NEAR EAST UNIVERSITY

Faculty of Engineering

Department of ELECTRICAL AND ELECTRONIC ENGINEERING

MOBILE PHONE AND HUMAN HEALTH

Graduation Project

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Iam foremost thanking god for the accomplishment of this graduation project .

I have to say that the feeling of accomplishing this project is the most enjoyable that my life after this point would change forever to a different direction .

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I thank my family for their constant encouragement and support during the

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And for my loving family I want them to know that they are with me in every single step I move forward and I would dedicate this work to : My ant Hafeetha mobaideen

My brother Mohammad Abaisat

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Last but not least I would also like to thank all friends who were always available for my assistance throughout this project."

ABSTRACT

RF radiation can cause thermal injury to tissues, but such effects have only been reported from exposures above the current guideline levels for the UK Pulse modulated RF fields can give rise to audible buzzing or clicking sounds, which are produced through thermoelastic expansion of soft tissues in the head.

These noises could be annoying, but would not be expected to cause any long-term adverse effect on health. Some studies have suggested that exposure to microwave radiation can lead to minor defects in the posterior pole of the lens of the eye, but this has not been a consistent finding, and there is no indication that any form of RF radiation has caused clinically important cataracts in exposed people.

Three out of five published studies have suggested a reduction in sperm counts in workers exposed to RF radiation, but all of these studies were small and one was of doubtful rigour. Few epidemiological data are available on the relation of RF radiation to female fertility, and the findings are inconclusive. RF radiation does not appear to induce spontaneous abortion in women who are exposed during pregnancy, but a small effect on risk cannot be excluded.

Although several studies have suggested that RF exposure of mothers is associated with an increased frequency of birth defects, the associations have not related consistently to any one class of malformation, and may reflect biases in the ascertainment of exposures.

The current balance of evidence does not indicate an effect of paternal exposure to RF radiation on the risk of congenital malformations. Nor is there consistent evidence that exposure of either mothers or fathers is related to other birth outcomes.

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INTRODUCTION

The exposure to the body from an RF field is determined by the strength of the electric and magnetic fields inside the body, which are different to those outside. It is not usually possible, however, to measure these internal fields directly.

Radiofrequency (RF) fields are generated either deliberately as part of the global telecommunications networks or adventitiously as part of industrial and other processes utilizing RF energy. People both at home and at work are exposed to electric and magnetic fields arising from a wide range of sources that use RF electrical energy. The RF electric and magnetic fields vary rapidly with time. The rates at which they vary cover a wide spectrum of frequencies and lie within that part of the electromagnetic spectrum bounded by static fields and infrared radiation, in this document the frequencies considered lie between 3 kHz and 300GHz. This range includes a variety of RF sources In addition to those used for telecommunications. This region of the spectrum, together with optical frequencies, is therefore referred to as non-ionizing.

A number of published reports describe incidents in which people have experienced short-term exposures to levels of RF or microwave radiation well above currently recommended exposure limits. These unusual exposures have occurred in various circumstances including work close to radio and radar antennas while they were transmitting, and failure of protective interlocks on microwave ovens. In some cases only part of the body was irradiated.

CHAPTER ONE

Electromagnetic Fields Sources and Exposure

1. Introduction

Radiofrequency (RF) fields are generated either deliberately as part of the global telecommunications networks or adventitiously as part of industrial and other processes utilizing RF energy. People both at home and at work are exposed to electric and magnetic fields arising from a wide range of sources that use RF electrical energy. The RF electric and magnetic fields vary rapidly with time. The rates at which they vary cover a wide spectrum of frequencies and lie within that part of the electromagnetic spectrum bounded by static fields and infrared radiation .in this document the frequencies considered lie between 3 kHz and 300GHz. This range includes a variety of RF sources In addition to those used for telecommunications .These is shown in Figure, together with the International telecommunications Union (ITU) bands. Even at the highest frequency of the range. 300GHz, the energy quantum, hf, where h is Planck's constant and f is frequency, is still around three orders of magnitude too small to cause ionization in matter. This region of the spectrum, together with optical frequencies, is therefore referred to as non-ionizing.

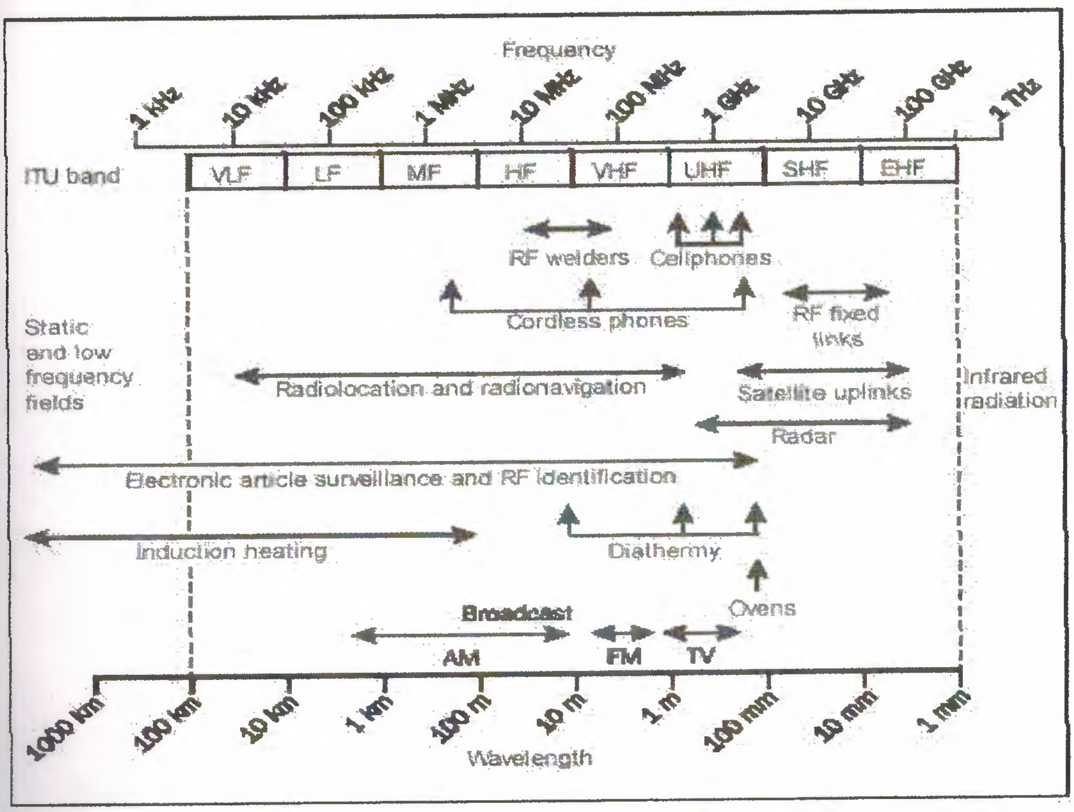


Figure 1.1 RF Spectrum and Sources

Frequency band	Description	Source	Frequency	Typical exposure*	Remarks
3 kHz	VLF Very low frequency	Induction heating	Up to 25 kHz	12 – 1000 A m^{-1}	Occupational exposures at close approach to coils, 0.1–1 m
		TV/VDU	15 – 30 kHz	1 – 10 V m^{-1}, 0.16 A m^{-1}	Public sitting at 30 cm from VDU
30 kHz	LF Low frequency	Induction heating	100 kHz	800 A m^{-1}	Limb exposures at close approach (0.1 m) to coils
		Electronic article surveillance (EAS)	130 kHz	Up to 20 A m^{-1}	Public exposure midway between panels when entering or leaving premises
300 kHz	MF Medium frequency	AM radio	415 kHz – 1.6 MHz	450 V m^{-1}	Occupational exposure at 50 m from AM broadcast mast
		Induction heating	300 kHz – 1 MHz	0.2 – 12 A m^{-1}	Occupational exposure
3 MHz	HF High frequency	Short-wave broadcast	3.95 – 26.1 MHz	340 V m^{-1}	Occupational exposure beneath wire feeders of 750 kW transmitter
		EAS	8 MHz	0.2 A m^{-1}	Public exposure close to a tag deactivating system
		PVC welding	27.12 MHz	Body: 100 V m^{-1}, 5 A m^{-1} Hands: 1500 V m^{-1}, 7 A m^{-1}	Operator position close to welding platform of a 10 kW dielectric heater
		Wood gluing	27.12 MHz	170 V m^{-1}	Operator body exposure at 50 cm from a 2 kW wood gluing machine
		CB radio	27 MHz (< 10 W)	1 kV m^{-1}, 0.2 A m^{-1}	Public exposure close to antenna of radio
30 MHz	VHF Very high frequency	FM radio	88 – 108 MHz	4 V m^{-1}	Public exposure at 1500 m from a 300 kW FM mast

Table 1.1 Sources of RF Radiation across the Spectrum and Typical Field Strengths/Power Densities at Accessible Locations

Frequency band	Description	Source	Frequency	Typical exposure*	Remarks
300 MHz	UHF Ultra high frequency	TV, analogue	470 – 854 MHz	3 V m^{-1}	Public exposure (maximum at ground level) from a high power 1 MW effective radiated power TV transmitter mast
		GSM handsets	900 MHz 1800 MHz	400 V m^{-1}, 0.8 A m^{-1} 200 V m^{-1}, 0.8 A m^{-1}	At 2.2 cm from a 2 W phone At 2.2 cm from a 1 W phone
		GSM base station	900 and 1800 MHz	1 mW m^{-2} (0.6 V m^{-1}, 1.6 mA m^{-1})	Public exposure at 50 m from a mast operating at a maximum of 50 W per channel
		Very Small Aperture Terminal (VSAT) Satellite Earth Station	1.5/1.6 GHz	8 W m^{-2}	Main beam direction
		Microwave cooking	2.45 GHz	0.5 W m^{-2}	Public exposure at 50 cm from an oven leaking at BSI emission limit
3 GHz	SHF Super high frequency	Radar air traffic control	1 – 10 GHz 2.8 GHz	0.5–10 W m^{-2} 0.16 W m^{-2}	Exposure at 100 m from ATC radars operating over a range of frequencies
		VSAT	4 – 6 GHz	< 10 W m^{-2}	Maximum in the main beam
		Satellite news gathering	11–14 GHz	< 10 W m^{-2}	Maximum in the main beam
		Traffic radar	9 – 35 GHz	< 2.5 W m^{-2} < 1 W m^{-2}	Public exposure at distances of 3 m and 10 m from 100 mW speed check radar
30 GHz – 300 GHz	EHF Extra high frequency	Transmission digital and analogue video signals	38 GHz/55 GHz	< 10^{-4} W m^{-2}	Public exposure at 100 m outside main beam of microwave dish

Table 1.2 These Are Typical Exposures At High Frequencies And In The Field Of Sources Where The Electric And Magnetic Field Strengths Are Orthogonal And To Each Other And To The Direction Of Propagation And There Is Simple Relation Btw E And H That Means The Wave Can Be Described In Terms Of The Power Density.

In contrast to ionising and ultraviolet radiation, where natural sources contribute the greaterproportion of the exposure to the population, man-made sources tend to dominate exposure to time-varying electromagnetic fields over the spectrum shown In Figure. Over parts of the Frequency spectrum, such as those used for electrical power and broadcasting, manmade fields are many thousands of times greater than natural fields arising from either the sun or the Earth. In recent decades the use of electrical energy has increased substantially, both for power distribution and for telecommunications purposes, and it Is clear that exposure of the population in general has increased. The otential for people to be exposed depends not only on the strength of the electromagnetic fields generated but also on their distance from the source and, In the case of directional antennas such as those used in radar and satellite communications systems, proximity to the main beam. High power broadcast and highly directional radar systems do not necessarliy present a source of material exposure except to specialist maintenance workers or engineers. Millions of people, however, approach to within a few centimetres of low power RF transmitters such as those used in mobile phones and in security and access control systems where fields can give rise to non--uniform, partial-body exposure. The field strengths often decrease rapidly with distance from a particular source.Everyone is exposed continually to low level RF fields from transmitters used for broadcast television and radio, and for mobile communications. Many Individuals will also be exposed to low level fields from microwave communications links, radar, and from domestic products, such as microwave ovens, televisions and VDUs. Higher exposures can arise for short periods when people are very close to sources such as mobile phone handsets, portable radio antennas and RF security equipment. Some of the sources of electromagnetic fields and the levels to which people are exposed both at work and elsewhere are shown in Table. The signals generated by various sources across the spectrum may be very different in character. While the underlying waveform from a source is usually sinusoidal, the signal may then, for example be amplitude modulated (AM) or frequency modulated (FM) for radio communication or pulse modulated for radar (Figure1.2a). Modem digital radio communication systems can use more than one of these types of modulation in the same signal (Figure 1.2b).Many industrial sources produce waveforms with high harmonic content resulting in complex waveforms (Figure 1.2c). Electric and magnetic field strengths outside the body are commonly used to describe exposure to the fields generated by RF sources. However, any biological effects would be the result of exposure within the body, although this cannot usually be measured directly. The nature of the fields and characteristics of particular RF sources differ considerably and the waveform, spatial and temporal characteristics of the field are important In exposure assessment and their effect on instrumentation. This chapter is concerned with exposure and its assessment arising from a wide variety of sources of RF fields. It gives general background Information about the nature of electromagnetic fields and their interactions with the body before considering specific sources and summarizing the exposures they create. Appendices A and B should be read in conjunction with this chapter. Appendix A illustrates and describes the types of equipment used for measuring fields, while Appendix B summarizes the

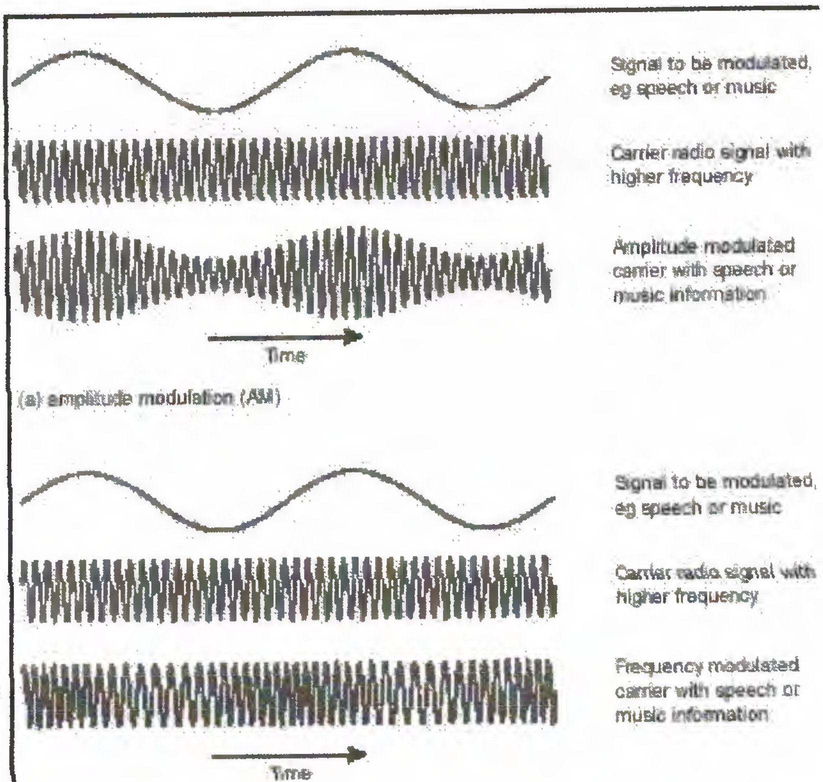


Figure 1.2 (a) Different Forms of Analogue Modulation Commonly Applied To Radio Signals

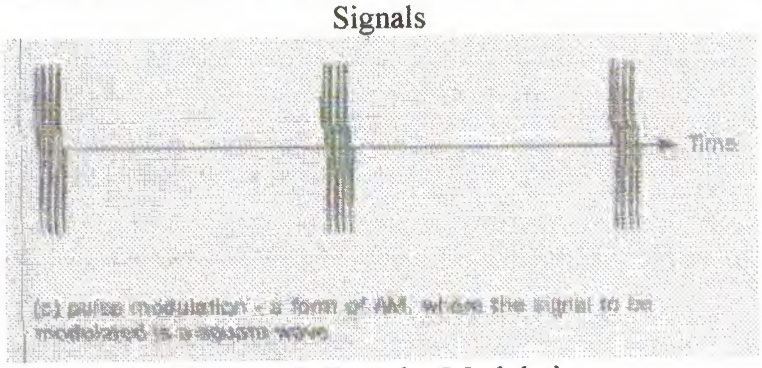


Figure 1.2 (b) Pulse Modulation

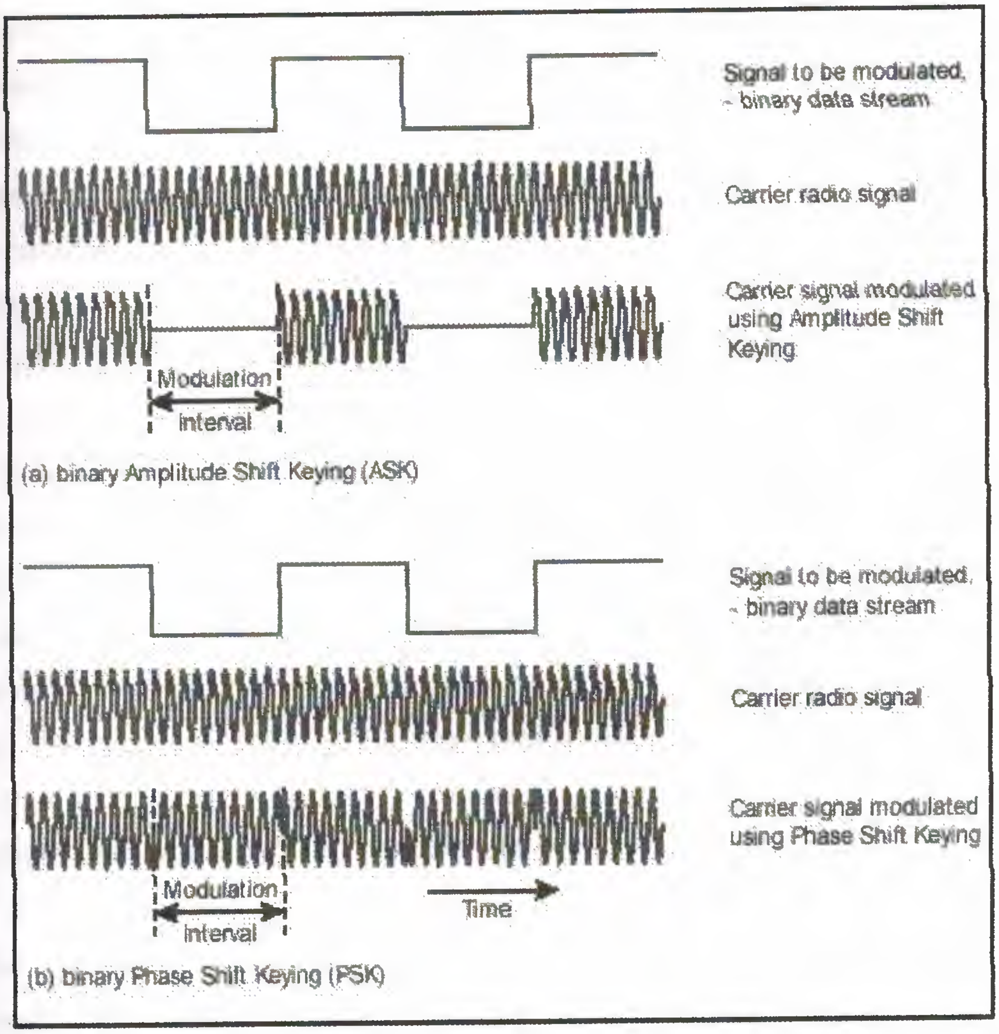


Figure 1.3 Examples of Two Simple Digital Modulation Schemes

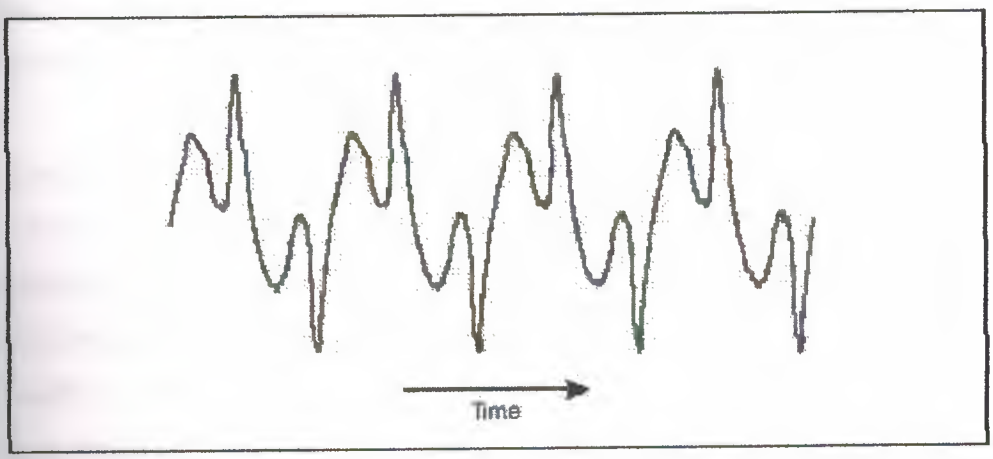


Figure 1.4 Industrial Magnetic Field Wave Form with High Harmonic Content

1.1 Characteristics of Electromagnetic Fields and Aspects of Dosimetry

The exposure to the body from an RF field is determined by the strength of the electric and magnetic fields inside the body, which are different to those outside. It is not usually possible, however, to measure these internal fields directly. So studies to evaluate exposure are normally carried out either by using computational methods or by making measurements on a physical model of the head or body .The computational methods rely upon the detailed anatomical Information that can be obtained by magnetic resonance Imaging plus Information on the electrical properties of the different components of the body tissue, bone, etc. The physical models, or phantoms, that have been used range from hollow shells filled with a fluid whose electrical properties are similar to the average values of body tissue, to more complex models using materials of different electrical properties. The electric field at various points inside simple phantoms is often measured using a robotically positioned probe controlled by computer. This is the type of approach used in assessing energy deposition in phantom heads arising from mobile phones. At the lower frequencies, below around 100MHz, it has also been possible to make direct measurements of the induced RF current flowing through the body and to earth. One technique uses a solenoidal coil placed around the ankles, or other parts of the anatomy; the RF body current passing through the coil induces a voltage in its windings. For simple exposure conditions the strength of the electromagnetic fields inside the body, and hence exposure, can also be assessed to a reasonable approximation from the strength of the fields present in that region before the body is placed there.

1.1.1 General Characteristics of Electromagnetic Fields

An electromagnetic field or wave consists of electric, *E*, and magnetic, *H,* fields that oscillate sinusoidally between positive and negative values at a frequency, *f*. The distance along a wave between two adjacent positive (or negative) peaks Is called the wavelength, X , and is inversely proportional to the frequency. The strength of the electric or magnetic field can be indicated by its peak value (either positive or negative), although it is more usually denoted by the rms, or root mean square, value (the square root of the average of the square of the field). For a sinusoidally varying field, this is equal to the peak value divided by *1.4* ($\sqrt{2}$). At a sufficient distance from the source where the wave can be described as a plane wave, the electric and magnetic fields are at right angles to each other and also to the direction in which the energy is propagating

The amount of electromagnetic energy passing through a point per unit area at right angles to the direction of flow and per second is called the power density (intensity). S. So, if a power of 1 W passes through one square metre, the power density is 1W m^{-2}. A long way from a transmitter, the positive (or negative) peaks in the electric and magnetic fields occur at the same points in space. Hence, they are in phase, and the power density equals the electric field strength multiplied by the magnetic field strength, $S=EH$.

