effect of 50 Hz magnetic fields as regards to cognitive functions in humans concludes that power frequency magnetic fields of 0.6 nT can lead to some temporary deterioration in attention whilst working due to a loss of some memory performance. There does not appear to be any effect on the speed of carrying out a task. There does not appear to be any evidence with regard to these effects from a static magnetic field of the same magnitude.

ELECTROMAGNETIC RADIATION AND SICKNESS BUILDING SYNDROME EXPERIMENTS

Electromagnetic radiation can be reduced at source, by distance or by the introduction of various tuning fork resonance devices between the source and the person. This experiment uses an alpha

oscillator* and compares the building sickness syndrome scores for people with and without the oscillator attached to the VDU.

Method

A double blind crossover study was conducted among 107 office workers in the South West Health Authority, UK. The building sickness symptom scores were ascertained using a 19 item questionnaire covering general stress, environmental and ergonomic factors (see Appendix I). 46 subjects answered the questionnaire by interview (stage 1). Active and dummy alpha oscillator devices were given randomly to the 46 subjects situated in two wings. Neither the subjects nor the researchers knew from the colour coding which was an active or dummy device (stage 2).

After a month the subjects answered the questions again then swapped active for dummy devices and vice versa (stage 3). After a further month the subjects answered the questions again (stage 4).

An analysis of the findings took place after identifying the colour coding for the active, dummy devices. Stage 2 used active oscillators in the South Wing and dummies in the North Wing; in Stage 3 this situation was reversed.

Thus the only difference between the stages, apart from the day, was the introduction of an alpha oscillator which interacts with magnetic ELF's

Analysis and Results

Single paired t-tests were used in the statistical analysis thus eliminating any variation due to location of subjects. The average readings at Stage 1 was 6.652 symptoms per subject and at Stages 2 and 3 the average for active antennae was 4.457 (33% reduction from Stage 1) and 6.152 for dummies (7.5% reduction from Stage 1).

Comparing *Active* with Stage 1 gives

$$t = 6.00 \quad p < 0.001 \text{ highly significant} \quad (1)$$

Comparing *Dummy* with Stage 1 gives

$$t = 1.64 \quad = 0.054 \text{ not significant at 5\% level (placebo effect)} \quad (2)$$

The differences were normally distributed but non-parametric tests (Wilcoxon Signed Rank Test) was applied and similar conclusions were drawn. Power tests checks revealed there is almost 100% certainty that the conclusions are correct.

*Tecno AO (electromagneto-bioprotective technology; international patent) device is a magnetic oscillator (AO for alpha oscillator, peak of 8-12Hz; at ultra low magnetic intensity: 100-150fT) made of a double antenna filled with an electromagnetically treated saline solution.

CONCLUSIONS

Subjects in this office experience building sickness syndrome due to general stress, environmental and ergonomic factors healthy buildings usually score 4 or less symptoms per person. This building has an average score of over 6 per person (based on 20 symptoms). By the use of an alpha oscillator on the VDU the symptoms of building sickness were reduced by an average of 33% (t-tests analysis). Thus these symptoms are partly due to the low frequency radiation (1/3), which reacts with the alpha oscillator and prevents its transmission through the head to the brain, and to other factors (2/3).

Building sickness syndrome arises from various combinations of environmental factors. There is usually a principal factor which triggers a chain of events by initially lowering the immune system and hence increasing the likelihood of other factors affecting the body.

VDU's can provide three sources of trigger reactions those derived from posture, eyestrain and extremely low frequency radiation. In this experiment it has been shown that the latter can be highly significant.

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APPENDIX I

Stress, Environment and Ergonomic Questionnaire

Ref:	Name:	Organisation:			Department - Location
M F	Height	Age: <20 <40 <60 <60+		VDU hrs	Job Title - Activity
Date					

Have you experienced any of these symptoms in the last four weeks? 1 = yes 0 = no

	Stage	1	2	3	4	Comments
1. Headaches						
2. Cough/sneezing						
3. Dry, itchy or tired eyes						
4. Blocked or runny nose						
5. Tiredness/fatigue						
6. Rashes, itches, dry skin						
7. Cold or flu Symptoms						
8. Dry throat, thirsty						
9. Sore throat						
10. Breathing difficulties						
Pain stiffness or discomfort in						
11. Lower back						
12. Shoulders						
13. Neck						
14. Arms & elbows						
15. Hands, wrists & fingers						
Occasionally feeling						
16. Irritable, tense						
17. Depressed/pessimistic						
Occasional problems with						
18. Concentration						
19. Short term memory						
Total Raw Symptom Score						

Appendix II

Electric Fields: measured in volts per metre (Vm^{-1}).

Magnetic Field Strength: measured in ampères per metre (Am^{-1}).

Magnetic Flux Density: this is measured in the units of Gauss and the metric unit is the Tesla (T).
 $1\text{mG} = 100 \text{ NanoTesla}$ ($1\text{G} = 10^{-4}\text{T}$). $1 \text{ Gamma} = 10^{-5} \text{ T}$.

The geomagnetic field on the surface of the earth has a magnetic field strength which varies from 0.35 - 0.70 Gauss (35-70 micro-Tesla).

Magnetic storms: are classed according to their magnetic field strengths:

Very strong

Over 200 Gammas

Weak

50 Gammas

Pineal Gland: minimal detectable magnetic fields is 0.24 nT.

Schumann Resonance: this spectrum of the earth to ionosphere cavity resonance covers the range 1-30 Hz. The 8 Hz component has been regarded as particularly important and generally beneficial to living systems, and it also happens to coincide with the brain's alpha rhythm of 8-12 Hz.