1.3 Modulation

Where information such as speech is to be conveyed by radio, it is first converted into an electrical signal. This signal, which is of much lower frequency than RF, is then mixed with an RF signal. This mixing process is called modulation and can be achieved.In a number of ways. For example, in amplitude modulation (AM) the amplitude of the RF signal follows the fluctuations of the low frequency signal (see Figure 1.4), while in frequency modulation (FM) the frequency changes by small amounts proportional to the size of the low frequency signal at that time (see Figure 1.4). The RF signal that carries the information is called the carrier wave. Digital modulation systems involve defining a number of fixed amplitude and phase states for a carrier wave and then modulating the carrier wave so that it changes from one state to another according to the data to be transmitted (see Figure 1.4).Complex waveforms are not confined to signals generated by communication systems, For example, in the case of cathode ray tube displays such as those used in televisions and VDUs, the electron beam has to travel rapidly across the width of the tube and back even faster. The deflection is produced by an electric field with a variation in time, which resembles a saw-tooth.

1.3.1 Pulsing (Pulsed Modulation)

RF signals are often transmitted in a series of short bursts or pulses - for example, in radar applications. Radar pulses last for a time that is very short compared with the time between pulses. The pulse duration could be one microsecond (one-millionth of a second), while the time interval between pulses could be one millisecond (one-thousandth of a second). The signal reflected from a distant object also consists of a series of pulses and the distance of the object is determined by the time between a transmitted pulse and its reflection .The long interval between pulses is needed to ensure that an echo arrives before the next transmitted pulse is sent. Thus, a feature of radar signals is that the average RF power output over time is very much less than the power transmitted within a pulse, which is known as the peak power. The ratio of the time-averaged power to the peak power is known as the duty factor.

GSM mobile phone signals and TETRA handset signals (see paragraphs 37 and 43, respectively) are also pulsed, and In these cases pulsing is introduced to achieve time division multiple access (TDMA). This allows each frequency channel to be used by several other users who take it in turns to transmit (IEGMP, 2000; AGNIR, 2001). For GSM phones and base stations, a 0.58 ms pulse is transmitted every 4.6 ms resulting in pulse modulation at a frequency of 217 Hz; pulsing also occurs at 8.34 Hz and at certain other frequencies (IEGMP, 2000). The most recent GSM phones, often described as 2½G, have enhanced data capabilities and can transmit pulses of greater durations that are multiples of 0.58 ms .In the extreme case, pulses that fill the entire 4.6 ms could be produced and pulsing would disappear. For TETRA handsets and mobile terminals, the main pulse frequency is 17.6 Hz The signals from TETRA base stations are continuous and not pulsed (AGNIR, 2001).Third generation (3G) mobile phones use a system that in Europe Is called UMTS (Universal Mobile Telecommunications System). The modulation system, code division multiple access (CDMA), allows several users to use the same frequency channel by 'labelling' each of their transmissions with a specific coding scheme. The UMTS standards allow for communications to be carried out between handsets and base stations using either frequency division duplex (FDD) mode or time division duplex (TDD) mode. FDD mode Is used with systems currently being deployed In the UK and this uses separate frequency channels for transmissions From the handset and the base station .Each transmission is continuous and so there is no pulsing, although the adaptive power control updates (see paragraph 41) that occur at a rate of 1500Hz will cause this component to `colour` the otherwise broad spectrum of the power modulation. With TDD mode, transmissions are produced in bursts at the rate of 100Hz and so pulsing would occur at this frequency, in addition to the frequency of the adaptive power control.

1.4 Source-Dependent Considerations

The properties of an electromagnetic field change with distance from the source. They are simplest at distances more than a few wavelengths from the source and a brief description of properties in this far-field region is given below. In general, the fields can be divided into two components: radiative and reactive. The radiative component is that part of the field which propagates energy away from the source.while the reactive com-ponent can be thought of as relating to energy stored In the region around the source. The reactive component dominates dose to the source in the reactive near-field region, while the radiative part dominates along way from it in the far-field region. Whilst the reactive field components do not contribute to the radiation of energy, the energy they store can be absorbed and indeed they provide a major contribution to the exposure of people in the near-field region. The measurement of the reactive components of the field can be particularly difficult since the introduction of a probe can substantially alter the field. Roughly speaking, distances within about one-sixth of a wavelength ($\lambda/2\pi$) from thesource define the reactive near-field region, while distances greater than $2D^2/\lambda$ (where D is the largest dimension of the antenna) define the far-field region. Since Dis usually comparable in size to λ (or larger). $2D^2/\lambda$ is roughly comparable to λ (or greater). Distances between $\lambda/2\pi$ and $2D^2/\lambda$ form a transition region In which radiative field components dominate ,but the angular distribution of radiation about the source changes with distance. This is known as the radiating near-field region. Since wavelength is inversely proportional to frequency, it varies considerably, from 1mm to 100km over the range of RF frequencies considered here (3kHz - 300GHZ). Hence, for frequencies above 300MHz (or 1 m wavelength) exposure tends to occur in the far-field region except when approaching very close to the source. This is not the case at lower frequencies.

1.5 Far-Field Characteristics

As already noted, the power density of an electromagnetic wave, S, is equal to the product of the electric and magnetic fields, $S= EH$ Since $E= 377H$ (assuming the quantities are all expressed in SI units), this becomes

$S=E^2/377 = 377H^2$ (Wm^{-2})

Hence $E=19\sqrt{S}(Vm^{-1})$ and $H=0.052\sqrt{S}(Am^{-1})$

Table illustrates the far-field values of electric field strength and magnetic field strength for power densities from 0.1 to 100 Wm^{-2}.

1.6 Near Field Characteristics

The field structure in the reactive near-field region is more complex than that described above for the far-field .Generally, the electric and magnetic fields are not at right angles to each other and they do not reach their largest values at the same points in space, ie they are out of phase. Hence, the simple relation between S, E and H given in Table is not obeyed and calculations of energy absorption in tissue in this region are more complicated than in the far-field region.

Power density ($W m^{-2}$)	Electric field strength ($V m^{-1}$)	Magnetic field strength ($A m^{-1}$)
0.1	6.1	0.016
1.0	20	0.052
10	61	0.16
50	140	0.36
100	200	0.51

Figure 1.5 Examples of Far-Field (Plane Wave) Relation Ships

1.7 Dissymmetry

Dissymmetry is the term used to describe the process of determining internal quantities relating to exposure in tissues such as the electric field strength, induced current density and energy absorption rate, from external fields. Both experimental and numerical dosimeters techniques are used. The experimental techniques frequently involve the use of fluids with electrical properties similar to the averages for those of the exposed tissues. Very small probes are used to measure the electric fields inside the models, while minimizing the changes in the fields produced by the presence of the probe. The numerical techniques use anatomically realistic models of an average person, together with values of the electrical properties for the different simulated tissues in the model Both dissymmetric techniques can calculate internal fields for a fixed body and source geometry - for example, that which might be expected to give maximum coupling between them, and hence maximum exposure. Neither numerical nor physical phantoms can easily be flexed at joints, so considering moving people requires a number of fixed positions to be evaluated in sequence. Given the effort involved with constructing multiple phantoms and performing multiple assessments, this poses a challenge for evaluating typical time-averaged exposures in terms of dosimetric quantities.At frequencies below 100 kHz, the electrical quantity identifiable with most biological effects is the electric field strength in tissue, which is related to the current density. However, the more appropriate quantity at higher frequencies is the specific (energy) absorption rate. SAR, which is related to the electric field strength squared in tissue. At Frequencies above about 1 MHz, the orientation of the body with respect to the incident field becomes increasingly important .The body then behaves as an antenna, absorbing energy in a resonant manner that depends upon the length of the body in relation to the wavelength. For standing adults, the peak of this resonant absorption occurs in the frequency range 70-80 MHz if they are electrically isolated from ground and at about half this frequency if they are electrically grounded. Smaller people and children show the resonance characteristic at higher frequencies. In the body resonance region, exposures of practical significance arise in the reactive near-field where coupling of the incident field with the body is difficult to establish owing to non-uniformity of the field and changing alignment between the field and body. In addition, localized increases in current density and SAR may arise in parts of the body as a consequence of the restricted geometrical cross-section of the more conductive tissues. As the frequency increases above the resonance region, power absorption becomes increasingly confined to the surface layers of the body and is essentially confined to the skin above a few tens of GHz.

1.8 Body Currents

Body currents in people can be determined using a whole-body model. Currents Induced by electric fields usually flow through the legs and feet to the floor (ground). So the currents can be obtained from the voltage drop across a resistance placed between the feet and the floor or by using a coil around the ankles. The situation is more complicated, however, if the currents are eddy currents Induced by magnetic fields. Such currents circulate about the cross-section of the body, are greatest near the surface and do not usually leave the body through the feet or at any other point. Hence they are difficult to measure.

1.9 Specific (Energy) Absorption Rate (SAR)

The rate at which energy is absorbed by a particular mass of tissue, *m*, is $m\sigma E^2/\rho$, where σ and ρ are, respectively, the electrical conductivity and density of the tissue and E is the rms value of the electric field strength. The quantity $\sigma E^2/\rho$ is called the specific (energy) absorption rate and is measured in watts per kilogram

(Wkg^{-1}). It varies from point to point in the body both because the electric field changes with position and also ecause the conductivity is different for different types of tissue (the density is much the same for all tissues apart from bone). In practice, the SAR may be ascertained by averaging over a small mass of tissue or over the whole body mass. Both approaches are used for comparison with the limits on exposure advised in protection guidelines. The most commonly used methods for the direct experimental measurement of SAR involve measurement of the internal electric field strength or the rate of temperature rise within an exposed object. The internal electric field strength may be measured with an implantable E-field probe but this is not practicable where living people are concerned. So, as noted earlier (see paragraph 11), SARs are usually measured using phantoms or are calculated.

1.10 Radio Frequency Sources and Exposure

The sources of exposure discussed in this section include intentional radiators such as the antennas used for telecommunications, RF identification, and security and access control. Other sources include those that give rise to adventitious emission of RF fields - for example, those used for induction heating, dielectric heating and an microwave cooking. Many of the measurements reported here are `spot measurements', ie they are made at a point in space and at a point in time. Often the data represent maximum field strengths that a person may encounter when near a source, as is appropriate for comparison with reference levels (ICNIRP, 1998). Sometimes the spot measurements are analysed further to take account of time and spatial variations in the electromagnetic field, particularly where spot measurements show the presence of field strengths approaching the ICNIRP reference levels.

1.10.1 Communications

Antennas generate electromagnetic fields across the spectrum At very low frequencies (VLF) the structures are massive with support towers 200-250 m high and the Yields may be extensive over the site area. Electric field strengths of several hundred Vm^{-1} may be encountered within the boundary defined by the antenna structures. Magnetic field strengths in the range 2-15 A m^{-1} have been measure close to VLF antenna feeds and 0.2-52 A m^{-1} close to LF towers. In transmitter buildings magnetic field strengths were in the range <0.1 mA m^{-1} -11 A m^{-1}. Through these frequency bands and up to about 100MHz under uniform field exposure conditions, measurements and calculations have been made of induced currents related to external field strengths. The currents induced in the body that flow to ground through the feet (short-circuit current) rise to a theoretical maximum of 10-12 mA per V m^{-1} at the resonance frequency of around 35MHz for an electrically grounded adult (Chen and Gandhi. 1989; Dimbylow, 1991). Measurements indicate that under more normal grounding conditions, e.g. when wearing shoes, the current is reduced to about 6-8 mA per V m^{-1}. At distances from antennas comparable to or smaller than their physical dimensions, field distributions can be non-uniform. This is particularly so for mobile and portable systems where the field strengths change rapidly with distance from the antenna. Electric field strengths of about 1300 V m^{-1} have been measured at 5cm from 4W CB transmitters, whereas at 60cm the field strengths fall to less than 60V m^{-1} (Lambkin, 1978). In the USA, long before the advent of mobile telephony a study of population exposure to background fields from VHF and UHF broadcast transmitters (Tell and Manti ply, 1980) showed that the median exposure for 15 cities was 50 μW m^{-2} (0.14 V m^{-1}), although some cities had median exposures of 200 μ W m^{-2} (0.3 V m^{-1}). Maximum exposures, which were from local FM radio stations, were about 0.1 Wm^{-2} (6Vm^{-1}). These values are all well within the ICNIRP reference levels of about 25 to 60 V m^{-1} for this frequency range (ICNIRP, 1998).

1.10.2 Handheld Equipment

Handheld radio transmitters include mobile phones, cordless phones. emergency service communications (e.g. TETRA) and professional mobile radios PMRs (walkie-talkies). Newer devices include laptop, palmtop and wearable computers with built-in antennas. The radiating structures of these devices tend to be integrated into or onto their body-shell and will typically be within a few cm of the user's body. The output power levels range from a few mW for cordless phones up to a few watts for PMRs, and the frequency bands range from 30 MHz to 5GHz.

1.10.3 Mobile Phones

The most widespread handheld transmitter is the mobile phone. The large majorities of mobile phones in use in the UK is so-called second generation or 2G phones and use the SM900 or GSMI800 systems. Table 2.3 lists these systems and also some other systems that are available in the world. Rather few analogue {First generation) phones are still in use and the UK networks, which used ETACS (an extension to the Total Access Communications System), were shut down in *2000/2001.* First generation networks used in other parts of the world include AMPS (Advanced Mobile Phone Systems) and NMT (Nordic Mobile Telephony). Second generation networks in North America include D-AMPS, CDMA IS-95 and PCS, or GSM19OO. PDC phones are used in Japan.

Mobile phone system	Type	Frequency band (MHz)	Maximum time-averaged power (W)
NMT (Nordic Mobile Telephone)	Analogue	450, 900	1
ETACS (Extended Total Access Communications System)	Analogue	900	0.6
AMPS (Advanced Mobile Phone System)	Analogue	800	0.6
D-AMPS (Digital AMPS)	Digital	800, 1900	0.2
GSM900 (Global System for Mobile Telecommunication)	Digital	900	0.25
GSM1800/1900	Digital	1800, 1900	0.125
IS-95 (CDMA Code Division Multiple Access)	Digital	800, 1900	0.2
PDC (Personal Digital Cellular)	Digital	800/1500	0.2

Table 1.3 Mobile Phone Systems and Handset Powers

The table does not include the 2½G phones (GPRS. HSCSD. EDGE) currently being introduced as extensions to GSM to allow access to the internet etc, or the 3G phones (UMTS - Universal Mobile Telecommunications System) being introduced The 2½G phones are extensions to GSM900/1800 with a maximum peak power output of 1W. However, the average power output for data transmission can be higher than with voice transmissions since there may be transmission for more than one-eighth of the time. Even so, when using the phone for data transmission it would not normally be held close to the head. Third generation phones in the UK operate around 1950MHz and have the same output power as GSM phones operating in the 1800 MHz band, i.e. 125 mW. At distances less than 1cm from the antenna the localized electric field strengths may be hundreds of volts per meter. However, such localized field strengths produced in the absence of a body and so close to an antenna cannot be used as a ready measure of exposure. In these circumstances, the mutual interaction of the head and phone must be fully taken into account. The approach taken to determine exposure in people has been to use models and assess the internal dissymmetric quantity, SAR, as a function of the power fed to the antenna (Diablo and Mann, 1994). Standardized procedures for assessing SAR have been developed by various bodies including CENELEC (2001) and manufacturers now provide information on measurements made on various models. Figure (1.6) An Example Of The Maximum SAR Values Measured In A Phantom Model Of The Head For A Range Of Mobile Phones. The values are maxima found when each of the phones was placed in a set of standard positions and radiated at a number of standard frequencies. Whilst the SAR, values are based on the maximum output power of the particular phone the exposure of the user will vary according to location, the position of the phone relative to the head and the size of the head The geographical location is particularly important since adaptive power control (APC) can reduce the power emitted by the phone by up to a factor of 1000. Personal exposure will also depend on the average number and duration of calls. Where compliance with guidelines is concerned, it is necessary to average over an appropriate time period specified, eg any six-minute period.

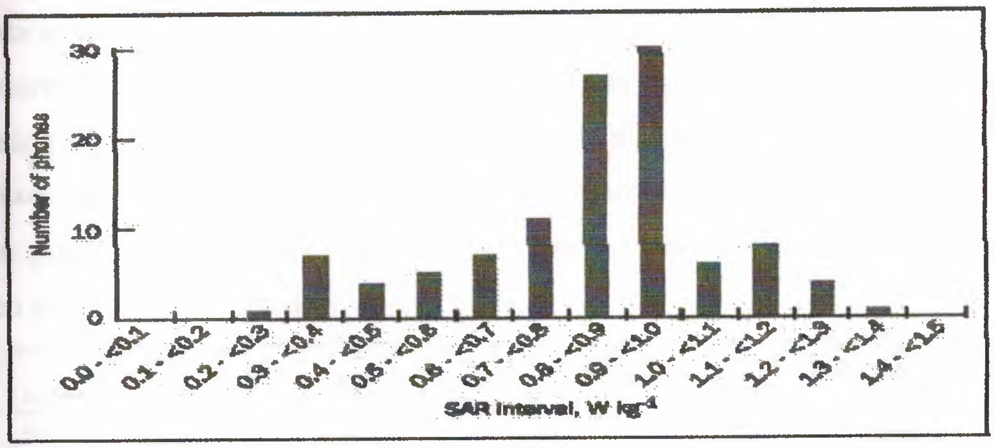


Figure 1.6 Distributions of SARs Produced By 111 Mobile Phone Handsets

1.10.4 Cordless Phones

Both analogue cordless phones (for example, CTO, CT1 and JCT) and digital cordless phones (for example, CT2, DECT and PHS) have average output power levels of around 10 mW. However, digital systems can involve time sharing and so peak powers can be higher - for example, with DECT the peak power is 250mW with no adaptive power control and the emissions are in the form of 400μs bursts. Average powers are thus ten or more times smaller than those from mobile phones operating at their highest power level (see Table 1.4a). Hence, the powers should result in much smaller values of SAR than those shown in Figure. Even so, it is conceivable that in normal use phones favourably located with respect to a base station would reduce their output power and therefore the SAR below that of cordless phones.

1.11 Tetra

Since 1997, countries including the UK have been introducing an emergency service radio system known as terrestrial trunked radio (TETRA). The system operates using frequecies around 400MHz and the digitally based features provide improved data transmission capabilities and added security over existing analogue systems. The features of the system, in particular the discontinuous nature of the waveform, which is similar to GSM in that TDMA (see paragraph 18) is used, and similar to older mobile radio in that it uses push-to-talk mode, have been considered in depth in an earlier report by the Advisory Group (AGNIR, 2001). The duty factors of the hand-portable equipment mean that average powers for the 1 and 3W transmitters are 0.25 arid 0.75W, respectively, but could increase if additional available channel space were to be utilized for data transmission. A comparison of output powers is given in Table(1.4b).

Exposures have been estimated for maximum power transmission using experimental modeling (Gabriel. 2000) and the SAR produced in a phantom head is shown in Table. Increases due to channel utilization would in theory increase the SAR by a factor of four but in practice the exposure conditions are likely to change when data rather than speech are being transmitted.

System	Maximum output power (W)		APC available
	Peak	Average	
Analogue police radio (450–460 MHz)	1.5	1.5	–
TETRA* Class 3 radio (380–385, 410–415 MHz)	3	0.75	✓
TETRA* Class 4 radio (380–385, 410–415 MHz)	1	0.25	✓
GSM900 (890–915 MHz)	2	0.25	✓
GSM1800 (1710–1785 MHz)	1	0.125	✓

* APC is available for TETRA handsets in their usual trunked mode of operation, but not when they are used in direct mode (AGNIR, 2001).

	SAR (W kg^{-1}) for 1 W radio			SAR (W kg^{-1}) for 3 W radio		
	Spatial peak	1 g averaged	10 g averaged	Spatial peak	1 g averaged	10 g averaged
Left ear	1.40	1.16	0.89	5.07	3.92	2.88
Right ear	1.72	0.94	0.88	5.07	2.74	2.33
Front	0.35	0.28	0.24	0.92	0.72	0.53

Table 1.4 (a) Peak And Time-Averaged Out Put Powers For Various Types Of

Different Handheld Radio Terminals When Operating At Their Maximum Power Level (For One Time Slot). **(b)** Measured **SARs** Produced In A Phantom Head Expose To Radio Signals From 1 And 3 **WTETRA** Hand Portables.

1.12 Bluetooth Technology

This is a technique for connecting mobile devices (computer, mouse, mobile phone, etc) using radio rather than wires. The systems operate at 2.45GHz with a 1mW peak power permitting them to be used over a 10 m range. The low power outputs will give rise to correspondingly low exposure, well below guideline levels.

1.13 Wireless Local Area Network (Wireless LANs)

These are systems for networking computers and other portable devices via radio. The computer terminals are known as clients and have antennas either mounted outside their body-shell or integrated internally. The clients communicate to fixed access points with antennas that receive/transmit the radio signals From/to the clients and provide an interface with a conventional wired computer network. Many of these systems use the IEEE8O2.1 la and IEEE8O2.1 lb standards (IEEE, 1999.2000), which are limited to peak output powers of 100mW in Europe. IEEE802.11a uses frequencies in the bands 5.15-5.25.525-5.3.5 and 5.725-5.825 GHz. and a modulation scheme known as OFDM (orthogonal frequency division multiplexing). IEEE8O2.1 lb uses frequencies in the 2.4-2.4835GHz range with spread-spectrum modulation, using either CDMA or frequency hopping. Wireless LAN transmissions are intermittent and so time-averaged powers will be lower and depend on the amount of data transmitted by a device. Exposures to wireless LAN equipment will depend on how the transmitting antennas are located with respect to the body, the duration of any transmissions and the peak output power. NRPB has made measurements of the power density of radio waves generally in and about the offices where wireless LANs are deployed and these have always been found to be very much below the ICNIRP reference levels (ICNIRP. 1998). The situation is rather more complicated for exposure within the first few cm of the transmitters. eg for the situation where a laptop computer is placed on someone s lap. This is the situation where exposure would be highest and there is no practical assessment that can be rapidly performed to check levels with an installed system. Nevertheless, given the low powers, it would be expected that these would comply with current guidelines.

1.13.1 Hands-Free Kits

An important feature of hands-free kits for use with mobile phones is that they move the major source of RF exposure, the antenna, away from the head and sometimes also from other parts of the body. The kits consist of an earpiece and a microphone connected to the phone either with wires or a wireless Bluetooth radio link The use of a hands-free kit would be expected to reduce the SAR in the head because of the increased distance between the antenna and the head and because Connecting wires would not be expected to form an efficient RF waveguide. Nevertheless, It has been claimed that, under certain conditions, the SAR near to the earpiece of a wired hands-free kit can exceed the SAR at the same point from the phone when that is held next to the head (Consumers' Association. 2000). However, the methodology used for this work has been criticized (Bit-Babik et al, 2003).

1.13.2 Fixed Antennas - Broadcast and Telecommunications

The frequency bands used for broadcasting terrestrial radio and television services in the UK are shown in Table. The approximate number of transmitters, grouped by band and power, is shown in Table (1.5a, b).

Designation	Frequency range	Usage
LF (long wave)	145.5 – 283.5 kHz	Radio
MF (medium wave)	526.5 – 1606.5 kHz	Radio
HF (short wave)	3.9 – 26.1 MHz	International radio
VHF (Band II)	87.5 – 108 MHz	FM radio
UHF (Band IV–V)	470 – 854 MHz	Television

	Effective radiated power, ERP (kW)					
Service class[†]	0–0.1	>0.1–1.0	>1.0–10	>10–100	>100–500	>500
Analogue TV	3496	589	282	122	86	19
Digital TV	134	177	192	2	–	–
DAB	4	126	121	–	–	–
VHF FM radio	632	294	232	98	72	–
MW/LW radio	14	125	38	19	12	–

Table 1.5 (a) Broadcasting Bands In The UK. **(b)** Broadcast Transmitters In The UK.

1.13.3 Digital Terrestrial Broadcasting

In the UK this comprises Digital Audio Broadcasting (DAB) radio services and Digital Video Broadcasting (DVB-T) for terrestrial (as opposed to satellite) television Transmissions have also commenced in the MF and HF bands in the Digital Radio

Mondiale (DRM) format. DAB in the UK uses frequencies in the 220MHz region, a total of seven multiplexes have been allocated in the UK The channel width of a DVB-T multiplex is 8MHz (the same as a conventional TV channel), and the width of a DAB multiplex is about 1.5MHz. All systems are based on a digital modulation scheme - coded orthogonal frequency division multiplex (COFDM). In this scheme there are a number of discrete carrier frequencies spaced across the channel block which carry the digital information (DVB-T uses 1705, and DAB uses 1536 equally spaced carriers). Modulation of the carriers implies that there are short-term excursions in output power, which in the extreme could lead to a maximum of 32dB above the average output level. Engineering considerations mean that this is limited in practice to 10dB ($\times$ 10) above the average value. The total power of the DAB and DVB-T transmissions is lower than that for analogue broadcasts; the highest power DVB-T transmitter has an average ERP (*effective* radiated power) of 10kW per multiplex, as opposed to its analogue counterpart with a total of 1000kW ERP per service. A DAB channel transmitter will also have an ERP up to 10kW, but often lower. This can be compared with a main VHF FM transmitter ERP of 250 kWper service. People subjected to the highest exposures will be antenna riggers and engineering staff working in transmitter halls or under open-wire antenna feed lines. The following sections present measurements that have been made in the vicinity of permanent broadcast installations.

1.14 MF and HF Radio

Measurements have been made by NRPB of the electric and magnetic fields and body currents close to a number of HF broadcast antennas and feeder arrays where fields maybe non-uniform and can vary by a factor of two over the body height. In some localized areas, the maximum electric field was 340 $V\,m^{-1}$. Where the spatially-averaged value of the field strength over the body height was less than 60V m^{-1}, induced body currents were below 100 mA. The maximum magnetic field strength was 0.5A m^{-1} (Allen et al, 1994). As part of a preliminary study to investigate if the exposure of broadcast and tele- communications workers can be appropriately categorized, personal dosemeters have been worn by various workers on HF sites to provide an indication of relative exposure. The exposure information so gathered was downloaded from data-logging devices attached to a commercially available `pocket' instrument incorporating orthogonal electric and magnetic field sensors. Figure shows a typical trace acquired in this way in which the electric field index of exposure is a percentage of the corresponding ICNIRP occupational reference level (ICNIRP, 1998). Measurements at an MF station with one 50 kW and one 70kW transmitter showed fields of $60 \mathrm{V\,m^{-1}}$ beneath the antenna feeders. Fields in excess of $1500 \mathrm{~V\,m^{-1}}$ were measured 1.5 m from the half-wave vertical antenna mast. In the USA measurements have been made of electric and magnetic field strengths at distances of 1 to 100m from a number of AM broadcast towers (Mantiply et al, 1997) with operating powers from 1 to 50kW over the frequency range from 500kHz to 1.6MHz. Within a metre or two of the towers electric field strengths were between 95 and $720 \mathrm{V\,m^{-1}}$ and magnetic field strengths ranged from 0.1 to $9.3 \mathrm{A\,m^{-1}}$. At 100m the electric and magnetic field strengths varied over an order of magnitude to $20 \mathrm{~mV\,m^{-1}}$ and $76 \mathrm{~mA\,m^{-1}}$, respectively. A review of general population exposure (Hankin, 1986) revealed that the median exposure of the urban population to AM broadcast in the USA was $280 \mathrm{mV\,m^{-1}}$ and 98% of the population were exposed to levels above $70 \mathrm{~mV\,m^{-1}}$.

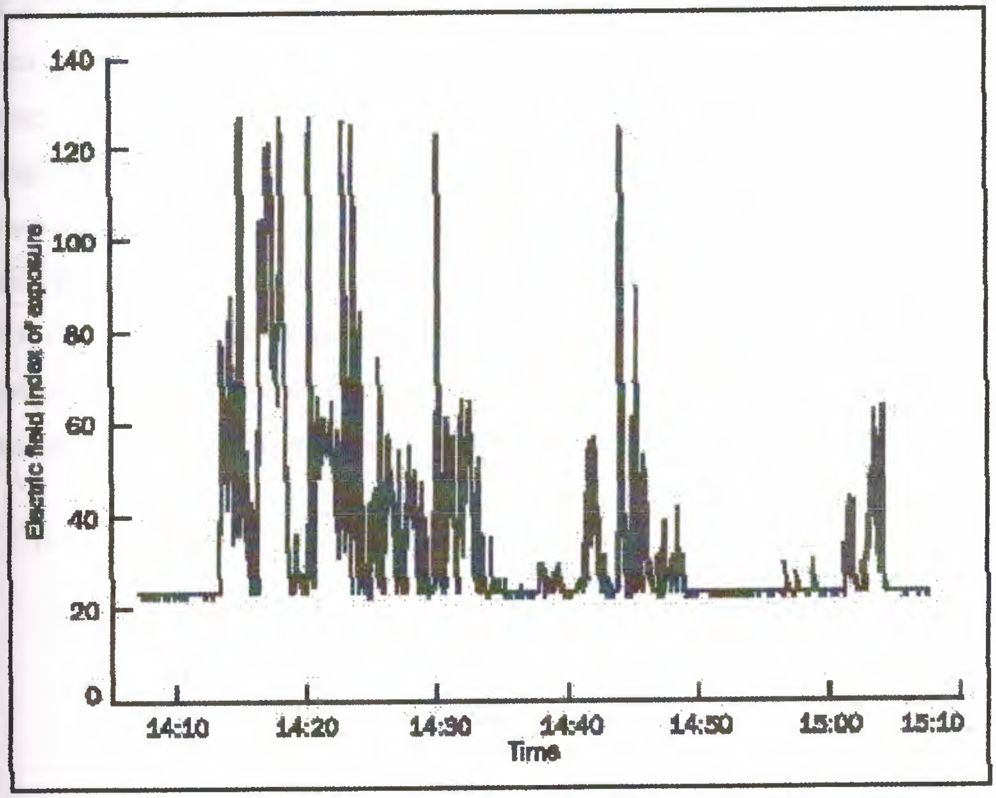


Figure 1.7 Trace Acquired From a Body-Mounted Personal Exposure Meter Worn By a Worker at an HF Broad Cast Site

1.15 VHF Transmitters

In a similar manner to that described for HF measurements, electric and magnetic field strengths have been assessed for antenna riggers while they were climbing on masts behind operating antenna stacks. Examples of the Field variation during these periods are shown in Figures (1.7a,b) and (1.8a,b). For one antenna rigger climbing through a 250kW VHF FM antenna array, time-and spatially-averaged electric and magnetic field strengths were 92 $V m^{-1}$ and 0.22$A m^{-1}$, respectively; the peak fields encountered were 250 $V m^{-1}$ and 0.38 $A m^{-1}$.

1.16 Mobile Phone Base Stations

The mobile phone base station is ubiquitous and there are around 35000 in the UK. Antennas used with macrocellular base stations are generally placed between 15 and 50 m above ground level because they are designed to provide communication over distances of several kilometres. Microcellular base stations have their antennas mounted nearer ground level as communications are only carried out over distances of a few hundred metres. Picocellular base stations provide localised coverage inside buildings.Antennas tend to be mounted directly on. Existing structures, such as buildings, when this is convenient, but ground-based lattice towers, shorter masts mounted on roofs, and lamp-post type systems are also used. The power classes specified by standards for GSM transmitters operating at 900 and 1800MHz are shown In Table () ,However, not all classes of transmitter are necessarily used in practice. Base stations can utilise more than one transmitter but in the UK it is unlikely that a single transmitter operates at powers exceeding 100 W on a macrocellular site. Whilst

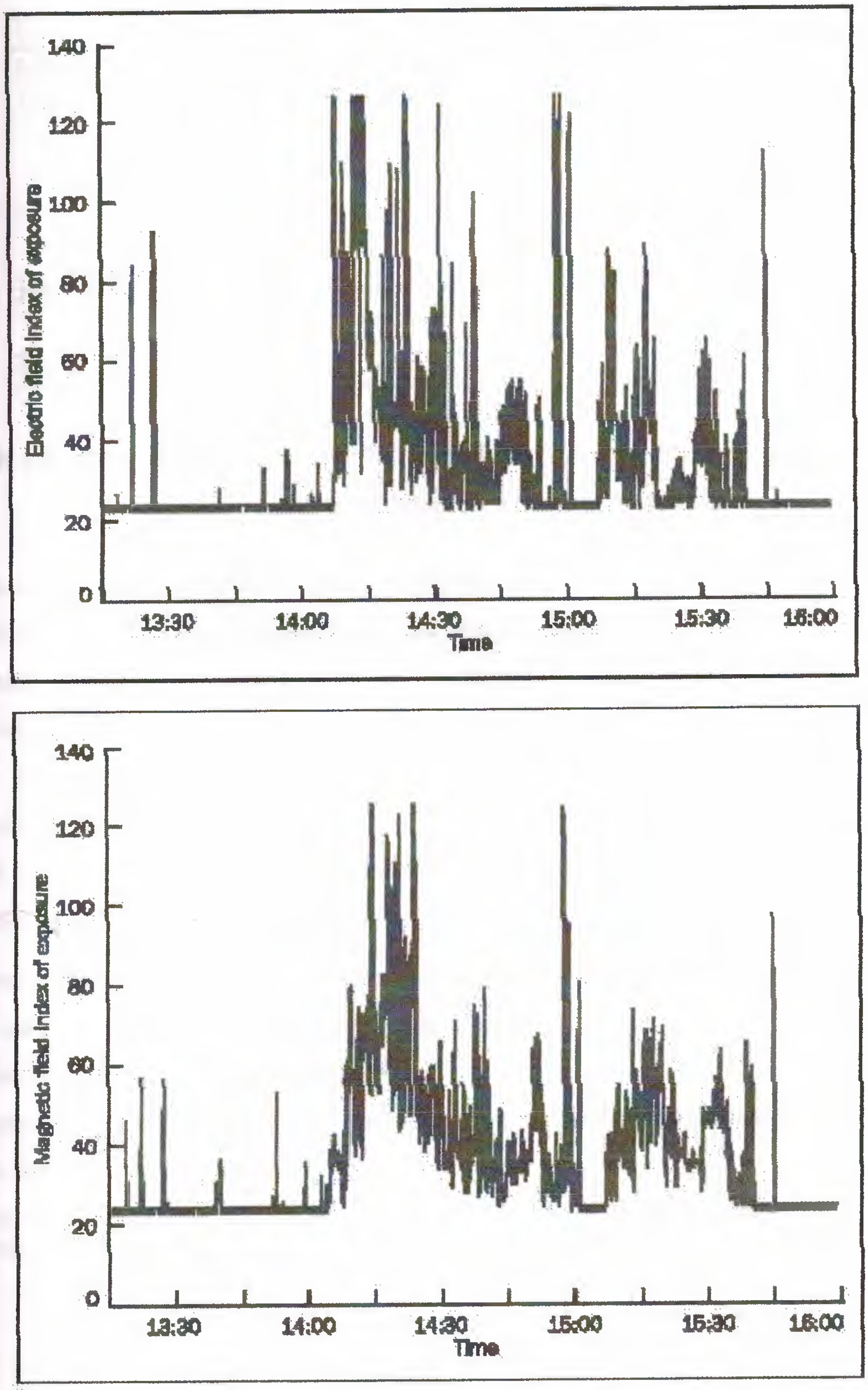


Figure 1.8 (a) electric field trace acquired from a body-mounted personal exposure meter worn by a worker at a vhf broad cast site. **(b)** Magnetic field trace acquired from a body-mounted personal exposure meter worn by a worker at a vhf broadcast site.

GSM900			GSM1800		
Cell type	Power class	Power (W)	Cell type	Power class	Power (W)
Macro	1	320 - (< 640)	Macro	1	20 - (< 40)
	2	160 - (< 320)		2	10 - (< 20)
	3	80 - (< 160)		3	5 - (< 10)
	4	40 - (< 80)		4	2.5 - (< 5)
	5	20 - (< 40)			
	6	10 - (< 20)			
	7	5 - (< 10)			
	8	2.5 - (< 5)			
Micro	M1	(> 0.08) - 0.25	Micro	M1	(> 0.5) - 1.6
	M2	(> 0.025) - 0.08		M2	(> 0.16) - 0.5
	M3	(> 0.008) - 0.025		M3	(> 0.05) - 0.16
Pico	P1	(> 0.02) - 0.1	Pico	P1	(> 0.04) - 0.2

Table 1.6 Output Powers From GSM900 And GSM 1800 Base Station Transmitters, As Defined In The GSM Phase 2+ Technical Standard .

these are potential transmitter output powers, the power density arising from a particular antenna will depend upon power into the antenna and the gain of the antenna, the product of which gives the effective isotropic radiated power (EIRP). Licence restrictions placed on EIRPby the Radiocommunications Agency for purposes other than ensuring compliance with guidelines act to restrict the power density from individual transmitters. In a study carried out by NRPB (Mannetal,2000) at 118 locations on 17 sites, where signals were obtained from base stations, most of the exposures were between $10\,\mu W\,m^{-2}$ and $1mW\,m^{-2}$, the maximum being $8.3mW\,m^{-2}$. At locations where power density exceeded $1mW\,m^{-2}$, the local base stations dominated the signal strength and other environmental signals had little additional effect. Figure (1.9) shows the measured total power density from the base stations local to the measurement sites. In 73 locations, all radio signals over the range from 30MHz to 3GHz were evaluated and these are summarised in Table (1.7) and flgure (1.9).

In the UK measurements have been carried out by the Radiocommunications Agency (2003) as part of a base station audit recommended by IEGMP (2000).

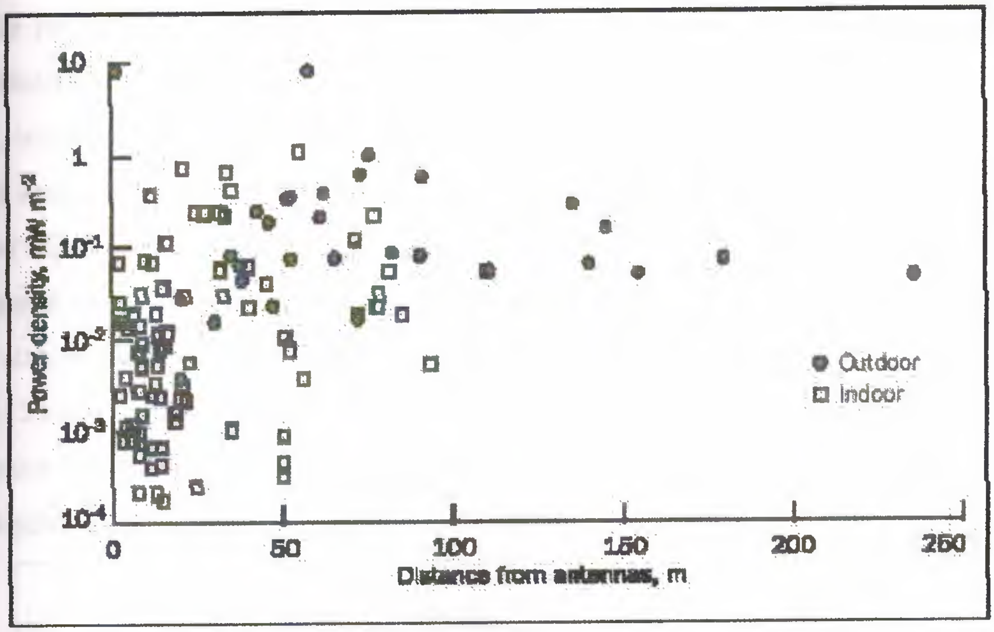


Figure 1.9 Total Power Density From Local Base Stations

	Geometric mean and range (5th-95th percentiles) of power density (μW m^{-2})			
	Local base stations	Total of all signals	Total neglecting local base station	Total neglecting all base stations
Indoor	17 (0.32-570)	75 (1.9-1000)	16 (0.76-970)	5.0 (0.23-420)
Outdoor	130 (19-930)	240 (49-1700)	37 (0.5-360)	12 (0.5-360)
All locations	33 (0.91-700)	110 (3.5-1100)	21 (0.84-970)	6.6 (0.23-380)

Table 1.7 Geometric Mean Power Densities

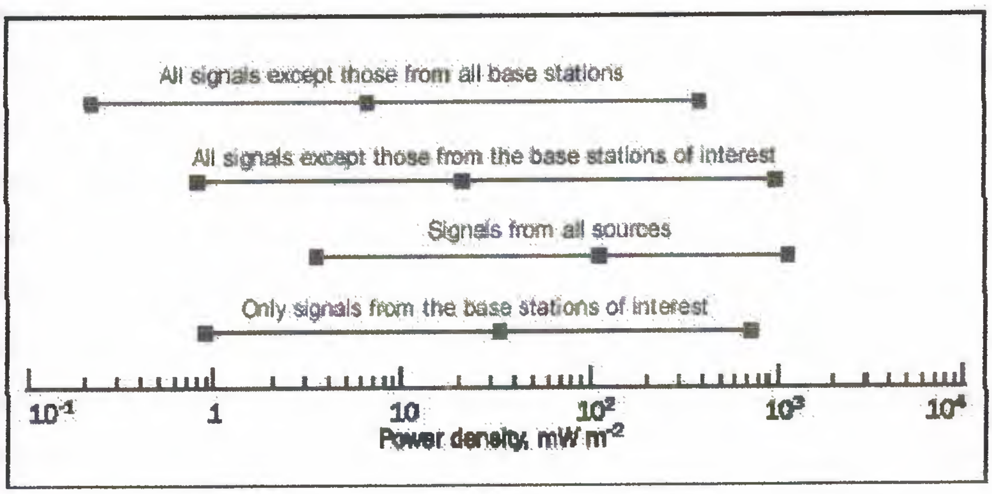


Figure 1.10 Range And Mean Power Density From All Measured Signals

The audit concentrated on what were described as `sensitive sites' close to mobile phone base stations, such as schools and hospitals. In addition to the majority of GSM mobile phone signals, ten sites where TETRA antennas were mounted were assessed specifically with regard to the strength of those signals. The progress and results of the audit, including the TETRA measurements, are summarised in Table 1.8.

In all cases, measurements of fields from base stations at positions of normal public access show that exposures are a small fraction of exposure guidelines. It has been suggested that, for epidemiological studies, an appropriate surrogate for exposure to base station fields might be the distance of a particular residence from the base station mast. There are material difficulties in using what appears to be a simple index of exposure based on distance from the source. These difficulties are associated with the low signal strength associated with public exposure, the contribution from other

Year	Schools	Hospitals	Other	Maximum fraction of ICNIRP public reference level
2001	100	-	-	1/279
2002	82	27	4	1/731
2003 to date	38	3	-	1/1834
TETRA: 10 sites				1/336

Breakdown by exposure fraction decade						
	$>10^{-2}$	$<10^{-2}-10^{-3}$	$<10^{-3}-10^{-4}$	$<10^{-4}-10^{-5}$	$<10^{-5}-10^{-6}$	$<10^{-6}$
Excluding TETRA	-	11	93	105	37	8
TETRA: 10 sites	-	6	3	-	1	-

Table 1.8 Radio Comunications Agency Mobile Phone Base Station Audit Summary

environmental sources of RF with similar field strength magnitude, and the variability in the local field strength that depends upon the call traffic. In addition, the propagation of fields to locations in homes is affected markedly by local perturbation. It has been concluded (Schuz and Mann, 2000) that this metric is a poor proxy taking into account the directional beam characteristics, the scattering, attenuation and reflection of the signal by houses, and the contribution from other sources. Spot measurements in homes are unlikely to be a good indicator of exposure over Time in the light of time-dependent signal variability, the effect of signal attenuation by housing material and the presence of other RF sources. One possibility of carrying out exposure prediction is the use of software tools owned by the mobile phone operating companies for the purposes of research.

1.17 Terrestrial And Satellite Microwave Links (3-200 GHz)

Frequencies used by fixed-site telecommunications services range from the VLF band to the high microwave region Services include public and private communications networks, satellite ground stations and control/telemetry services to remote sites The majority of these are point-to-point microwave communications links, but the principles of exposure assessment would apply equally to mobile systems A summary of fixed microwave links is given in Table (1.9a).

Most of these systems use parapolic dish reflectors up to 3.7m in diameter, mounted on towers or buildings. Satellite uplink services are detailed in Table (1.9b). The Very Small Aperture Terminal (VSAT) systems are transportable. A theoretical assessment of the power density from a typical 14GHz VSAT terminal has shown that the power density rises along the axis in front of the dish for about 40 m but then starts to fall off. These systems generally use parabolic reflectors of circular cross-section with diameters varying from 1 or 2 metres to tens of metres with many falling in the range 5-15 m. Since these diameters are much greater than the 2cm wavelength, the antenna gains are very large, ranging from 30 to 80dB, so that line-of-sight communication is possible over large distances. The power output normally varies from less than a watt to a few watts but may be in excess of a kilowatt for satellite links. Various approaches have been used to estimate the potential exposure to fields from such antennas

Band (GHz)	Power to antenna (W)	Number of installations
1.7-2.45	5	250
4	20	1200
6	10	3000
7	-	500
11	10	1800
13	10	1500
15	3	500
18	0.4	1600
23	1	4500

Type	Band (GHz)	Power (W)	Dish (m)	Number
Broadcast uplink	14	600	3-5.5	12
VSAT	14	2-5	1.8	200

Table 1.9 (a) Fixed Microwave Links İn The UK . **(b)** Satellite TV Uplinks.

(Hankin, 1974; Ministry of Defence, 1989). Although, in principle. It is possible to be exposed to power densities of a few hundred Wm^{-2} (a few hundred $V m^{-1}$) near these high power antennas, this is most unlikely to be the case for members of the public. The antenna is directed at a satellite so, since nearby buildings need to be avoided, exposure to the main lobe is unlikely to arise. Only people who have access to the vicinity of the reflector or approach the usefull beam at low elevation angles are likely to be materially exposed and their exposure he to fields around a few tens of W m^{-2}, below the ICNIRP reference level for occupational exposure (ICNIRP, 1998). Public exposure at normally accessible positions will be typically below 10^{-4} Wm^{-2} (0.2 Vm^{-1}) at distances in excess of 100m measured along the axis of the dish.

1.18 Induction Healing

RF induction heaters are used extensively in industry for a variety of purposes such as surface hardening, zone refining annealing and brazing. The frequency and power used depend upon the process requirements but an important parameter in choice of frequency is the depth of penetration of the field or skin depth. The powers range from about 1 to 10kW and the coils may be small, single-turn devices of a few cm diameter used for heating localised regions of a product to larger multi-turn systems.

Measurements of electric and magnetic field strength made on induction heaters operating in the frequency range from 395 kHz to 3.8MHz (Cooper ,2003)are summarized inTables (1.10) and (1.11).

Machine	Frequency (kHz)	Power (kW)	Reference level ($V m^{-1}$)	Distance from unit (cm)	Electric field strength ($V m^{-1}$)
1 (coil 1)	395	10	610	20 100*	100 30
1 (coil 2)	395	10	610	10 100*	300 20
2	2200	~1	277	10 30*	100 55
3	2400	~1	254	10 30*	100 55
4	3800	~1	161	10 30*	220 32
5	2550	~1	239	10 30*	45 <10

Table 1.10 Electric Field Strenghts From İnduction Heaters.

At frequencies of 300 to 500kHz operator exposure to 16 induction heaters (Conover et al,1986) of nominal RF output powers ranging from 2.5 to 50kW, indicated that the magnetic field strengths were in the range <0.08 to 17.6 Am^{-1}. Measurements on ten heaters with powers ranging from 2.5to 15kW in the frequency range from 300 to 790 kHz (see Table) illustrate that fields can be highly localised. Coil impedance rises with frequency and, at frequencies of several hundred kHz and above, electric field strengths may become of greater relevance than magnetic fields when compared to exposure guidelines. In general, it is necessary to make measurements of both electric and magnetic field strength around LF, MF and HF induction heaters.

Machine	Frequency (kHz)	Power (kW)	Reference level (µT)	Distance from unit (cm)	Magnetic field strength ($A\,m^{-1}$)
1 (coil 1)	395	10	5.1	5 30 100*	336 14.4 2.8
1 (coil 2)	395	10	5.1	5 30 100*	384 27.2 0.6
2	2200	~1	0.91	10 30*	5.0 <0.3
3	2400	~1	0.83	10 30*	2.4 <0.3
4	3800	~1	0.53	10 30*	2.3 <0.3
5	2550	~1	0.78	10 30*	5.8 0.4
6	0.15	1500	167	–	40
7	0.15	1500	167	–	21.6
8	1	750	30.7	15 100 250 500	1360 240 64 13.6
9	436	7.5	4.6	5 20	59.2 2.0

Table 1.11 Magnetic Field Strenghts From İnduction Heaters.

Frequency (kHz)	Magnetic field strength ($A\,m^{-1}$)			Electric field strength ($V\,m^{-1}$)		
	Head	Hands	Abdomen	Head	Hands	Abdomen
484	1.44	–	1.68	650	8175	500
743	0.88	0.72	0.40	160	213	32
394	1.52	12.88	5.44	168	840	70
300	0.24	0.24	0.24	16	16	8
630	1.28	0.80	0.80	35	35	23
785	14.64	9.92	0.72	929	310	36
715	18.00	–	6.72	1583	–	326
790	7.04	8.64	1.2	413	722	16
434	20.48	20.48	14.64	1192	1828	646
500	8.48	–	3.52	192	–	64

Table 1.12 Measurements At Specific Anatomical Positions.

Figure (1.11) shows the decrease with distance of electric and magnetic field strength from a 3.8Mhz induction heater. Figure (1.12) illustrates the non-uniform nature of the field distribution at positions occupied by an operator. Measurements tend to be made at specific positions but the information on time spent by operators at these positions is limited. The rapid variation in field strength at close distances to small coils is an

1.19 Plasma Discharge Equipment

1.19.1 Plasma Etchers

Plasma etchers are used in various stages of the semiconductor fabrication process to break down polymer etch-resistant coating etch metals deposited on the semi-conductor wafer, or assist in building up deposits on the wafer through plasma-assisted chemical vapour deposition (PACVD). The technique involves the delivery of RF energy to a pair of electrodes inside an evacuated reaction vessel, in which the wafers to be etched are placed, in order to establish and maintain a plasma discharge.

Model	Frequency (MHz)	Power (kW)	Reference level ($V m^{-1}$)	Distance (cm)	Electric field strength ($V m^{-1}$)
1	13.56	–	61	10	10
2	13.56	0.74	61	10	7
3	13.56	0.8	61	5	2
4	13.56	0.2	61	5	<0.5
5	13.56	0.5	61	5	<0.5
6	0.28	0.5	610	5	<0.5
7	13.56	–	61	25	27
8	13.56	0.06	61	5	<20
9	0.375	1.5	610	5	<0.5

Table 1.13 Electric Field Strenghts At A Specified Distances From The Reaction Vessels Of Plasma Etchers And Chemical Vapour Deposition Equipment.

Model	Frequency (MHz)	Power (kW)	Reference level ($A m^{-1}$)	Distance (cm)	Magnetic field strength ($A m^{-1}$)
1	13.56	–	0.16	5	< 0.05
2	13.56	0.74	0.16	5	< 0.05
3	13.56	0.8	0.16	5	< 0.05
4	13.56	0.2	0.16	5 20 30	1.54 0.28 0.07
5	13.56	0.5	0.16	20 30	0.16 < 0.05
6	0.28	0.5	5.7	5	< 0.08
7	13.56	–	0.16	25	0.006
8	13.56	0.06	0.16	5	< 0.05
9	0.375	1.5	4.3	5	< 0.08*
10	13.56	0.45	0.16	5	< 0.03
11	13.56	0.1	0.16	5	< 0.03
12	13.56	2	0.16	5	0.06†
13	13.56	0.4	0.16	5	< 0.03
14	0.38	1	4.2	5 20	13 0.5
15	0.14	130	11	5 10 30	50 8 2

Table 1.14 Magnetic Field Strenghts At Specified Distances From The Reaction Vessels Of Plasma Etchers And Chemical Vapour Deposition Equipment.

Measurements of electric and magnetic field strength close to plasma etchers and PACVD equipment and measurements of contact current from the surfaces of reaction vessels have been made (Cooper, 2003) and the results are given in Tables 1.16 and 1.17. The recorded electric and magnetic field strengths are representative of the maximum values at the specified distances from the reaction vessels. Measurements of field strength a few centimetres from the vacuum chambers represent hand exposures; exposures of the head or torso are indicated by measurements at greater distances.

1.19.2 RF Sputterers

RF sputterers are similar to plasma etchers in that the process applies coatings tocomponents placed inside an evacuated chamber by means of a plasma discharge. Measurements of electric and magnetic field strength have been made close to the vacuum chambers and control/matching units of four sputtering units operating at 13.56 MHz; the results are reported in Tables (1.15a) and (1.15b). It is unlikely that parts of the body such as the head or torso would be substantially exposed at the closest measurement distances given in Tables (1.15a)and(1.15b).

Model	Power (kW)	Distance (cm)	Electric field strength (V m^{-1})
1	3.6	5 15	150 22
2	3.5	3 10 20	280 10 <61
3	3.5	3 10 30	180 61 <27
4	0.08	5	<0.5

Model	Power (kW)	Distance (cm)	Magnetic field strength (A m^{-1})
1	3.6	5 15	0.53 0.12
2	3.5	10 30 50	>1.10 0.40 0.16
3	3.5	10 30	0.16 <0.07
4	0.08	5	<0.05

Table 1.15 (a) Electric Field Strengths From 1356 MHz RF Sputteering Units. **(b)** Mgnetic Field Strengths From 1356 MHz RF Sputtering Units .

1.19.3 Plasma Torch

Plasma torches are used as part of mass spectrometry systems. The torch assembly comprises a glass cylinder that contains the discharge electrodes. The coaxial coil was excited by a 27 MHz RF signal with an operating power of 1.4 kW - the electric and magnetic field strengths measured at various positions of the torso are given in Table (1.16).

1.19.4 Security And Access Control

Under the general heading of security and access control, there are three broad types of equipment that generate RF fields. These are metal detectors, electronic article surveillance (anti-theft devices) and RF identification (RFID) systems.

Operating conditions	Region of exposure	Electric field strength ($V\ m^{-1}$)	Magnetic field strength ($A\ m^{-1}$)
Inner and outer shields removed	Hands	316	2.2
	Head	30	0.14
	Torso	30	0.25
Inner shield in place, outer shield removed	Hands	-	0.22
	Head and torso	<30	<0.07
Inner and outer shields in place	All exposures	<30	<0.07
Reference level	-	61	0.16

Table 1.16 Electric And Magnetic Field Strengths Around A Plasma Torch.

1.19.5 Metal Detectors

Metal detectors are to be found in airports, prisons and other high security areas. The detectors can be of the walk-through type or handheld units for close body inspection.

1.19.6 Walk-Through Detectors

Walk-through detectors are usually configured as an arch with the vertical pillars containing the pulsed magnetic field coil generator and the receiver which detects currents induced in metal by the transmitter. Typically the pulses exhibit bipolar pulses which, when analysed, demonstrate broad spectral content peaking in the kHz frequency range. Figure (1.13) shows an example of a waveform of the magnetic field emitted by a walk-through metal detector. Table (1.17) gives measurements of peak magnetic field strength measured on two such metal detectors.

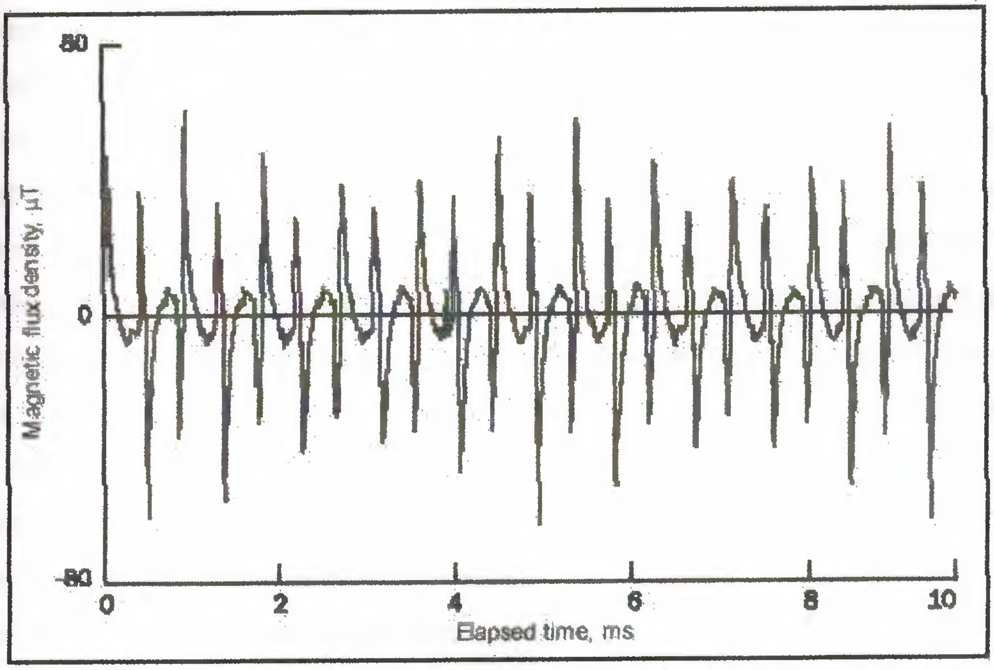


Figure 1.13 Magnetic Field Waveform From A Walk-Through Metal Detector

Metal detector	Peak magnetic field strength ($A\,m^{-1}$)
1	75
2	84

Table 1.17 Exposures From Walk-Through Metal Detectors.

1.19.7 Handheld Metal Detectors

The alternating current in the coils in handheld devices is often in the kHz frequency region. Eddy currents produced in nearby metal disturb the magnetic fields produced and lead to a change in the coil`s frequency response, which is detected. Examples of the magnetic field strengths generated by two metal detectors are shown in table (1.18).

Metal detector	Peak magnetic field strength, 2.5 cm from casing ($A\,m^{-1}$)	Frequency (kHz)
1	25	20
2	4	94

Table 1.18 Exposures from Handheld Metal Detectors

1.19.8 Electronic Article Surveillance

Electronic article surveillance (EAS) equipment is used to prevent theft from establishments such as shops and libraries EAS systems comprise a detection unit a tag to be detected and sometimes a tag deactivator. The principles of operation are similar to those of metal detectors and RFID systems In that an electromagnetic field is produced over a defined volume. If a tag that has not been deactivated, or removed from the item to which It is attached, enters the detection region, the resulting characteristic perturbation of the field is detected As with RFID systems a broad range of frequencies is used by different types of EAS equipment from sub-kilohertz frequencies to microwave frequencies. EAS detectors typically contain two or more elements for the generation and detection of fields which have the appearance of flat panels, loops or pillars and are positioned either side of the customer exit of the shop or library, etc. At least one of the elements contains transmitter coils: the other element or elements contain receiver coils, and possibly transmitter coils too if a Helmholtz configuration is employed. Systems also exist that employ just a single antenna containing coils that are connected to the transceiver. Deactivators are generally desktop devices installed at the customer checkout. Disposable tags containing resonant circuits may be deactivated by overloading the circuit using a pulsed RF magnetic field at the resonant frequency. Measurements of electric and magnetic field strength close to EAS equipment and of contact current from some devices have been carried out; the results are summarized in Tables (1.19a) and (1.19b). The field strength values given in these tables are the maximum ones measured at a given distance from the device. In the case of exposures to pulsed fields, the displayed field strengths are the maximum rams field strengths during a pulse.

1.19.9 Dielectric Heating (10-100 MHz)

Machines used for RF dielectric heating have been identified as potentially one of the most important sources of RF exposure amongst the working population and have been the focus of some attention (Conover, 1980; Erikson and Hansson Mild, 1985; Bini et al, 198o). The wavelength range in air of this type of equipment is 3-30 m, thus exposure occurs well within a wavelength of the source where complex field distributions occur. Dielectric heaters have output powers ranging from less than a kW to tens of kW and can be completely shielded and automated or be unshielded and operated manually.

Device	Frequency (MHz)	Transmission characteristics	Distance (cm)	Electric field strength ($V m^{-1}$)
Detector	7.4–9.1	Continuous, swept frequency	10	4.0
Detector (single antenna)	7.4–8.8	Continuous, swept frequency	2.5	< 1
Detector	7.4–8.8	Continuous, swept frequency	2.5	< 1
Deactivator (detection mode)	7.4–8.6	Pulsed, frequency stepped	10 20	89 21
Deactivator (detection mode)	7.4–8.8	Continuous, swept frequency	2.5	< 1
Deactivator (deactivation mode)	7.4–8.6	Pulsed, fixed frequency	10 20	86 20
Deactivator (deactivation mode)	7.4–8.8	Pulsed, fixed frequency	5 10 20	190 60 9

Device	Frequency (MHz)	Transmission characteristics	Distance (cm)	Magnetic field strength ($A m^{-1}$)
Detector	0.001953	Pulsed, fixed frequency	25 100	350 30
Detector	7.4–9.1	Continuous, swept frequency	15 20	0.09 0.06
Detector (single antenna)	7.4–8.8	Continuous, swept frequency	0 10 20	2.0 0.39 0.18
Detector	7.4–8.8	Continuous, swept frequency	15 35	0.12 0.03
Deactivator (detection mode)	7.4–8.6	Pulsed, frequency stepped	3 10 50	12.3 3.1 0.18
Deactivator (detection mode)	7.4–8.8	Continuous, swept frequency	2.5	0.12
Deactivator (deactivation mode)	7.4–8.6	Pulsed, fixed frequency	3 10 30 50	58 2.7 0.34 0.13
Deactivator (deactivation mode)	7.4–8.8	Pulsed, fixed frequency	5 10 20	10 3 0.8

Table 1.19 (a) Electric Field Strengths From Eas Dtectors And Tag Deactivators At Specified Distances From The Plane Of The Antenna Casing Of Each Device .The Dtectors Were Dual Antenne Systems Unless Noted Otherwise **. (b)** Magnetic Field Strengths From Eas Detectors And Tag Deactivators At Specified Distances From The Plane Of The Antenna Casing Of Each Device .The Dtectors Were Dual Antenna Systems Unless Noted Otherwise .

In general, the greatest exposure arises from machines of a few kW used for welding PVC where, in particular, operators of machines using C-frame presses to weld PVC often sit 30-50 cm from the welding electrodes. Electric field strengths can be up to 500 $V m^{-1}$ at the positions of the torso, and hands may be placed in regions where the field strength exceeds $1 kV m^{-1}$. Magnetic field strengths vary from less than $80 mA m^{-1}$ to about 0.4 $A m^{-1}$ at the position of the torso, whereas the hands may be transiently exposed to fields around several $A m^{-1}$.

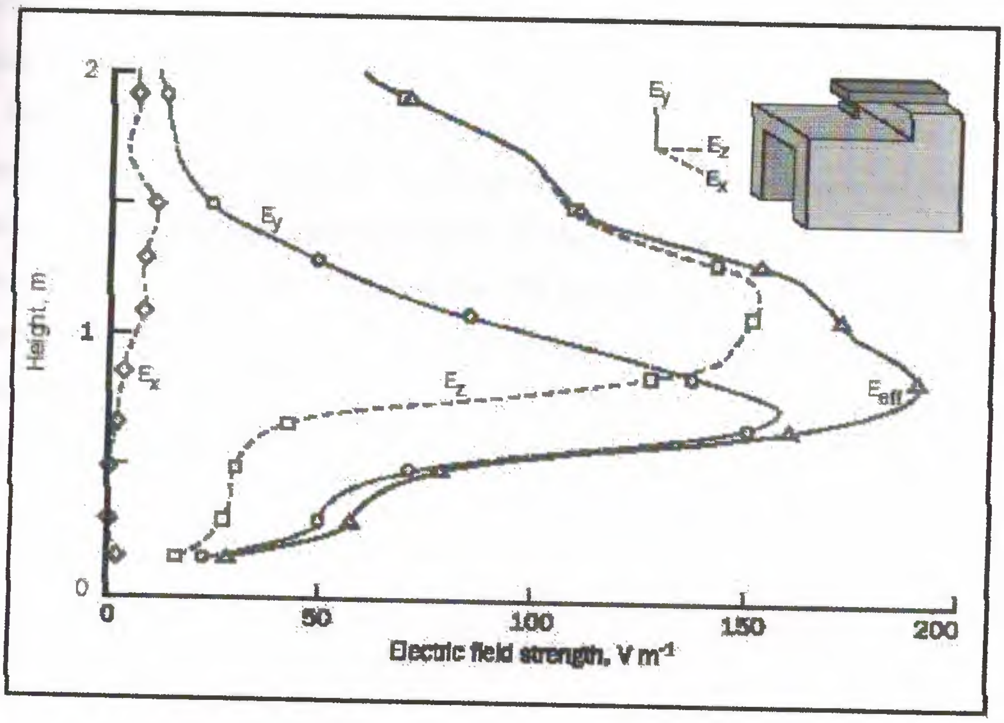


Figure 1.14 Electric Field Strength Distrbutions Neara 27.12 MHz PVC Welding Machine

The RF grounding of the frame of the machines can substantially affect the current distribution on the machine and therefore the magnetic field generated. In addition, the spatial distribution of electric field strength at positions occupied by the operators is highly non-uniform, resulting in a reduced energy absorption rate in the near-field. Figure (1.14) illustrates atypical electric field strength profile. The problems of evaluating exposure to this type of equipment are complicated by the nature of the work. The weld cycle is usually a matter of seconds and the duty factor (RF on time to total cycle time) can vary from about 0.1 to 0.5. During each weld cycle the field strengths vary and the operators may need to place their bands in regions of high field strength. At the frequencies used for RF dielectric heating it is possible to obtain a measure of the currents induced in the body resulting from exposure to the electric fields (Allen et al,1986; Conover et al 1992). The development of approaches using induced current provides an improved indicator of exposure. Table (1.20) gives the currents measured by NRPB For a variety of machines.

1.19.10 Diathermy

Short-wave and microwave diathermy is used as an adjunct to physiotherapy to alleviate acute or chronic conditions of the muscles, ligaments, tendons and joints by heating tissue using RF energy. The consequence of this tissue heating is stimulation of the blood supply and enhanced metabolism in the treated area. The levels of electromagnetic energy required to achieve desired localised temperature rises exceed those set down in current safety standards. In the case of the patient It is expected that there will be a net benefit. Some of the RF energy may be scattered and possibly absorbed by the operator. In the case of directed microwave energy it is possible that part of the useful beam, which does not irradiate the patient, could be intercepted by the physiotherapist.

Frequency (MHz)	Power (kW)	Ground	E_{max} (V m^{-1})	H_{max} (A m^{-1})	Duty cycle factor (DCF)	Operating ankle current (mA)		Non-operating ankle current (mA)	
							DCF corrected		DCF corrected
27	–	Rubber/concrete	280	–	0.3	84	46	79	43
27	3	Concrete	280	0.45	0.3	270	148	280	153
27	3	Concrete	212	–	0.3	85	47	55	30
27	1	Concrete	40	–	0.5	18	13	17	12
27	1.6	Concrete	150	0.16	0.3	100	55	–	–
28	15	Concrete	316	–	0.5	70	49	70	49
29	3	Wood/concrete	37	–	0.2	27	12	19	8
36	1.6	Rubber/concrete	30	–	0.5	17	12	13	9
45	7	Concrete	100	–	0.16	60	24	60	24
50	3	Concrete	113	–	0.13	190	69	120	43
51	7	Wood	100	–	0.2	37	17	37	17

Table 1.20 Electric and Magnaticfield Strengthes and Currents

1.19.11 Short-Wave Diathermy

In the case of short-wave diathermy equipment the electrodes are 'close coupled' to the treatment area (Table). Nonetheless, stray leakage fields will be present in the region of the applicator and from the supply leads.

Reference	Position	Electric field strength ($V m^{-1}$)	Magnetic field strength ($A m^{-1}$)
Hansson Mild 1980	1.7 m – 0.6 m from electrodes	43–600	0.12–1.2
	1 m from electrodes	270	0.32
	1.5 m – 0.35 m from leads	–	0.12–1.2
	1.5 m – 0.5 m from leads	43–430	–
Stuchly et al. 1982	0.2 m from electrodes	80– > 1000	0.3–2.0
	0.4 m from electrodes	40–500	0.2–0.8
	0.6 m from electrodes	20–160	0.1–0.6
Martin et al. 1990	0.2 m from electrodes	45–5000	0.03–11
	1 m from electrodes	3–90	0.002–0.6

Table 1.21 Fields From Short Wave 27.12 MHz Diathermy equipment

1.19.12 Microwave Diathermy

The frequency used for microwave diathermy is 2450MHz. Typically the operating power of such equipment is around 200W and energy is directed to the patient using reflector-type antennas, but the design and field characteristics of each type of applicator vary considerably. Power densities measured at distances varying from 0.3 to 1.2 m from five different applicators ranged from 0.3 to $100Wm^{-2}$. Power densities can exceed reference levels close to applicators. On the basis of stray field measurements made on available microwave equipment, parts of the body may be exposed transiently to power densities in excess of $50Wm^{-2}$ if the operator is in front of the plane of the front surface of the applicator.

1.19.13 Visual Display Units (VDUs) (15-30 kHz and Harmonics)

Visual display units used as computer displays are found in virtually every workplace and in many homes, the principal difference between VDUs and televisions that generate similar fields being the generally closer distance of people to VDUs. In addition to static electric fields, electric and magnetic fields are produced in the ELF and VLF bands from the power supply and the line-scan and screen refresh generators. There have been a number of studies quantifying the exposure to these fields (AGNIR,1994). Radiofrequency fields in the VLF range are generated by the horizontal deflection coils with a line-scan frequency typically from 15 to 35kHz with harmonics up to several hundred kHz. Measurements made at operator positions about 30-50cm from the screen indicate that the ElF and VLF electric field strengths are in the range 1-

15 V m^{-1}, although close to the surfaces of the equipment field strengths may be 200-300 V m^{-1}.

Parameter	ATC radar	Tracking radar
Wavelength	23 cm	3 cm
Peak power	2.3 MW	200 kW
Average power	3.4 kW	300 W
Aperture	10 m	1 m
Near-field boundary	154 m	12 m
Distance to 100 W m^{-2}	132 m	33 m
Distance to 10 W m^{-2}	553 m	102 m
Maximum power density in near-field	173 W m^{-2}	1528 W m^{-2}

Table 1.22 Typical Characteristics of Two Radar System

The VLF magnetic field strength at operator distances is in the range 4-480 mA m^{-1}, although most exposures are below 160 mA m^{-1}. ELF magnetic flux densities tend to be higher by a factor of two or more. Close to the VDU cases, VLF magnetic field strengths can be several A m^{-1}. Product emission standards are based on technically achievable values rather than on the basis of safety considerations however, exposure levels are considerably lower than those suggested in current guidelines.

1.19.14 Air Traffic Control

Responsibility for civil air traffic control (ATC) radars within the UK is undertaken by National Air Traffic Services (NATS). This includes primary (surveillance), approach, ground movement and secondary (transponder) radars. A summary of civil ATC radars is given in Table (1.23). For most radar systems there is a high peak power in the pulse compared with the average power determined from the pulse repetition rate and pulse width. In addition to the reduction in average power due to the pulse characteristics, surveillance radar systems such as ATC frequently use a narrow beam of only a few degrees (typically about $3°$) which is rotated several times per minute and this reduces the average power by a further factor. The beams are highly directional and, outside the main beam, the power density decreases by several orders of magnitude. Measurements at several hundred metres from such systems indicate average field strengths of tens of $\mathrm{mV\,m^{-1}}$ (around $10^{-5}\,\mathrm{W\,m^{-2}}$) and peak field strengths of several $\mathrm{V\,m^{-1}}$ (around $10^{-1}\,\mathrm{W\,m^{-2}}$). At an ATC test facility with the antenna stationary. NRPB has made measurements in the vicinity of a radar operating at a

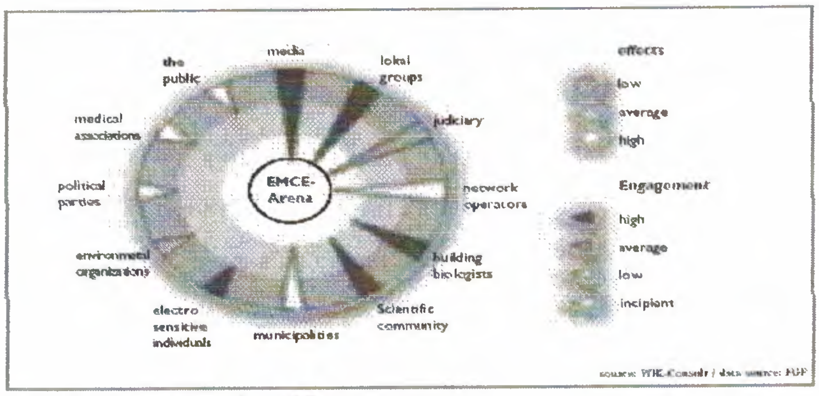


Diagram 1: actors' rolls in the EMCE- arena

Figure 1.15 Actors` Rolls İn The Emce-Arena

1.19.17 Risk Perception And The Public's Evaluation

Fundamentally the survey was based on a representative demographic variable according to sex, age, education, income etc. Information was obtained through telephone interviews (CATI), 1000 people were interviewed. 14-17 year olds were included in the survey but they were asked questions which were different from what the other interviewees were asked. In different sets of questions the interviewees were asked to give a general assessment on mobile phone use, they were also asked about the latest information on the subject, about an evaluation concerning risks related to mobile radio communication, about possible precautionary measures and providing information. Since the survey itself was so broad the results can only be presented in a condensed outline form.

CHAPTER TWO

Human Brain Activity and Cognitive Function

2. Recent Experimental Studies

The IEGMP (2000) report reviewed studies investigating the effects of mobile phone signals on brain activity or cognitive performance that had been published as of early 2000. In respect of brain (EEG) activity, the report concluded that, while findings were inconsistent, the balance of the evidence favoured the view that mobile phone signals at exposure intensities within international guidelines (ICNIRP, 1998) produced reliable changes in brain activity. A similar conclusion was reached in respect of cognitive performance: whereas inconsistencies remained, findings from three studies (Preece et al, 1999; Koivisto et al, 2000a,b) suggested that exposure to low intensity mobile phone signals gave rise to a slight shortening of reaction time on certain cognitive tasks, in the absence of an effect on error rates. This chapter reviews relevant studies published since the completion of the IEGMP Report, namely those studies concerned with direct effects of mobile phone signals on cognitive function and electrical measures of brain activity. Indirect effects, such as distracting effects of mobile phone conversations during driving are not covered.

2.1 Brain Activity

Hietanen et al (2000) recorded resting EEGs from 19 volunteers during sham exposure, and exposure to signals from five different mobile handsets (analogue and GSM at 900 and 1800 MHz) operating at full power and positioned over the left side of the head. Specific (energy) absorption rates (SARs) were not given, but peak power was reported as between 1 and 2W. Statistical analysis of spectral parameters of the EEG revealed an effect in only one frequency band in one exposure condition. The authors attributed this finding to chance. Lebedeva et al (2000) recorded EEGs from 24 subjects during sham exposure and exposure to a 900 MHz signal (quoted intensity 0.6 $W\,m^{-2}$) directed at `the back of the head'. The EEG was quantified by indices representing the `dimensional complexity' of the signals; these were reported to vary significantly as a function of exposure condition, leading the authors to conclude that their chosen measure of EEG was more sensitive to the effects of radiofrequency (RF) signals than conventional indices. It should be noted, however, that the results of this study were reported in the absence of almost any information about how the data were analysed statistically, and with no information about levels of statistical significance. Krause et al (2000) investigated event-related `desynchronisation` of the EEG elicited by the visual presentation of letters during an 'n-back' working memory task. Twenty-four subjects were employed, using an on/off single-blind procedure with a 900MHz GSM signal (2W peak output) transmitted through a handset positioned over the right side of the head. Exposure effects were observed in two specific bands of the EEG spectrum, at 6-8 and 8-10 Hz, although for 'target' letters only. There were no exposure effects on the behavioural measures of error rate and reaction time (cf Preece et al, 1999; Koivisto et al, 2000a,b).The authors concluded that, as in their previous study, the findings suggested that RF effects on the EEG are most prominent during active cognitive processing. Jech et al (2001) studied EEGs in 22 patients with narcolepsy. In 17 of these patients brain activity (event-related potentials) was studied during a visual `oddball` task. In this task, rare horizontally-striped 'targets' (the oddballs) were interposed among presentations of more frequent non-targets (vertical stripes). Both classes of stimulus could occur in full field, or restricted to one or other side of the visual field. Exposure was double-blind, with sham exposure and exposure conditions occurring on separate days (ordering of conditions was counterbalanced). Recordings were obtained during exposure, which took the form of a 900 MHz GSM signal transmitted from a commercial headset mounted over the right ear; the SAR was estimated to be 0.06 W kg^{-1}. No effects of exposure were found for any measure of sleep behaviour or EEG. However, exposure was found to enhance the amplitude of two components of the brain's response to the oddball stimuli (`N2' and 'P3a' components), but only when the stimuli were presented to the right half of the visual field. This effect was most marked in waveforms from right hemisphere electrodes. In addition, exposure was found to shorten reaction time to both stimulus classes by approximately 20 ms.These findings add to previous reports (IEGMP, 2000) of such effects on cognitive and brain function of RF exposure within ICNIRP (1998) guidelines. One caveat concerning the generality of the findings arises from the nature of the study sample, which was composed exclusively of narcoleptic patients, the majority of whom were medicated. It is possible, therefore, that the findings reflect an unusual sensitivity to RF exposure in such Individuals, although this would not detract from their importance in demonstrating that low level RF exposure can lead to biological effects.Croft et al (2002) recorded EEGs from 24 subjects in a single-blind on/off design, focusing on both event-related desynchronisation during an auditory discrimination task and parameters of the resting EEG. Exposure was via a 900 MHz GSM handset positioned over the midline posterior scalp. As confirmed by personal communication (RJ croft, 10 October 2002). the phone was operated in `listening' mode and therefore gave rise, due to discontinuous transmission (DTX), to low intensity emissions only (estimated by the authors to have an average power of 3-4 mW, some two orders of magnitude lower than that employed in most previous studies employing GSM handsets). Nevertheless, the authors reported significant exposure effects on both event-related desynchronisation and resting EEG parameters, although there was no effect on task performance. Since several of these effects were dependent on time, the authors concluded that the RF signal in this study had only an indirect effect on brain activity, rather than directly altering the neural circuits that generate the EEG pattern Should these findings prove reliable, they would indicate an effect on brain function of mobile phone signals even when the intensity was markedly less than current guidelines. In the meantime, the results must be interpreted with caution, particularly given that the study was not double-blind. Huber et al (2002) studied the effects of electromagnetic field signals similar to a GSM phone on regional cerebral blood flow measured by positron emission tomograph (PET), and on both sleeping and waking EEG. In the PET study, a 900MHz signal was pulse modulated by extremely low frequency fields at 2, 8,217 and 1730 Hz and corresponding harmonics, to approximate the spectrum of a GSM mobile phone signal. The signal was delivered by two planar antennas to the left side of the head .The peak SAR was estimated at 1 $\mathrm{Wk\,g^{-1}}$. Thirteen subjects were tested in exposed and sham exposed conditions in counterbalanced order, using within-subjects double-blind design At least 1 week elapsed between the two tests. In each test, regional cerebral blood flow (rCBF) was measured over three 1-minute periods, starting 10,20 and 30 minutes after completion of a 30-minute exposure to a pulse modulated electromagnetic field or sham exposure. Rcbf is a reliable marker of neural activity in a local brain region. Subjects were asked to count silently during the scans, to balance cognitive function across scans. The results showed a significant increase in rCBF in the dorsolateral prefrontal cortex of the left (exposed) brain hemisphere. This brain area is known to be involved in working memory, which may be impaired by electromagnetic field exposure (Koivisto et al, 2001b). However, the result could also reflect differences between conditions in silent counting, since no independent measure of counting performance was obtained. It remains unclear why rCBF differences were seen in quite specific frontal regions of the brain, despite an exposure which presumably covered the entire left hemisphere. Huber et al (2002) also studied effects of the same exposure on the EEG. The modulation components were as in their PET study. This was compared with a continuous wave version of the same signal and with sham exposure. The left side of each subject's head was exposed to each of these signals for 30 minutes on three separate evenings. Subjects then slept while their EEG was monitored. A double-blind design was used Pulse modulated, but not continuous wave, electromagnetic fields produced a significant increase in alpha-wave (12.25-13.5 Hz) EEG activity (known as sleep spindles owing to their typical appearance on EEG recordings) in ensuing sleep, without changing other aspects of EEG or sleep behaviour. Analysis of individual EEG spindles showed greater spindle amplitude in pulse modulated electromagnetic fields than in either continuous wave electromagnetic field or sham exposure conditions. This effect did not diminish during the course of sleep. The mechanism of such enduring effects is unclear. Finally, the effects of pulse modulated electromagnetic fields on the EEG, although statistically reliable, are small relative to the normal variation in EEG activity during sleep.

Taken together, the studies by Huber et al suggest a direct effect of pulse modulated electromagnetic fields on the normal activity of the brain, and particularly of the spontaneous oscillatory activity of networks of neurons. This effect appears to outlast the period of exposure. However, the mechanism of the effect remains unclear. Nor is it clear whether the effects on neural oscillations and on rCBF are related or independent effects. Finally, these studies contained no measures of cognitive performance, so the impact on brain function of the changes induced by pulse modulated electromagnetic fields is unclear, as is their impact on health.

2.2 Cognitive Function

Edelstyn and Oldershaw (2002) employed a between-subjects design (n =19 per group) to assess the effects of mobile phone signals on six common neuropsychological tests (digit and spatial span, forwards and backwards, serial subtraction, and verbal fluency).As confirmed by personal communication (N Edelstyn, 10 and 13 September 2002) exposure (single-blind) was effected by requiting subjects to hold a 900MHz GSM phone to their left ear and to answer a series of questions posed by the experimenter. Who was in the same room. Exposure duration was for a total of 30 minutes. Although subjects were not exposed while undertaking the neuropsychologlcal tests. In additional exposure would not have been constant during the period because of DTX. No dosimetry was calculated. Subjects were blinded to exposure condition (exposed vs sham) by coveting the phone display so that it could not be determined whether the phone was on or off. Testing was undertaken in a pre-exposure baseline period, and 15 and 30 minutes after exposure. Exposure effects were inferred on the basis of statistical analysis of difference scores as performance on successive test periods (baseline -test 1; test 2- test 1).The main effects of exposure group were found for digits forward, serial subtraction, and spatial backwards; in addition, group x time interactions were reported for digit span forward and spatial span backwards (not, as stated in the article, serial subtraction; N Edelstyn, personal communication, 10 September 2002). These effects were reported to take the form of greater improvements in performance between the baseline and subsequent periods for the exposed group (unfortunately. the actual data were not reported), and the authors interpreted their findings as being consistent with those of Preece et al (1999) and Koivlsto et al (2000a,b). Their experimental procedures leave room for doubt; however, as to whether subjects in the exposed group were treated equivalently to the controls, as well as whether the subjects were unaware of handset status. Smythe and Costall (2003) tested performance on a verbal memory task in three groups of healthy students. All subjects studied a list of 12 words, arranged in a pyramidal spatial shape, for 3 minutes. Subjects then performed a distracter task (reading aloud) for 12 minutes, and were asked to recall the word list, placing each word in the spatial location seen previously. Subjects returned 7-8 days later, and repeated the recall phase of the task. The subjects were assigned to three exposure groups. The 'active' group held an Ericsson A2618s mobile phone to their left ear during the study phase only. For the `inactive' group, the phone was switched off. The phone operated at 1800MHz, and induced an SAR of 0.79W kg^{-1}, presumably measured as a local peak, according to the manufacturer's figures. The actual SAR during the tests was not measured but is likely to have been very low due to DTX. An additional `no phone' control group did not hold the phone, and was not exposed. Since this last group was effectively unblinded the key statistical comparisons were between the active and inactive exposure groups. The results showed that the 15 male subjects in the active group tended to recall more words than males in the Inactive control group, although this effect did not reach conventional significance levels. They also made significantly fewer errors in spatial placement of correctly remembered words. These effects were confined to immediate recall. There were no effects of exposure condition at delayed testing, suggesting an effect on short-term rather than long-term memory. There were no significant effects in the female subjects. An improvement in immediate memory following mobile phone exposure seems consistent with previous reports of shorter reaction times (Koivisto et at 2000a, b), since speed and accuracy are closely related in such tasks. However, some aspects of the study of Smyth and Costal (2003) suggest a need for caution in interpreting their results. The number of subjects per group was relatively small, and it is unclear whether the unusually large age range was balanced across groups, which weakens any comparison across groups. In addition, the experimenters were not blind between the `active` and `inactive` groups. Since subjects positioned and held the phone themselves, and since the phone was not driven by a quantified signal, the effective exposure is unclear, and could vary across groups. Finally, it is unclear why the facilitatory effect was sex-specific, suggesting this may be a chance finding in a subgroup. An attempt to replicate theses effects in a larger, well-characterized sample would be valuable. Until then, this study alone cannot be taken as strong evidence for any direct effect of mobile phone signals on cognitive function. Lass et al (2002) studied the performance of 100 Estonian students on three cognitive tasks. These were visual attention (searching for digits in pre-specified sequence within a random spatial pattern), short-term memory recall for visually-presented pictures, and a visual search test of sustained attention. Subjects were allocated randomly to an exposed or sham exposed group, and were tested single-blind. In the exposed group, a 450MHz RF signal, amplitude modulated at 7Hz with a 50% duty cycle, was amplified to a 1W electromagnetic field output power, and guided to an antenna 10cm from the right side of the head. The measured field power density was $1.58 W m^{-2}$, and the SAR, estimated using anatomical models, was $0.0095 W kg^{-1}$, too low to produce thermal effects. The authors do not specify the procedure for sham exposure. Exposed subjects made significantly fewer errors on the memory recognition task than sham exposed subjects. In contrast, the trails task and visual search task which require more effort and are more demanding, produced small and non-significant effects in the opposite direction, showing worse performance and greater inter-subject variability, in the exposure than the sham exposure group. The authors suggested that the pulsed signal acted as a low level stressor (although their data provided no statistically reliable evidence for a drop in performance). They further suggested that the brain may over-compensate for this stress during easy cognitive tasks, leading to the improved accuracy in the relatively easy memory task. Effects of the electromagnetic field signal on cognitive performance may reflect strategic compensation by the brain. Previous studies have also reported electromagnetic field effects which vary with task difficulty (Koivisto et al, 2000a), but in those cases performance benefits were Found only when the memory task was difficult. For this reason, the results and coclusions of Lass et al (2002) should be treated with some caution. In addition, the authors used different subjects for the exposure and sham exposure treatments; although these groups were quite large, and were said to represent a relatively homogeneous population, it was possible that psychological differences between the two subject groups were confounded with the exposure effect. In general, a within-subjects design in which each subject performs both exposure and a sham exposure condition is preferable to a between-subjects comparison in experiments of this kind. Haarala et al (2003) replicated and extended the study of Koivisto et al (2000a}. That study had suggested that exposure to a 900 MHz GSM signal could shorten reaction times in some cognitive tasks. The Haarala et al (2003) study reports an attempt by the same research team to replicate these effects, using a superior experimental design. The authors tested 64 subjects in two independent laboratories in Sweden and Finland. Each subject performed nine different cognitive tasks, which varied in difficulty, mainly due to differences in working memory load and in the need to actively inhibit some responses while making others. Speed and accuracy of performance were measured on each task Subjects performed the tasks in counterbalanced order in two sessions lasting 65 minutes on two successive days. They were exposed to electromagnetic fields during one session, and sham exposed in the other, incounterbalanced order. Participants and experimenters were unaware of the exposure condition. The electromagnetic field was delivered by a 900 MHz GSM phone with DTX inactivated and the earphone removed. The mean power was 0.25W, pulsed at 217 Hz with a pulse width of $577 \mu S$. The average SAR was measured with a dosimetric assessment system as 0.88 W kg^{-1} averaged over 1g, with a peak of 1.2W kg^{-1}. The phone was held against the left side of the head by a rubber cap, in the standard position of use. The authors also measured the thermal effects of the phone on the skin in both exposure and sham exposure conditions. The thermal effects were small and the subjects were unable to discriminate between the exposure conditions using thermal cues. The reaction times and error rates on all nine cognitive tasks were compared statistically. No reliable differences between exposure and sham exposure conditions were found, and the authors concluded that electromagnetic field exposure has either no effect or only small and unreliable effects on human cognitive function. These findings are particularly noteworthy as they represent non-replication of an earlier report of facilitatory effects of electromagnetic field exposure on cognitive function (Koivisto et al, 2000a) that had considerable impact. The study reported here used a superior design to that employed in the earlier work and their evidence therefore carries more weight. A comparison between the later findings and the earlier results underlines the importance of three key features of best scientific practice in this area experiments should be double-blind, they should use an adequate sample size, and they should be replicated in a multicentre study. Zwambrn et al (2003) compared the effects of whole-body exposure to 945MHz GSM,1840MHz GSM, or 2140MHz UMTS RF signals and sham exposure, experienced 3m from a base station antenna (closer than is usual in the normal environment), on cognitive function and subjective reports of well-being in two groups: a group that had reported subjective complaints linked to GSM signals, and a control group. However, the two groups were not matched for age or other relevant factors. All exposures were well below ICNIRP guidelines. The study was double-blind, subjects performed four tests of cognitive function, namely reaction time, memory comparison, dual-tasking and filtering irrelevant Information, during each exposure session. In addition, current subjective well-being using a standard questionnaire was reported immediately after each exposure session. In the cognitive function tests, 900-MHz-type GSM signals were associated with significantly increased (ie slower) reaction times in the subjects with complaints, while UMTS-like signals significantly increased reaction times in control subjects. Performance of a memory comparison test was significantly faster, in control subjects only, during exposure to 1800-MHz-type GSM and UMTS signals compared to sham exposure. Visual selective attention appears to have been significantly impaired in both groups during UMTS exposure only. Two measures of dual-tasking performance were used; one measure showed significant changes with 1800MHz GSM-type signals in the control group only, while the other was sensitive to 900MHz GSM-type signals in the subjects with complaints. In addition, both groups of subject reported significantly lower overall well-being following exposure to the UMTS signal only, compared to sham exposure.The study appears carefully-conducted, well-designed and has reasonable statistical power. It suggests that some direct effects of RF signals on well-being and human cognitive function might exist; however, the authors did not state that they had used Statistical adjustment for multiple comparisons between several exposure conditions. As a result, some of the comparisons between exposure and sham conditions which are reported as significant may not be in fact be reliable. Furthermore, the pattern of the results on cognitive function was not consistent across the three RF signals, the four different cognitive tasks or the two study groups, which argues against a true effect. The reaction time data deserve special consideration. Although a previous study had reported faster reaction times during RF exposure (Koivisto et al, 2000a), the study by Zwamborn et al found significantly increased (slower) reaction times, but the groups were inconsistent regarding which RF signal produced such increases. However, the results did suggest a consistent effect of UMTS signals, but not GSM signals, on subjective well-being in subjects in both study groups. Since the study was double-blind, this result suggests that some RF signals might produce subjective symptoms in some individuals. In contrast, a previous study had reported no such effects (Hietanen et al, 2002). These inconsistencies leave it unclear whether any effect truly exists. Lee et al (2001) compared the petformance of 5th form schoolchildren, segregated according to mobile phone usage into two groups (users vs non-users, n =37 and 35, respectively), on three 'paper and pencil' tests of cognitive function: symbol-digit matching, Stroop test, and trail making. Mobile phone users were selected according to self-reported usage (indexed as time with phone x average minutes used each day), and comprised the 37 heaviest users meeting other inclusion criteria. The controls were age- and sex-matched, but it is unclear whether they were matched for intelligence (no such background data were reported). The performance of the user group was found to be significantly better than that of the controls on both versions of the trails test (version A - where it is merely necessary to join up a series of randomly displayed numbers in the correct order; version B - where numbers and letters must be joined in alternation). The authors interpreted their findings as evidence that mobile phone use facilitated 'attentional' function. This conclusion can be questioned on at least two grounds. First, the finding of an effect on both versions of the trails task is more consistent with an interpretation in terms of enhanced sensorimotor function than attention. More seriously, as was acknowledged by the authors, the effect may reflect the influence of one or more variables confounded with phone use, rather than a direct effect of mobile phone signals on cognitive function. This study therefore does not provide unambiguous evidence of a direct effect of mobile phone signals on cognitive function.

CHAPTERTHREE

Electromagnetic Fields, The Modulation Of Brain Tissue Functions A Possible Paradigm Shift İn Biology

3. Introduction

All life on earth is bathed in a sea of natural low-frequency electromagnetic (EM) fields from conception to death. Generated principally by thunderstorm activity in equatorial zones, these fields exhibit peaks in the ELF spectrum between 8 and 32 Hz – the [Schumann (1957)] resonances. Their energy is measured in billions of coulombs. They are ducted worldwide between the earth's surface and the ionosphere approximately 140 km above the earth. With a circumference of 41,000 km, the earth may act as a cavity resonator in this ducted propagation, with a resonant frequency around 8 Hz for waves moving at the velocity of light (300,000 km/s). Schumann fields are weak, with electric components of about 0.01 V/m, and magnetic fields of 1–10 nanotesla. We may contrast these weak extremely-low-frequency (ELF, with frequencies below 300 Hz) fields with the earth's much larger static geomagnetic field, typically around 50 microtesla (μT). Over the last century, steadily increasing use of electric power in all industrialized societies has sharply increased the EM environment and modified its spectral content. In U.S. urban environments, typical 60 Hz domestic ambient fields may be in the range 0.03–0.3 μT, but substantially higher near washing machines, hair dryers, electric shavers, etc. There is great and growing use of microwave devices, thus extending utilization of the EM spectrum many octaves, from a few cycles/sec (Hz), with corresponding wavelengths of 10,000 km or more, to millimeter waves and the far-infrared region. [Bullock (1991)] has defined induced brain rhythms as "oscillations caused or modulated by stimuli or state changes that do not directly drive successive cycles". This perspective directs attention to two sets of related but inverse problems. There are tonic central nervous responses to rhythmic stimuli, responses that extend beyond a brief epoch of rhythmic stimulation. There are also phasic responses to continuing rhythmic stimuli. Aspects of their significance in brain functions has been revealed through imposition of EM fields as tools that induce brain tissue fields mimicking in varying degrees components of intrinsic brain electrical rhythms. Initial studies with imposed EM fields in the nervous system centered on modulation of brain ionic mechanisms ([Adey, 1981a] [Adey, 1981b][Bawin and Adey, 1976]; [Bawin et al., 1975][Bawin et al., 1978]; Blackman et al., 1979][Blackman et al., 1985]) and behavioral responses [Gavalas et al., 1970]; [Gavalas-Medici and Day-Magdaleno, 1976]; [Kalmijn, 1974]); Embryonic exposure of the developing vertebrate nervous system to EM fields at specific frequencies (50 or 60 Hz) may establish thereafter lasting frequency-dependent sensitivities in cerebral calcium binding ([Blackman et al., 1988]) Initial studies on ionic mechanisms were followed by investigations of developmental modifications and behavioral teratology following embryonic and fetal exposures ([Delgado et al., 1982]; [Juutilainen et al., 1986]a, 1986b; [McGivern et al., 1990]; [Sikov et al., 1987]). More recent epidemiological studies have reported developmental defects in motor skills, memory and attention in children exposed throughout life to high intensity radar fields pulsed at EEG frequencies ([Kolodynski and Kolodynska, 1996]). An association between occupational exposure to power frequency magnetic fields and Alzheimer's disease has been reported in joint studies of two series of patients in California and one in Finland ([Sobel et al., 1995]). These studies in brain tissue have led to investigation of the possibility of similar phenomena in non-nervous tissue, with the conclusion that sensitivity to weak low-frequency EM fields may be a more general property of cells in tissue (for reviews, see [Adey, 1992a][Adey, 1992b] [Adey, 1999]). They point to a private language of intrinsic communication by which cells may "whisper together" in activities such as metabolic cooperation and growth regulation ([Adey, 2003a). Intracellular enzymes mediating metabolic, messenger and growth functions have been used as molecular markers of transductive coupling of EM fields in cell surface receptor mechanisms. Representative studies in each of three membrane-related enzyme groups include adenylate cyclase ([Luben et al., 1982]; [Luben and Cain, 1984]), guanylate cyclase ([Bawin et al., 1994][Bawin et al., 1996]), protein kinases ([Byus et al., 1984]; [Uckun et al., 1995]), and ornithine decarboxylase ([Byus et al., 1987][Byus et al., 1988]; [Litovitz et al., 1993]). In addition, low frequency magnetic fields induce rapid transitory intracellular expression of heat-shock proteins that mediate a wide range of cellular stress responses ([Lin et al., 1997]; Lin et al., 1998]).

3.1 Brain Interactions With RF/Microwave Field Generated By Mobile Phones

Neither radiofrequency (30 kHz-300MHz) nor microwave fields (300-3000 MHz) exist as significant components of the natural terrestrial electromagnetic environment. In consequence, our human generation is the first to voluntarily expose itself to artificial RF/microwave fields that cover a wide spectrum of frequencies and intensities. In general suburban environments, these newly introduced fields now have average intensities around 1 ∝W/cm2 (4V/m). Typical mobile phones radiate an average power of 0.2-0.6 W. When hand-held and operated close to the head, background levels are sharply distorted, with 40 percent of radiated phone energy absorbed in the hand and the head ([Kuster et al., 1997]). In this mode of operation, a mobile phone may be regarded as a quite powerful radio transmitter. Its emission at the head surface is typically 10,000 times stronger than fields reaching the head of a user *standing within 30 m of the base of a typical mobile phone relay transponder mounted* on a tower 30m above ground.

3.2 Historical Development of Analog and Digital Mobile Phone Transmission Systems

The rapid worldwide development of mobile phone communication systems over the past decade has involved an equally rapid technological progression. In consequence, the heads of many current phone users have been exposed to a sequence of microwave fields modulated in substantially different ways ([Adey,1997]). Initially, voice information was universally signaled by frequency-modulation (FM) of the microwave carrier wave. In a biophysical perspective, the carrier wave remains constant in amplitude throughout the transmission epoch, all voice information being transmitted in the frequency domain. Although these FM (analog) systems are still in common use, radio engineering considerations, such as economy of power usage in phone operation, and optimal utilization of the limited available microwave spectrum, have led progressively to general adoption of digital transmission techniques ([Kuster et al., 1997]). Initial transmission systems utilized 400 MHz frequencies, but current systems generally transmit at 900 and 1800 MHz.

Two methods of digital modulation now widely used in mobile phone systems exemplify these techniques. The North American Digital Cellular (NADC) standard used in North America and Japan employs Time Division Multiple Access (TDMA) modulation with speech encoding at 50 pulses/sec. The Global System for Mobile Communication (GSM) system employed throughout Europe and in much of the rest of the world is encoded at 217 pulses/sec.

3.3 Influence of Microwave Phone Fields on Human Cognitive Performance

Changes in human cognitive performance have been reported during exposures to simulated or actual GSM phone fields, and to FM (analog) phone fields. With simulated GSM and FM fields, there was increased speed in choice reaction time, greater in FM exposures than GSM ([Preece et al., 1999]). Using six cognitive neuropsychological tests (digit-span and spatial-span forwards and backwards, serial subtraction and verbal fluency), performance was facilitated following 30 min exposure to a 900 MHz GSM mobile phone field in two tests of attentional capacity (digital span forwards and spatial span backwards), and processing speed (serial subtraction) ([Edelstyn and Oldershaw, 2002]).

3.4 Subjective Symptoms Reported From Prolonged Mobile Phone Use

A wide range of subjective symptoms has been reported with prolonged use of mobile phones. They include dizziness, discomfort, concentration and memory difficulties, fatigue, warmth on and behind the ear, and burning sensations in the face. Scandinavian studies of these symptoms have involved 6379 GSM phone users and 5613 NMT (analog) users in Sweden, and 2500 from each category in Norway ([Sandstrom et al., 2001]; [Wilen et al., 2003]). These studies took account of energy absorption (SAR) in head structures adjacent to the user's ear, and indicators of the amount of daily use, as determined from the calling time/day and the number of calls/day. They conclude that subjective symptoms, especially dizziness, discomfort and warmth behind the ear, correlate with high SAR values (> 0.5 W/kg) and longer call times/day.

3.5 Alterations In Eeg Records and Cerebral Blood Flow During and Following Mobile Phone Field Exposure

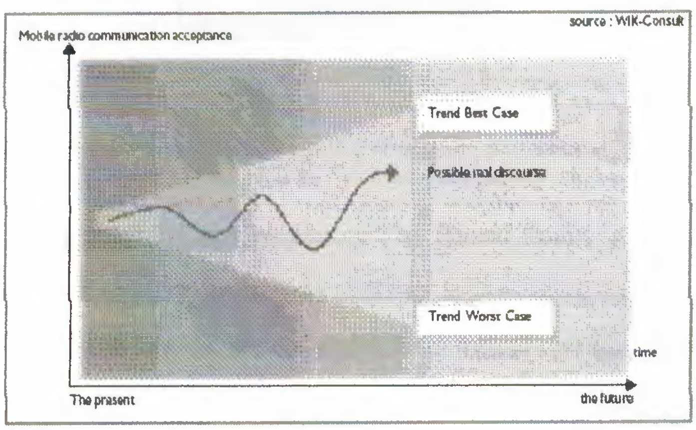
GSM mobile phone fields are reported to alter EEG patterns during and following exposure, with evidence for concomitant changes in cerebral blood flow. During cognitive processing of a visual sequential letter task, 902 MHz digital fields altered event-related EEG desynchronization/synchronization responses in the 6-8 and 8-10 Hz bands, but only when examined as a function of memory load, and depending also on whether the presented stimulus was a target or not ([Krause et al., 2000]). Positron emission tomography (PET) after unilateral 30 min head exposure increased relative cerebral blood flow in the dorsolateral prefrontal cortex on the exposed side. These pulsed GSM fields also enhanced EEG power in the alpha (8-13 Hz) range prior to sleep onset and in the spindle frequency range during Stage 2 sleep. Importantly, exposure to unmodulated (CW) fields at the same average power density as the GSM fields did not enhance power in the waking or sleeping EEGs, supporting concepts that pulse-modulation is necessary to induce waking and sleeping EEG changes ([Adey, 1997]; Huber et al., 2002]).

3.6 Modification of Blood-Brain-Barrier Permeability By Mobile Phone and Other Microwave Fields

In an historical perspective, initial observations of possible disruption of the blood-brain-barrier (BBB) by microwave fields used 3 GHz radar fields at presumed nonthermal incident levels (3 mw/cm2) ([Oscar and Hawkins,1977]). They reported increased brain uptake of mannitol and inulin through the BBB in rats, but not of dextran. This pioneering observation was overshadowed by subsequent collaborative studies in which Oscar participated, with findings of no BBB permeability change to sucrose ([Oscar et al., 1982]; Gruenau et al., 1982]). The original study using mannitol and inulin was not repeated at that time. More extensive studies since 1988 by Salford and colleagues have reported significant leakage of albumen through the BBB in rats exposed once to GSM phone fields for 2 h at whole body average energy absorption rates of 2 mW/kg, 20 mW/kg, and 200 mW/kg ([Salford et al., 2003]). All field levels would be consistent with nonthermal exposures. Exposed animals were allowed to survive for about 50 days. Albumen antibodies displayed positive foci around finer blood vessels in gray and white matter. Damaged neurons, as revealed by cresyl violet staining, were found amongst normal neurons in cerebral cortex, hippocampus and basal ganglia., with a maximum incidence around 2%, but in some restricted areas, dominated the picture. Scores differed significantly between the groups, with evidence for a dose-dependence ($P<0.002$). The authors conclude that "the time between the last exposure and sacrifice is of great importance for detection of foci of leakage, since extravasated albumen rapidly diffuses below concentrations possible to demonstrate accurately immunohistologically. However, the initial leakage may start a secondary BBB opening, leading to a vicious circle – as we demonstrate albumen leakage even 8 weeks after the exposure.....We and others have pointed out that when such a relatively large molecule as albumen may pass the BBB, many other smaller molecules, including toxic ones, may also escape into the brain due to RF exposure." At the cellular level, a model of the BBB can be achieved *in vitro*, in a co-culture of rat astrocytes and porcine brain capillary endothelial cells ([Schirmacher et al., 2000]). The existence of a BBB formed by these capillary endothelial cells was confirmed by the presence of the *zona occludens* protein as a marker of intercellular tight junctions, and also by the close contacts between these cells, together with an absence of intercellular clefts. Permeability measurements with radiolabeled sucrose also correlated with a physiological "tightness." Exposure to GSM phone fields at 1800 MHz for 4 days significantly increased permeability to radiolabeled sucrose in comparison to unexposed controls.

3.7 The results of a study comparing different countries

The debate on the possible risks posed by electromagnetic fields in other European countries is based on different focal points. As a general guideline almost everywhere the ICNIRP-value limits (International Commission on Non-Ionising Radiation Protection) recommended by the European Council are valid. There are, however, a few exceptions on a national level, where a country has legally established these value limits, for example in Germany. There were essential differences with regard to value limits and other basic conditions when the different countries were compared within the framework of this study. In particular, the debates that are taking place in each individual country proceed very differently. Great Britain can be used as a "positive" example for its rational dialogue on EMFresidual risks. In Great Britain the authorities and the network providers have been successful in extending their networks and have successfully continued to expand without any disturbances or protest. This is due to an early and foresighted information policy. Plans as to where a base station will be set up are published and the municipalities are to a great extend included in the decision. In regions where the protest potential may be high, mediators are sent in and clearing offices are set up. Moreover, already years ago projects on potential risks were carried out with scientific investigations. The Stewart-Report, where many different actors participated, contributed to the excellent reputation the British have with regard to their value limit policies. Many of the recommendations made in the report have in the meantime been put into practice, for instance intensifying the measuring operations in accordance with German location procedures as well having the network operators expand their information policies. "Negative" examples for how a national EMCE-debate is progressing are: Switzerland, Austria and especially Italy. The politically normative introduction of the socalled "precautionary value-limits", which are currently well below the ICNIRP values, have on the whole lead to an intensification of the public debate. The Swiss value limits which are lower by a of factor 10, the "Salzburger milliwatt" and the different regional value limits in Italy have made people become more apprehensive and has caused the protest potential to increase. There is no end in sight to the new demands being added to the catalogue of demands by citizens' action groups, constant inquires about value limits has led to a "value-limit spiral". Precautionary value-limits which are not based on plausible scientific correlations, can be correctly regarded as the result of a political negotiating process and correspondingly they are subjected to continuous demands from the public to keep on lowering the value limits. A significant result of this comparative study is that many measures and demands are merging closer together in order to de-emotionalise the public debate and to re-establish trust in public and research institutions and in the network operators; information campaigns, dialogue processes among social groups, locations being announced to the public, control measurements, intensifying research all belong to the set of measures that are being taken by the network operators and the authorities. Informing the public as early as possible about extension plans as well as including municipalities in location decisions are additional steps which will reinstate trust. Our body consists of individual organs and organ systems, which require different but constant conditions to function, such as nutrients, hormones and electrolytes. All of the body's organs are connected to each other by the circulatory system.



Szenario: Entwicklung der EMVU-Debatte

Figure **3.1** Entwicklung Der EMVU Debatte

Since the blood contains all of the components needed for providing the body with what it needs and for purification processes, filter systems have to ensure that the necessary substances pass through the organs and that some substances are partly held back. Some of the known blood barriers are as follows: the blood tissue barrier, also known as the blood arenchyma barrier, the blood liver barrier, the blood-cerebrospinal fluid barrier, the blood brain barrier, the cerebrospinal fluid brain barrier, the blood nerve barrier, the blood retina barrier, and the placental barrier. This filter mechanism functions with a so-called barrier effect, this means certain substances are permitted to permeate the barrier and others are restricted when the organ system does not need the components or only needs them in lower concentrations. These "barriers" are not independent organs but are made up of many cells and space that exists between the cells allowing blood gases, nutrients, and certain chemicals permeate the barriers. They are made up of endothelial pores which hold back macromolecules ,or they could be lipid membranes located in vascular walls which have an inhibiting effect on the permeation of non lipid soluble substances or they have the selective effect of taking an active part in capillary transport processes. The brain and the nerve tissue are protected by two filter systems, the blood cerebrospinal fluid barrier and the blood brain barrier. The blood-cerebrospinal fluid barrier This fluid is a brain and spinal cord fluid, which fills the inner and outer cerebrospinal fluid space in the cranial vault and in the vertebral canal.

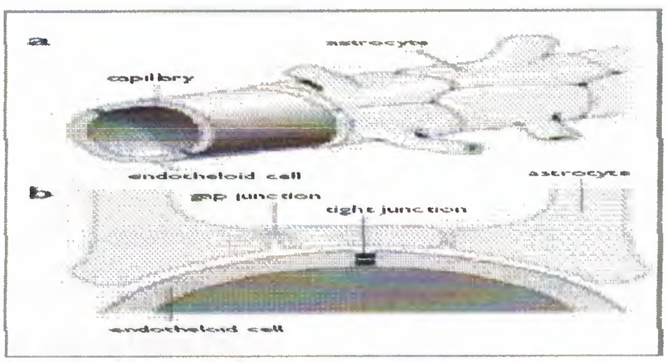


Figure 3.2 Construcion of The Blood Brain Barrier

During cerebrospinal fluid production as well as when substances cross over from the blood into the fluid, filtration, diffusion and active transfer processes of carbon dioxide, glucose and amino acids take place. This exchange of substances is regulated by the bloodcerebrospinal fluid barrier, which is formed out of capillary endothelial cells and brain covering and can be found between blood vessels and the cerebrospinal fluid space. The different concentrations of glucose, protein and electrolytes in the blood and in the CSF is regulated by these filter functions in order to maintain optimal concentrations in the brain. The Blood Brain Barrier The existence and the function of the so-called blood brain barrier has been know for more than 100 years and as early as

1885, Paul Ehrlich proved its existence in experiments. Within the central nervous system the space between the neurons is almost completely filled with glia cells and their end feet/expansions. The entire nerve cell metabolism takes place via these glia cells or endothelial cells, whose purpose is to install nerve cells and fibres, and to nourish and isolate them. A type of glia cells are astrocytes. One type of astrocytes has numerous expansions of end feet which adhere to capillary walls and another type encloses the capillaries on all sides with a nearly leak-proof lining of endothelial cells. These endothelial cells are joined together by connective elements, or tight junctions (see diagram) and are quipped with a selective substance permeability which allows only particles with a diameter of less than 20nm to cross over. In this way the entire metabolism of nerve cells takes places via this endothelial network, so that when necessary any substances present in the blood are immediately passed through a biological filter. However, any substances which may harm brain function are kept away from the nervous system. Blood brain barrier function This endothelial network and the endothelial cells which cover the capillaries as a basal membrane, is designated as the blood brain barrier. Unhindered oxygen, carbon dioxide, D-glucose, D-Hexose, some L-amino acids and lipid soluble substance permeate the BBB, which are all necessary for proper brain function. In this way breakdown products are also passed on into the blood. The feet end and extensions of astrocytes represent a certain barrier for specific hormones, non soluble lipids, water soluble and numerous other chemical substances, and this ensures that a constant environment is maintained for neurons and the nervous system. Blood brain barrier malfunctions The cell structure of astrocytes is so constructed that it is able to build an effective shield against higher molecular substances and organisms. However, under normal conditions it is not completely sealed, so some particles are able to permeate the barrier. In cases of infection, trauma, inflammation, poisoning, hypoxia-dose, fever and in cases of tumours, the tight junctions between the endothelial cells become stretched out due to astrocyte swelling and this in turn makes the BBB more permeable for other substances. Changes in the width of the openings are due to the swelling and the de-swelling of endothelial cells. Even the capillary basal membrane is not a sealed layer. Whether or not there are pores in the membrane, which play an active part in the exchange of substances, depends on the density of the fibre network. The vascular systems of pathological tumours do not develop any blood brain barriers. Since this has been known, it has been used in diagnostic procedures. A contrast medium is administered into the vascular system to check if the contrast medium stays in the vascular system or passes over into the tumour. Long before the use of antibiotics, physicians increased the permeability of the blood brain barrier by inducing an artifice fever, similar to what occurs during an infectious illness. This type of treatment was used to treat syphilis of the central nervous system and for shock therapy in the field of psychiatry, with this type of treatment medication could be administered directly to the brain. When the conditions that produced the blood brain barrier's temporary increase in permeability are stopped it returns to its original state. Conclusions When considering this article in its entirety it would make more sense to consider blood brain barrier as a selective filter rather than a barrier. Investigations have shown that permeability increases when there is an increase in the body's temperature and when there is an increase in function. An increase in the brain's temperature while using a mobile phone hardly ever occurs. Concerning this, after the test person had been using the telephone for a quarter of an hour at maximum power, the temperature under the cranial calotte was increased by 0.1°K. During a warm bath, hard physical l abour or being exposed to the sun for a longer period of time all lead to an greater increase in temperature. How the blood brain barrier reacts in these situations or how the body tolerates such changes is yet to be investigated. Since the extent of permeability returns to its original state after an increase in temperature, experiments should be done investigating these effects shortly after the influential factors produce an effect. If changes are discovered weeks after exposure, as described in the Salford (5) study, it can not be ruled out that in the duration there were other effects which could have affected the test animals and gave rise to changes affecting the filter function of the blood brain barrier.

Again and again the public is alarmed by reports stating that telephoning with a mobile phone will cause the blood brain barrier BBB to open and nerve damage will result or even brain tumours may develop. How serious are these warnings and how protected are we by the current limit values?

Firstly, it must be established that the blood brain barrier is not an anatomically localized organ but is a special feature of the blood capillaries located in most areas of the brain. In order to protect the brain, which is the most sensitive organ in the human body, from toxic substances the capillary endothelial cells are joined by tight junctions, a sealing mechanism that makes it difficult or impossible for certain substances to permeate the BBB. Only soluble gases required for cell respiration, oxygen and carbon dioxide, as well as nutrients such as D-glucose, D-hexose, Lamino acids and lipid soluble molecules are able to permeate this barrier. In stress situations, cranial trauma and with various illnesses a malfunction of the barrier can occur, these malfunctions are usually quickly repaired. (Blasberg et al. 79). Quite early on one thought that high frequency fields could cause an increase in temperature and quasi induce an artificial fever and this in turn would lead to the BBB being affected. This unwanted side-effect had been observed in conjunction with the so-called short-wave therapy. However on the other hand, it was

used to administer medication directly to the brain (Lin et al. 98). Therefore, this effect has been investigated for more than three decades. The first animal experiments in connection with possible harmful effects to the BBB caused by radio and radar fields were done in the 1970s by Frey et al., at first they thought that this would also promote cancerostatica in the brain (Frey et al. 75,Frey 79). Sutton and Carroll (79) have pointed out that when the temperature of rats' brains is increased to 45° C induced by a 2450 MHz-field there is an increase in protein absorption. Oscar and Hawkins (77) examined in rats the absorption of 14C marked sugar molecules of various molecular weights, while they were being exposed to different power densities of continuous and pulsing fields of 1.3 GHz. While dextrin with a molecular weight (MG) of 60.000-75.000 was not absorbed at all, they discovered that mannitol (MG = 182.2) and inulin (MG = 5.000-5.500) had an absorption intensity as a function of the applied power flow density, which showed the maximum to be at about 10 W/m2. Pulses of the same average power flow density but of differthe ent lengths and frequencies showed differences in absorption intensities. These results could not be confirmed later (Merrit et al. 78, Preston et al. 79, Gruenau et al. 82, Ward et al. 82, 85).How can this contradiction evident in different investigation be explained? Obviously there is a series of methodological difficulties which are easily open to isinterpretations (Rapopor et al. 79, Williams,Hoss, et al. 84, Williams, Plattner et al. 84). So for example, a change in capillary perfusion could slightly increase the permeability of substances, without a change in normal permeability taking place. However, artefacts are to be seriously considered, which can occur during the dissection of the brain and during its histological processing. If the fixation process or the freezing of the tissue which follows is not done properly, the substances being investigated could during this process permeate the BBB. During the storage of preserved brains the diffusion of these substances can enter into areas of the brain that are not protected by the BBB. What can also occur is that the indicator substances can smear during dissection and this can especially happen when histological slides are being prepared. Since the BBB is without a doubt permeable for larger molecules when there is a clear rise in temperature, an exact dosimetry is all the more necessary. An erroneous assessment of local SAR-values in the brain with the application of HF-fields can easily lead to such an effect being produced by warming. In various studies Salford et al. (92, 93, 94) as well as Persson, Salford et al. (92) have shown with histochemical techniques that pulsing as well as continual 915 Mhzfields are able to temporarily make the BBB permeable to plasma-albumin. Unfortunately, in these studies there is no reliable data on the power density and SAR-values. In spite of this the results received a lot of attention and different attempts have been made to verify the rehour sults. Fritze et al. (97) exposed rats during the course of 4 hours with these frequencies, where different SAR-values were applied, from 0.3-7.5 W/kg. Only with extreme irradiation, 7.5 W/kg, could these authors produce with certainty an increase in brain temperature and consequently a significant cross over of albumin into the brain. Even this effect was rather slight when compared to the effects produced in the positive controls where the animal had to undergo a cold shock. Recently two articles on this subject were published by Finnie et al. (01, 02). In the first publication, the Australian team reported on experiments where rats were irradiated for one hour at SAR-values of 4 W/kg (898,4 MHz, 217 Hz pulsed). In contrast to the positive controls after applying clostridium toxin, no difference could be found between the irradiated rats and the rats which were not irradiated. In the second publication they attempted to find an answer to the question as to whether or not during long-term exposure albumin could permeate into the brain. During the course of 104 weeks, mice were exposed to a 900 MHz far-field, five days a week for one Rehour per day, which corresponds to SARvalues ranging from 0.25 to 4 W/kg. In this long-term experiment in an extreme case there were some negligible traces of albumin detected in the brain. However, these can be ignored when compared to the effects the toxin produced. Even experiments testing the BBB permeability to other substances while under the influence of high frequency fields with intensities below the limit values showed no results (Lange et al.91, Lin et al. 98, Masuda et al. 01, 02). The work of a Japanese study by Tsurita et al. (2000) has to be mentioned in this context. In this experiment rats were irradiated with fields according to the Japanese TDMA-standard for two hours a day for 2 to 4 weeks (1439 MHz, SAR for the head: 2W/kg, the entire body SAR 0.25 W/kg).

In this carefully conducted experiment neither the absorption of the vital staining substance Evans-blue nor morphological changes in the cerebellum nor could Purkinje cells be detected. On the other hand, clear effects were shown in the positive controls, where head temperature was increased for a short time or where they were under cooled. In an analysis of the work done by the Salford group, Tsurita et al. criticized it in this publication for their faulty irradiation and dosimetric techniques. If one were to sum up the current developments in research regarding this area, one could come to the conclusion that no effects to the BBB can be verified stemming from weak mobile radio fields. Only concerning flow densities which have a thermal effect on the brain, is the BBB temporally permeable to proteins and other large molecules. A short while ago, after a 10-year break, an report by Leif G. Salford's working group on new experiments involving the effects of mobile radio fields on the brains of rats appeared. In contrast to the first experiments, which were published in a journal that uses a referee system, this report was published in the National Institute of Environmental Health Sciences own journal. (Salford et al. 2003). The article pertains to an experiment conducted on 32 rats of both sexes, which were divided into 4 groups each containing 8 rats. The rats from 3 of these groups were irradiated individually and only once for 2 hours in a TEM cell at a power flow density of 0.24; 2.4 and at 24 W/m2. The rats in the fourth group were the control group. Calculations resulted in entire body SAR-values of 2; 20 and 200 mW/kg. After a course of 50 days the rats were finally examined, they were sacrificed being anaesthetized and the brains were fixated with a formol-perfusion. Histological examinations revealed that the irradiated rats had albumin-positive staining near the smaller blood capillaries and there was further albumin spreading between nearby cells and neurons. Moreover, with regard to the irradiated rats it was demonstrated with Kresyl-violet staining techniques that there were scattered dark and obviously shrivelled and degenerated cells. The evaluation of the histological tests blindly ensued according to a half-quantitative evaluation system in three steps: 0 = no or very few dark neurons, 1= oderate occurrence, 2 = frequent occurrence. When these figures are applied to the intensity

of the exposure, a correlation can be made despite the heavy scattering effect. The authors gave a significance effect of $p<0.002$. The authors concluded from this experiment that through a non thermal effect, (the experimental set-up was located in a room with a thermostat), resulting from HF-irradiation an increase in BBB permeability occurred. As the authors had already hypothesized in an earlier study, when albumin penetrates the brain from the blood it could lead to a degeneration of nerve cells. Since the experimental animals were young rats, 12-14 weeks old, the authors considered the results especially relevant concerning the question as to whether or not teenagers are exposing themselves to any risks while using mobile phones. However, it has been conceded that the effects which were observed here are in principle repairable and therefore not an immediate health risk. Nevertheless, in the long run they can accumulate, or damage could occur in conjunction with other negative effects. The authors failed to mention that the low depth of penetration from these fields affected the entire brain of the rats, however with regard to humans only the surface layer is affected. Such findings are naturally well suited for causing alarm; this could have been the reason why the authors presented their results immediately to the public, instead of submitting them to a journal with a referee system, for example "Bioelectromagnetics". On the other hand this way of doing research is deplorable because the study contains a great deal of inaccuracies and regulation violations which the international community of scientists agreed on in order to ensure the quality of such experiments. These regulations are also recommended by the WHO. The reviewers of a scientific journal would have certainly reproached the authors about this. What is it dealing with in particular? The authors themselves concede that the number of rats was really too small to draw any valid conclusions. Of course, this applies all the more since the study deals with half quantitative evaluations concerning the effects, only with an absolute secure double blind evaluation while using several independent invigilators and a large number of slide preparations is it possible to make a conclusive statement. The appearance of degenerated nerve cells, proven with a Kesyl-violet staining, has been described in various neurophysiological studies without reference to the problem related to field effects. What triggers this mechanism and its cause are not fully understood. Usually it can be contributed to the phenomenon of differentiation, age or it is the result of different illness or stress factors. They occur in different regions of the brain in different intensities. Salford et al. did not go into any detail regarding this neurobiological aspect The above-mentioned regulations which are recommended for investigations on the effects of electromagnetic fields include the so-called "positive controls". As already mentioned, they have been observed by other working groups. For example, for a malfunction of the BBB to occur temperature shock is applied (Fritze et al. 97, Tsurita et al. 00) or certain toxins are administered (Finnue et al. 01, 02). Only through the use of such positive controls is it possible to evaluate the sensitivity and the meaningfulness of the observed effects. Only when such a comparison is made is possible to determine if the observed changes are relevant or not, or if it is merely a chance stray occurrence. In none of Salford's et al. studies, and not in his most recent study, were any positive controls done. One poses the following question: why were the rats first examined 50 days after exposure? Did they want to report on damage occurring much later? It is well known that slight changes in the permeability of the BBB occur, for instance, with the accompanied by a fever, and that these changes and effects are quickly repaired by the body. Different authors have proven that the effects triggered by HF-fields of very high intensities lead to an increase in the temperature of the brain, however after a few hours it can no longer be proven. 50 days after exposure the albumin serum would be reabsorbed, wouldn't it? On the other hand, one must consider that 50 days after exposure the rats were subjected to other influences, which can not be left out of a daily control. Despite a great deal of criticism concerning the preceding experiments, the exposure conditions of animals in this paper are very inadequately controlled. The regulations stipulate that actual energyabsorption measurements of the irradiated object or in a suitable model object must be taken. However, in this case the SARvalue was reported on theoretically without any experimental control. This can lead to serious false assessments, e.g. the body of an animal in a narrow space can destroy the field considerably. It must also be taken into account that during exposure, in a narrow cage fitted out with ventilation ducts, a possible increase in the animal's body temperature was not measured. It cannot be ruled out that the animals perspire during irradiation. This would be enough to explain why so few measured effects were produced. It is unimaginable that the above mentioned recommendations and criteria of the Bioelectromagnetic Society (BEMS) and the WHO for performing reliable experiments were not know to those doing this study. There is, however, an even more general codex for scientific investigations which was not observed in case: this codex stipulates that a study's results are to be discussed in light of current developments in research. In this case this would have been especially important. We have seen above that there were negative findings even before the Salford group's first experiments. But then, triggered by the first Salford investigation, a number of unsuccessful attempts to verify their results were made. In these publications the weak points of the previous Salford study were exposed and discussed. It would correspond to scientific honesty to quote these studies and at least to explain why in Lund and nowhere else, the effects of weak fields on the BBB can be measured. Actually in the report in question only publications are quoted from acceptable authors, even if they do not really have anything to do with the subject being discussed. So in this way the impression the unbiased reader gets from the report is that the findings of the Salford-group are in complete agreement with international research. How seriously the world took the Salford findings in 1993 became clear at the international BEMS conference in 2001 in St.Paul, Minnesota. At this conference there was a special section devoted to the problems surrounding the BBB. J.Merrit, P. Mason, J.Lin, H. Nagawa, H. Masuda showed with posters and lectures that it was not possible to verify the Salford findings or to find any other effects for that matter. Everyone was eager to hear the lecture the group from Lund (B. Persson, A. Brun, L.G. Salford) submitted for the conference. Unfortunately it turned out that none of the authors attended the conference. Their paper was presented by a colleague who had not taken part in the study. It only contained findings from the previous publication that were already known. Unfortunately, the speaker could not answer any questions because he said he had not taken part in the experiments. It was suggested that the investigation of the Swedish group be done again in an extensive study, including the Swedish authors, but without making the same methodical mistakes. This was not however mentioned in the publication in question. It is a pity that findings are reaching the public more often that have not undergone a voluntary scientific quality control, as it is done in peer review systems. These are findings that at the end of the day do not hold up against objective criticism. This does not help the urgent necessity to gain recognition in this area, but all it does at most is to stir up emotions.

An in vitro model of the blood-brain barrier using rat astrocytes and porcine brain capillary endothelial cells was investigated by Schirmacher et al (2000). The model was exposed to 1.8GHz radiation modulated at 217 Hz with a mean SAR of 0.3 $\mathrm{W\,kg^{-1}}$, and monitored over four days. The permeability to sucrose was significantly increased compared with non-exposed controls.

3.8 Direct Effect On Proteins

3.8.1 Enzyme Activity

Enzymes are proteins that catalyse chemical reactions; each enzyme is specific to a particular reaction and hence there are hundreds of different types of enzymes in the body. They play a vital role in function both within cells and in the body fluids, their activity being regulated by various local factors. Pashovkina and Akoev (2000,2001) investigated the effects of 2.4 GHz radiation pulse or amplitude modulated at 10-390 Hz with power densities up to $80 mW\,m^{-2}$. They showed that RF radiation for one to three minutes with an amplitude modulation frequency of 70HZ caused a two-fold increase in guinea pig serum alkaline phosphatase. Furthermore the aspartataminotranspherase activity of donor blood was dependent on both the pulse modulation and intensity. The maximum effect, a six-fold increase, occurred after five minutes at 390 MHz and $80mWm^{-2}$. No SAR values were given.

A power density 1000-fold higher was required to affect the activity of acetyl-cholinesterase in frog skeletal muscle (Ivanov et al, 2001). An exposure of continuous wave 2.45GHz radiation at $100Wm^{-2}$ for 30 minutes caused a 26% decrease in enzyme activity. No SAR value was given for this power density; it is therefore possible that there was a heating effect. The effect of pulse modulation was not investigated in this study. Safronova et al (2002) exposed mouse neutrophil cells, primed by a low dose of chemotactic agent, to 41.95 GHz radiation with an SAR of $0.45\ W\,kg^{-1}$ to show enhanced activation of the cells when triggered by a higher dose of the agent. The study indicated that protein kinases, key cellular enzymes that phosphorylate proteins, were actively involved in the process. An ultra-wide band pulsed signal was used to expose macrophages (RAW 264.7 cells). The cells received 1 ns pulses repeated at 600 Hz with an estimated average SAR of $0.106\ Wkg^{-1}$ for 30 minutes (Seaman et al, 2002). Nitric oxide production was unchanged unless nitrate was added to the culture medium, indicating a possible induction of nitric oxide synthase by ultra-wide band pulses.

Since the IEGMP report was published in 2000, a number of possible mechanisms for interaction between RF radiation and biological tissue have been explored theoretically. Attention has been given to the possibility that RF radiation can produce changes in protein conformation. For RF fields below guideline values, It has been shown that these cannot occur as a result of transient changes In temperature. An alternative model has been given involving RF excitation of coupled states of different conformation but no estimates have been made of the fields required to produce detectable effects. Ion pumping across membranes can evidently occur for RF fields above guideline values at frequencies below a few MHz and has been qualitatively accounted for by a theory involving changes in protein conformation. The effects have not so far been explained quantitatively but seem unlikely to occur at higher frequencies. The assumptions of the Frohlich model seem to be increasingly improbable following calculations of the lifetimes of vibrational states in structures such as microtubules and also of the very small energies that can be stored in these states as a result of exposure to RF radiation.

There have also been suggestions that biological effects might arise either through the excitation of plasma-like excitations at the surface of cell membranes or through changes in the probability of ligand binding to cell receptor proteins, but no reliable estimates have been made yet of the size of RF fields required to produce them.

Experimental work on bacteria containing magnetite found no effects attributable to RF exposure. The work leaves open the question as to whether the low frequency fields from handsets can interact sufficiently with the magnetite to produce bioeffects.

The possibility that chemical reactions can be influenced by RF exposure through the radical pair mechanism, and that this could have biological implications, is worth further investigation.

There has been very little discussion of non-linear mechanisms through which biological components might demodulate RF signals. However, a detailed proposal has been advanced to investigate non-linearity experimentally at the frequencies used for mobile telecommunications and the technique would appear to be capable of great sensitivity. Strong non-linearity at frequencies above 1MHz seems unlikely but, if present, would result in electrical signals at pulse frequencies.

There is no overall convincing evidence to support the view that RF radiation is directly carcinogenic agents or that it promotes other carcinogenic agents. The studies are summarised in Table 3.1 Most of the criteria used to assess genotoxicity are negative.

There was no increase in cell proliferation, cell transformation, mutation rate or sister chromatid exchange. Only one study found a chromosomal aberration and another reported that there was DNA damage through synergy with a genotoxic agent, although only at one dose. The results from the micronucleus assays are variable. For instance, in one laboratory human lymphocytes exposed to 837MHz radiation, with an SAR of 5 or 10 $W kg^{-1}$, for 24 hours showed an increased incidence of micronuclei; in another, human lymphocytes exposed to 835MHz radiation, with an SAR of 5.5 $W kg^{-1}$, for 24 hours showed no increase, ie apparently similar conditions produced contrasting results.

The importance to human health of the occurrence of micronuclei in isolated cells is unclear. This difficulty in interpretation is compounded by there being a natural incidence of micronuclei normal cells.

In the recent papers reviewed (summarised in Table 3.2) there appears to be some evidence for an increase in expression of heat shock proteins in response to RF exposure. However, the exposure conditions and timings needed to evoke this response vary between the models. At the higher SAR values the effects of heating may play a contributory factor at the lower SAR values (1 $mWkg^{-1}$) this would seem unlikely to be the case. The results reviewed in these few studies are too inconsistent to draw any conclusions. For instance, the pattern of which heat shock protein increased. Hsp-27 or Hsp-70, varied between the models. The fact that all the studies

Cell type	Exposure	Results	Reference
Human leukocytes	1.9GHz CW or 6.7 ms pulse at 50 pps for 2 h, SAR 0–10 W kg^{-1}	No DNA damage. No increase in micronuclei formation	McNamee et al 2002a,b
Human leukocytes Human lymphocytes	837 MHz CDMA, 837 MHz TDMA, 1.9 GHz for 3 or 24 h, SAR 1–10 Wkg^{-1}	4-fold increase in micronucleus induction in lymphocytes. No effect on leukocytes	Tice et al 2002
Human lymphocytes	1.7 GHz for 15 min, max SAR 5 W kg^{-1}	Increase in micronucleus induction in phase modulated field	d'Ambrosio et al, 2002
Human lymphocytes	900 MHz CW or pulsed (GSM), 0.58 ms pulses at 217 pps for 2h, SAR 0–10 Wkg^{-1}	No increase in chromatid aberrations or sister chromatid exchange	Maes et al 2001
Human lymphocytes	CW 830 MHz for 72 h, mean SAR 1.6–8.8 W kg^{-1}	Aneuploidy of chromosome 17, abnormal replication of region dealing with segregation	Mashevich et al 2003
Human lymphocytes	2.45 GHz, 7.7 GHz for 30–60 min, 300 W m^{-2} (no SAR)	Up to 5-fold increase in micronucleus induction	Zotti-Martelli et al, 2000
Human lymphocytes	2.45 GHz for 2 h, 50 W m^{-2} (no SAR)	No increase in micronucleus induction. Synergistic genotoxic effect at one dose of mitomycin	Zhang et al, 2002
Human lymphocytes Mouse fibroblasts C3H 10T½	836 MHz FDMA for 24 h, SAR 5.0 W kg^{-1} 848 MHz CDMA for 24 h, SAR 5.5 W kg^{-1} 2.45 GHz for 2 h, SAR 2.1 Wkg^{-1}	No increase in chromosomal aberrations, micronuclei induction or DNA damage	Vijayalaxmi et al, 2000, 2001a,b
Mouse fibroblasts C3H 10T½	836 MHz FDMA for 3–24 h, SAR 5.1 W kg^{-1} 848 MHz CDMA for 3–24 h, SAR 4.8 Wkg^{-1}	No increased micronuclei induction	Bisht et al, 2002
Mouse fibroblasts C3H 10T½	836 MHz FDMA, 84.8 MHz CDMA for 24 h, SAR 3.2–5.1 W kg^{-1}	No DNA damage	Li et al, 2001
Mouse fibroblasts C3H 10T½	836 MHz FDMA, 848 MHz CDMA for 7 d, mean SAR 0.6 W kg^{-1}	No change in transformation frequency	Roti Roti et al, 2001
Mouse fibroblasts C3H 10T½ Human glioma U87MG	836 MHz FMCW, 848 MHz CDMA for 100 h, mean SAR 0.6 W kg^{-1}	No change in cell progression	Higashikubo et al, 2001
Brain tumour MO54 cells	2.45 GHz for 2 h, SAR 100 W kg^{-1}	No DNA damage	Miyakoshi et al 2001
Nasopharyngeal carcinoma CNE	42.2 GHz for 30 min per day, 4 days, 10 W m^{-2} (no SAR)	Cell proliferation inhibited	Wang Y P et al 2001
MCF7, K562, epithelial cells	54–78 GHz for 1 h per day, 0.7 m W m^{-2} (no SAR)	Cell growth inhibited	Chidichimo et al, 2002
Yeast *saccharomyces cerevisiae*	900 MHz pulsed (GSM), 0.58 ms pulses at 217 pps for 36 h, SARs 0.13 and 1.3 W kg^{-1}	No increase in mutation rate	Gos et al, 2000

Table 3.1 Possible Carcinogenic Effects

Cell type	Exposure	Results	Reference
Nematode *C.elegans*	0.7–1 GHz for 20 h, SAR 1 mW kg^{-1}	Growth rate increased 11% Maturation to adulthood increased 40%	de Pomerai et al. 2002
Human epithelial amion	960 MHz pulsed (GSM), 0.58 ms pulses at 217 pps for 20 min, SAR 2.1 m W kg^{-1}	Increased heat shock protein Hsp-70, Hsp-27 could not be detected	Kwee et al. 2001
Chick embryo	915 MHz for 1 h per day, 4 days, SAR 1.7 W kg^{-1}	Decreased protection against hypoxia	Di Carlo et al. 2001
Human glioma MO54	2.45 GHz CW for 2–16 h, SAR 5–100 W kg^{-1}	SAR above 20 W kg^{-1}, 2 h increased Hsp-70	Tian et al. 2002
Human endothelial EA.hy926	900 MHz pulsed (GSM), 0.58 pulses at 217 pps, mean SAR 2 W kg^{-1}	Transient increase in Hsp-27 phosphorylation	Leszczynski et al 2002
Human skin fibroblasts	902 MHz pulsed (GSM), 0.58 ms pulses at 217 pps, mean SAR 0.6 W kg^{-1}	Increased gene expression and DNA synthesis	Pacini et al. 2002
Human monocytes	8.2 GHz, pulsed, 2.2 µs pulse at 1000 pps for 90 min, mean SAR 11 W kg^{-1}	3.6-fold increase in binding activity of NF-kappa B	Natarajan et al. 2002
Mouse neutrophils	41.95 GHz, SAR 0.45 W kg^{-1}	Enhanced activation response to chemotactic agent	Safronova et al 2002
Human leukaemic T-cells	915 MHz CW or pulsed (GSM), 0.58 ms pulses at 217 pps for 10 min, SAR 1.5 W kg^{-1}	No change in calcium level or signalling	Cranfield et al. 2001
Cerebellar granule cells Neonatal rat myocytes	380 MHz pulsed (TETRA), 14.2 ms pulse at 17.6 pps for 20 min, SAR 0.4 W kg^{-1}	No change in intracellular calcium	Green et al. 2002
Rat hippocampal slices	700 MHz CW for 15 min, SAR 4.4 m W kg^{-1}	Changes in electrically evoked field potential (−80 to +120%)	Tattersall et al. 2001
Human erythrocytes	2.45 GHz for 60 h, 0.25–100 W m^{-1}, 60 h (no SAR)	Biphasic effect on haemolysis, increased by short low power exposures, decreased by higher and longer treatments	Sajin et al. 2000
Rat astrocytes Porcine endothelial	1.8 GHz pulsed (GSM), 0.58 ms pulses at 217 pps for 4 d, mean SAR 0.3 W kg^{-1}	2-fold increase in permeability	Schirmacher et al. 2000
Serum enzymes	2.4 GHz CW or pulse modulation, 50–390 pps for up to 5 min, 80 mW m^{-2} (no SAR)	Alkaline phosphatase activity increased 2-fold; aspartataminotransphetase activity increased 6-fold	Paskovkina et al. 2001a,b
Frog muscle extract	2.45 GHz CW for 30 min, 100 W m^{-2} (no SAR)	Decrease (26%) in acetylcholinesterase activity	Ivanov et al. 2001
Macrophage RAW 264.7	Ultra-wide band for 30 min, SAR 0.1 W kg^{-1}	Increased nitric oxide production	Seaman et al. 2002

Table 3.2 Possible Carcinogenic Effects

reviewed showed positive effects, albeit in different heat shock proteins, over a wide range of exposures is Interesting. This may reflect a selection bias toward positive studies in the literature. It could be a heating artefact, or it may be a real phenomenon, which would require confirmatory studies. In contrast to earlier work studies since the 1980s have generally found no increase of calcium movement in tissues as a result of RF exposure under a variety of conditions and modulations. Two recent studies measured intracellular calcium ion concentration in cells exposed to pulse modulated RF signals. This is a sensitive indicator of cell pathology and shows transient changes not only within the cell but also in the flux of ions from the cell (efflux). These well-conducted studies found no effect of RF modulation on calcium ion concentration, and add further to the doubt about the existence of a specific pulse modulation effect on calcium movement in tissues. At present there are too few well-conducted studies using modern techniques to draw firm conclusions, but the weight of evidence appears to be against there being an effect of pulsed RF radiation on intracellular calcium concentration or flux.

The general hypothesis that low frequency pulse modulation of the RF signal is necessary for a biological effect has been neither confirmed nor negated, based on the papers reviewed. Effects, such as micronucleus formation, or lack of effects have been found for continuous wave and a range of pulse modulation frequencies.

The results from a four-day exposure of an in vitromodel of the blood-brain barrier permeability to sucrose are intriguing but would need to be confirmed in animal studies to show that the response also occurred in vivo.

Although there has been a wide range of diverse exposures and biological models investigated, no consistent pattern has emerged from the cellular studies of RF exposure. The balance of the findings on carcinogenesis is that there is little evidence and no known mechanism to support a direct or indirect effect of RF radiation on this process. Positive findings are not confirmed by other independent studies; apparently similar experiments fall to confirm each other and may even show contradictory results. The IEGMP report (2000) concluded that: the radiation lacks sufficient energy to disrupt molecular bonds directly; the literature on non-thermal effects is inconsistent; the effects reported are typically small and close to the level of statistical noise. A review of the more recent literature confirms that these conclusions are still valid for the experimental cellular studies.

3.9 Salford Study

Salford and his working group in Lund (Sweden) have recently published an alarming new study, which has gotten a lot of attention, in which the effects of mobile radio emissions on the development of "dark neurons" (DN) in conjunction with the occurrence of microscopic leeks allowing protein to enter the brain are described. Two reputable scientists closely examined the publication, which has only been published online and offered their opinions of it to the FGF. The following article is the joint opinion of Dr. Sheila Johnston (neuro-science expert, in London) and Dr. Helmut Franke (Clinic and Policlinic for Neurology, Müster) In the publication "Nerve cell damage in the mammalian brain after exposure to microwaves from GSM mobile phones", Salford et al., 2003, the reported nerve cell damage was brought about by the effects of mobile radio fields of unknown frequencies (only the GSM-standard was given) at a field strength of 0.24-2.4 W/m2, corresponding to 2-200 mW/kg. The publication is based on a single experiment, which has not been done again or reproduced. For such an experiment a very small test sample was used; 32 rats (altogether there were 4 groups, 8 in each group). Not earlier than 50 days after being exposed to a mobile radio field brain slides were first prepared with two different stains. The following serves as proof for Salford etal. that brain damage occurred:

• firstly, the staining of protein which had permeated the blood brain barrier in an unwanted (pathological) way; staining was aided by a protein specific antibody. Normally the blood brain barrier in a healthy state does not allow harmful substances and proteins to cross over to the brain into actual brain tissue, see Stögbauer, 2002.

• secondly, with a second staining an additional pathological finding was examined: namely, the development of the mentioned "dark neurons" DN. In the literature they are described as proof of diverse damage to nerve cells, caused by various kinds of mechanical effects and harmful metabolic processes (Vohra et al. 2002). A direct quote taken form the article in question reads as follows; "DNs develop under so many various conditions that the reason why they develop will remain a mystery". Generally, DN to be more exact are described as "argyrophile" neurons, whereas the medical term "argyrophilie" merely means the dark tissue staining brought about by silver coating with a ammoniacalic silver nitrate solution followed by a reduction caused by formol, tannin etc. (Roche Lexikon Medizin, Ver.3.5). Physicians usually use this staining procedure for particular proof of something e.g. in special tissue regions or in special cells. The staining method used by Salford et al. Differed from the one described above.

On one side the genetic makeup of the cells (DNA, RNA) is stained and on the other side another stain colour (cresyl violet) is used. On the other hand, this is a normal method of distinguishing damaged cells, (damaged, i.e. cell coverings pitted with holes) from undamaged cells. However, the results in this case are also called dark neurons. Gallyas et al. (1992) described numerous causes for the development of DN. Moreover, in his publication the appearance of DN is independent of their cause. Even after death, severe shaking of a brain that has not yet been dissected could be responsible for the appearance of DN. These are however not distinguishable from DN which previously occurred when the animal was alive. Basically various other causes should be considered for the development of DN, however the development of DN from mobile radio fields has to be considered since it cannot be completely ruled out. With the exception of a concussion occurring after death, other causes were not taken into account and discussed nor were any corresponding control experiments conducted by Salford and his colleagues. It is hard to understand why the rats, after undergoing 2 hours of field exposure, were first examined 50 days later. It is especially true in view of the fact that Vohra et al. (2002) described the development of DN as an aging phenomena that to date has not been explained. So without any outside influences rats that are already 6 months old show almost double the number of DN when compared to 3-month old rats. The rats at the beginning of the Salford et al. experiments had exactly this age difference. Moreover, for a publication with high academic standards, among other things, the specific absorption rate was not adequately standardized. The variation in SARdistribution was given at 6 dB, (SAR = "specific absorption rate"). This indicated a four-fold range of variation. It is amazing that a publication that receives international recognition in the field of mobile radio research only stated that GSM-field irradiation was applied but did not even once mention the frequency used in the investigation. Apart from that a great deal of the usual information for such a study was lacking.

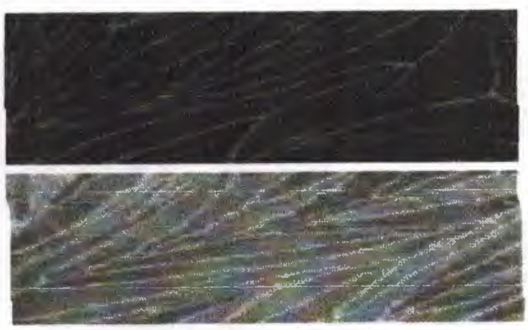
3.10 Results and the Discussion Section of the Publication

Remarks and comments made on the results in the discussion section of the article are very superficial. Salford did completely without a comprehensible numerical description of the exhibited transport of protein out of the vascular system (see above). A clearer correlation between the transport of protein and the development of DN was not demonstrated. In the rather short presentation of the results concerning protein staining, Salford et al. pointed out that the staining in the control group, displayed more often a dubious positive reaction (a reaction that really should not occur in a control group). Consequently a reliable assignment of the three ranks that he de termined for assessing protein staining were obviously not given. ("Quote: the control rats exhibited no positive reaction or only infrequent reactions and often they exhibited a questionable positive reaction to protein in the hypothalamus"). In one of the pictures in Salford's publication, two images of brain slides taken from an irradiated rat are compared to a slide taken from a rat in the control group. To which group the rat was assigned to was later indicated in a corrected version of the paper. By looking at the external form of the brain slides one can determine that they were not taken from the same area of the brain, a comparison is, therefore, only partially valid. Another image shows DN staining exclusively of rats which were exposed to mobile radio signals. Negative control images, in other words the images taken from the brains of rats that were not irradiated were completely lacking in the study. The field strengths assigned to these images were also not given. In a scientific publication this is a matter of course that this information is given. Moreover, what is very unusual for a scientific publication is that Salford et al., in the discussion of their results, did not cite any other references to substantiate their findings. Another point to consider concerns other similar studies conducted by the authors, where their results could not be reproduced. This was also not discussed or analysed in this publication. The hypothesis concerning a secondary opening in the blood-brain-barrier, which is supposedly caused by the observed flow of protein was mentioned in the discussion but this was not dealt with in detail nor was the reason for it discussed and therefore its existence is rather questionable. Ascertaining that 12-26 week old rats in their development stage are especially suitable for a comparison to teenagers addicted to mobile phones, is really a very daring statement, especially when there is no data to support it. Further statements regarding the special susceptibility of adolescents in this part of the discussion can only be considered as assumptions. For a scientific publication the facts and statements made in the discussion part of the paper seem to be rather sketchy.

3.11 Inadequate Dosimetry And Questionable Significance of DN

Sheila Johnston especially emphasizes in her opinion on Salford's publication that little attention was given to dosimetry and she questions the medical significance of the discovered "dark nerve cells". Regarding the given SAR-values, they obviously deal with *estimated* total body mean values, where the SAR-distribution in the brain was determined by a computer simulation. For this kind of study this does not fulfil the criteria of the World Health Organization (WHO), because the SAR-values for the brain are not measured but are only indirectly calculated. Moreover, Johnston noticed since 1998 in a whole series of Salford's investigations on the blood brain barrier that it is not possible to draw a conclusion from the actual SAR-values he employed because of defective dosimetry. Since these SARvalues were derived from the electrical field (E-field) that existed in the exposure chamber that was employed (a so-called TEM cell) these E-fields *cannot* correspond to the E-fields in the brains of the rats, it can be deduced that the SAR-evaluations are false. Sheila Johnston has disputed the rather far-reaching interpretations in Salford's et al. discussion with regard to the possible

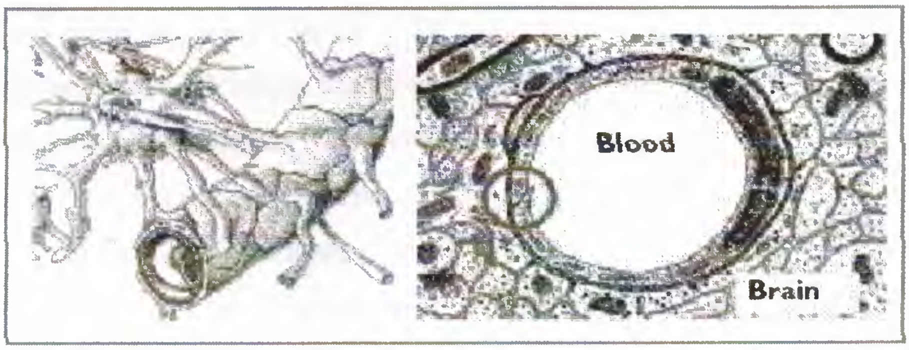
A microscopic image of endothelial cells (see picture page 25) in a cell culture dish. the spirally formed shape of the cells which are tightly packed together is typical for the blood brain barrier.



With the help of staining one can see in a culture dish how the special protein has been made the right seals of the endothelial cells visible.

Figure 3.3 A microscopic Image of Endothelial Cells

negative effects DN could have on human memory during the course of the aging process with the following arguments: Neuro-degenerative illnesses, (e.g. illnesses with memory loss) occur when the brain's main switching circuits are destroyed, which is caused by nerve cell death and the loss of synapses. This degeneration is selective, i.e. there are nerve cells that are more or less susceptible to such processes. The occurring symptoms of such an illness are dependent on the particular switching circuits which are detrimentally affected and hence give a picture of the *selective* vulnerability of the nerve cells. In the normal aging process, a reduction in the number of brain cells, caused by the dying of cells, is not a crucial process, at least not in the area of the brain that Salford et al. referred to. With regard to the counting of nerve cells, it is generally very difficult to make a functional association, because the regional differences and the dissimilarities among the cells of the cerebral cortex are enormous. Therefore, the studies which give the most insight into the aging process are those where a certain area of the brain is investigated which is correlated with bodily functions that are well understood (Morrison & Hof, 1997). However, the "dark nerve cells" (DN) that Salford et al. reported on were randomly distributed everywhere in the rats' brains and therefore it is *not* possible to make an association with particular switching circuits. Hence it is going too far, to try and derive some kind of neurological significance from the results or to interpret them as being indications of possible symptoms of an illness. Currently many investigations are being conducted on the possible effects to the blood brain barrier from electromagnetic fields by internationally recognized research groups in France, Japan, Germany, Germany, and in the U.S.A. The first results are expected to be published this year and one can hope that more solid results will come to light than what was discussed here. Obviously Salford's et al. work is more of a speculative nature than anything else.



The blood brain barrier forms a special wall covering within the microscopic blood vessels (capillaries, illustration on the left) in the brain. Larger molecules (e.g. protein) and toxins have no excess to the nerve cells in the brain. In the cross-section illustration of a capillary (on the right) one can see how the endothelial cells are tightly layered and packed together, they cover the inside of the capillaries and are sealed together by the so-called tight junctions (tj). All around them on the outside are the star shaped astrocytes and of course the nerve cells can also be seen.

Figure 3.4 The Blood Brain Barrier Forms A special Wall Covering

CHAPTER FOUR

Non-cancer Epidemiology and Clinical Research

4. Overview

This chapter focuses on other health outcomes that have been linked with exposure to RF radiation. In general, the chapter covers studies published before and since the IEGMP (2000) report in similar depth. The relation of various disorders to RF radiation from visual display units (VDUs) was considered in an earlier report from the Advisory Group (AGNIR, 1994), and therefore VDU studies evaluated before then have not been re-examined in detail.

4.1 Effects of Short-Term High Exposure

A number of published reports describe incidents in which people have experienced short-term exposures to levels of RF or microwave radiation well above currently recommended exposure limits. These unusual exposures have occurred in various circumstances including work close to radio and radar antennas while they were transmitting, and failure of protective interlocks on microwave ovens. In some cases only part of the body was irradiated.

As would be expected, sensations of warming are frequently reported (Daily,1943;Williams and Webb, 1980; Forman et al, 1982 ;Rchilling, 1997 ,2000;Reeves, 2000; Hocking and Westerman2001), and these have sometimes been associated with akin eythema and evidence of tissue damage. Other acute symptoms have included headache (Forman et al,1982; Schilling, 1997,2000; Reeves, 2000;Hocking and Westerman, 2001), fatigue (Schilling,2000; Hocking and Westerman,2000), vertigo (Forman et al, 1982), eye irritation (Forman et al, 1982; Reeves, 2000),photophobia(Forman et al 1982), blurred vision (Hocking and Westerman ,2001), indigestion (Forman et al ,1982), diarrhea(Schilling,1997,2000),anxiety, insomnia , and emotional lability (Forman et al ,1982), and numbness and paraesthesiae (sometimes with demonstrable impairment of nerve condition) (Tintinalli et al,1983;Marchiori et al , 1995; Schilling ,1997,2000). In some cases, abnormalities have persisted for months or even years (Marchiori et al, 1995; Schilling, 1997, 2000; Hocking and Westerman, 2001).

4.1.1 Conclusion

It is well established that acute exposure to RF radiation can cause thermal Injury to tissues. However, such injuries have not been shown to occur from exposures below current guideline levels in the UK. It is unclear whether the psychological symptoms that have been described reflect direct injury to the central nervous system or an indirect effect of stresses associated with the exposure incident.

4.2 Microwave Hearing

It has been well documented that people can hear buzzing. clicking or popping sounds when exposed to pulse modulated fields with frequencies between about 200MHz and 65GHz (Barron et al, 1955; ICNIRP, 1998). The phenomenon has been reported with average exposures as low as $4Wm^{-2}$ (Frey, 1961), and a threshold for perception of about 100-400 mJ rn^{-2} has been reported for pulses of duration less than 30 μs at 2.45GHz (ICNIRP,1998). Mechanical vibrations are induced through minute thermoelastic expansion in the soft tissues of the head, and are transmitted to the cochlea by bone conduction (IEGMP, 2000). The effect depends on the magnitude and rate of the transient temperature increases that are produced by the RF pulses , and in theory could occur over a wider range of frequencies than described above. The perception of sound that results could be annoying, but would not be expected to cause any long-term health effect.

4.2.1 Conclusion

There is convincing evidence that pulse modulated RF radiation with frequencies between 200 MHz and 65GHz can cause auditory stimulation at average exposure levels as low as $4W\,m^{-2}$. This results from thermoelastic expansion of tissues in the head as a consequence of minute fluctuations in temperature. Although the resultant perception of sound might be considered a nuisance, there is no reason to suspect that it has any long-term adverse impact on health.

4.3 Cataract

The possibility that microwave radiation might cause cataracts has long been a concern because the lens of the eye does not have a blood supply through which heat can be dissipated. A number of early surveys sponsored by the US Air Force were reviewed by Odland (1972). Some of these suggested more prominent posterior polar lens changes in individuals with possible occupational exposure to microwaves, but there was no evidence of more serious eye disease. Potentially more important lens changes were observed, however, among 35 individuals involved in incidents of acute over-exposure to microwaves (200-2000W m^{-2}) at a US Air Force facility (LaRoche et al, 1970).Of these, 12 were said to exhibit 'typical' microwave lens changes characterized initially by thickening and opacification of the posterior lens capsule, and eventually progressing to opacification of the lens itself.

To investigate the risk of clinically significant cataract, cleary and colleagues searched the diagnostic indices of hospitals in the US Veterans Administration system and identified 2946 white male Army and Air Force veterans born after 1910 who had been treated for cataracts during 1950-62 (Cleary et al, 1965). They compared them with a control group of 2164 men whose hospital registration numbers were adjacent to those of the cases. History of work with radar was determined from the subjects' military records. After exclusion from the ease group of congenital cataracts and cataracts associated with Down's syndrome, trauma and diabetes, the crude relative risk associated with radar work was 0.67. Furthermore, within three age strata, the highest relative risk was 1.02. No account was taken of potential confounding factors other than age. The study was powered to detect a doubling of risk.

Subsequently, the same authors carried out a cross-sectional survey of 736 workers with exposure to microwaves and 559 unexposed controls who were employed at the same locations (Cleary and Pasternack, 1906). The median duration of microwave work in the exposed group was 5.5 years. Each man underwent silt-lamp examination, with the examiner unaware of his exposure status. Abnormalities of the lens such as opacification, posterior polar defects, relucency and sutural defects were each graded to four levels, and summary 'eye scores' were derived. These scores were then regressed on exposure scores determined from each man's occupational history, with adjustment for age. Minor abnormalities. in particular posterior polar defects, tended to occur more frequently with exposure to microwaves, and their prevalence was related to duration of microwave work, and history of sensations of exposure such as cutaneous heating.

In the course of six-monthly eye screening at an American military base during 1968-71, workers were examined without knowledge of their exposure to microwaves (Appleton and McCrossan, 1972). In a comparison of 91 persons exposed to microwaves (in some cases since 1943) and 135 unexposed controls, no evidence was found of increased lens abnormalities. In Sweden, 68 workers exposed to microwave radiation in the electronics industry were examined by two eye specialists, together with 30 unexposed controls (Aurell and Tengroth, 1973). The examining doctors were not aware of subjects' exposure status. At younger ages, there was a higher prevalence of lens opacities among the exposed workers, but the importance of this finding is reduced in so far as the study was stimulated by an observed excess of such abnormalities in a screening programme. A survey of 841 men aged 20-45 years who were occupationally exposed to microwaves compared the prevalence of lens changes in 507 with higher exposures (2-60W m^{-2}) and 334 with lower exposures (Siekierzyneski et al,1974a). After allowance for age, no significant difference was found, but the method of statistical analysis was poorly described. Another cross-sectional survey compared the findings on ophthalmic examination in 417 workers exposed to microwave radiation at US Air Force bases and 340 unexposed controls (Sacklett et al, 1975). The examiner was unaware of the subjects' exposures. Abnormalities of the lens (opacities, vacuoles and posterior subcapsular iridescence) were classified according to pre-defined criteria, and while they increased in prevalence with age, they were not associated with exposure to microwaves.

In a study in the former Yugoslavia, ophthalmic and other investigations were carried out on 320 men aged 25-40 years, who had been exposed to pulsed microwaves from radar (generally at less than 50W m^{-2}) for five to ten years, and 220 controls matched for age and social conditions (Djordjevic et al, 1979). No significant differences were found in the prevalence of lens capacities (0.9% in both groups). There was no relation of lens changes to duration of radiation exposure in a survey of 121 Finnish radar workers (Castren et al, 1982). However, data on exposures were limited, and because the clinical assessment involved a two-stage process, the ascertainment of lens abnormalities may not have been complete.

In contrast, a survey in Australia found posterior subcapsular opacities on slit-lamp examination (conducted without knowledge of exposure status) in 11 of 53 radio line-men as compared with 3 of 39 age- and sex-matched controls (Hollows and Douglas, 1984). The linemen were exposed to microwave power densities measured at 0.8 to 39 560 Wrn^{-2}. The earlier Advisory Group review of health effects from VDUs (AGNIR, 1994) concluded that there was no evidence at that time that work with VDUs caused cataracts. However, no long-term follow-up studies of cataract in VDU users have yet been reported.

4.3.1 Conclusion

The available epidemiological evidence on microwave radiation and cataract is of variable quality. Many of the published reports do not provide quantitative data on exposures, or on the reliability of the methods by which pathology in the lens was assessed. Where eyes were examined with knowledge of exposure status, there was potential for bias. Even where they were examined without such knowledge (as was the case in most studies), non-systematic misclassification of disease will have tended to obscure any increase in risk from microwave exposure. In some investigations there may have been unrecognised confounding (positive or negative) from differences in exposure to ultraviolet radiation in sunlight or differences in age distribution.

Some studies have suggested that minor defects in the posterior pole of the lens are found more frequently in workers exposed to microwave radiation but this has not been a consistent finding, and the changes reported are of doubtfull clinical relevance. Overall, there is no indication that clinically important cataracts occur with increased frequency in microwave workers.

4.4 Male Sexual Functıon And Fertılıty

A cross-sectional survey in Romania (Lancranjan et al, 1975) examined sexual function in 31 male technicians (mean age 33 years) who had been exposed to microwaves For 1-17 years at levels that were often in the range of hundreds to thousands of W m^{-2}. Of these, 22 (70%) reported reduced libido and disturbance of erection ejaculation or orgasm, and abnormal spermatogenesis was observed in 23(74%). Sperm counts were significantly lower than in 30 unexposed controls (mean age 34 years) as were counts of motile sperm. However, no significant differences were found in the urinary excretion of 17 ketosteroids. (No information was given about the repeatability of the sperm counts or whether they were assessed blind to exposure status.) A survey of American soldiers compared semen analyses and blood levels of hormones in 30 artillerymen with potential exposures to lead, 20 operators of radar equipment, and 31 controls unexposed to lead or microwaves (Weyandt et al, 1996). The laboratory examination of semen included computer assisted sperm analysis (CASA), and was carried out without knowledge of subjects' exposure status. After adjustment for potential confounders, the radar operators bad a lower mean sperm count than the controls (1.3 10^7 mL^{-1} vs 3.5$10^7$ mL^{-1}) and a lower percentage of motile sperm (32% vs 43%). However, no significant differences were observed in various other measures of sperm quality, nor in blood levels of luteinising hormone or free testosterone. The authors noted the possibility that soldiers with concerns about fertility problems were selectively recruited into the study. This investigation was followed by a larger survey by the same group with a broadly similar design that included 33 soldiers with exposure to radar, 57 artillerymen and 103 controls (Schrader et al, 1998). No significant differences were found between the men exposed to radar and the controls for any of: serum and urinary follicle stimulating hormone and luteinising hormone; serum, salivary and urinary testosterone; semen analysis. The authors speculated that the exposures to radar may have been lower than in their earlier study. A preliminary survey of 19 Danish military personnel exposed to microwave-emitting radar systems (maximal mean exposure 0.1 Wm^{-2} but with occasional short-term exposures up to 10W m^{-2}) found that after adjustment for duration of sexual abstinence; their mean sperm count was 2.3$10^7$ mL^{-1} lower than for 489 men from other occupational groups studied previously (Hjollund and Bonde, 1997).

Investigators in the USA compared 33 parameters of semen quality and serum levels of four sex hormones in 12 RF heater operators and 34 unexposed controls (Grajewski et al, 2000). Participation rates were low, especially in the control group (34.1%), and there were major differences in the ethnic origin of the exposed and control subjects. Minor differences were found in several measures of semen quality, and serum FSH (follicle stimulating hormone) levels were slightly higher in the RF-exposed operators, but the occurrence of these results in the context of multiple statistical testing suggests that the finding might have been due to chance.

4.4.1 Conclusion

The current evidence base on RF radiation and male sexual function is extremely limited. Three out of five published studies have suggested a reduced sperm count in exposed workers, but all of these investigations have been small, and one (Lancranjan et al, 1975) was of doubtful rigour.

4.4.2 Female Sexual Function And Fertility

A Polish survey in the 1960s of 118 women working with microwave generators was reported to indicate an increased frequency of cervicitis and menstrual disturbance (Higier and Baranska, 1967). However, it is unclear from the English summary how the expected rates were derived, whether the comparison took account of potential biases and confounders, and whether the excess was statistically significant. More recently, an investigation of time to pregnancy was carried out among a cohort of Danish female physiotherapists (Larsen et al, 1991). Information about pregnancies and birth outcomes was obtained by linkage with registers of births and hospital in-patients, and interviews were conducted with women who had experienced spontaneous abortion (166 cases). Stillbirth or death in the first year of life (18), low birth weight (under 2500g) (44) or pre-term delivery *(86),* as well as a sample of those with pregnancies that did not fall into any of these categories. Among other things, the women were asked about time to pregnancy after cessation of contraception and about their exposure to short-wave diathermy during the first month of pregnancy. The latter was characterised by a time-weighted exposure index. No clear relation was found between prolonged time to pregnancy (over six months) and occupational exposure to microwave radiation (odds ratio, OR, for highest vs lowest exposure category of 1.7; 95% confidence interval, CI, 0.7-4.1).

4.4.2.1Conclusion

Only one epidemiological study of reasonable quality has addressed the impact of RF radiation on female fertility (Larsen et al, 1991), and the results are inconclusive.

4.5 Spontaneous Abortion

An early case report from the USA described a woman who miscarried following eight treatments with microwave diathermy during the first 59 days of pregnancy for chronic pelvic inflammatory disease (cited In Michaelson, 1982). More recently, a nested case-control study of spontaneous abortion was conducted among a national cohort of some 5000 female physiotherapists in Finland (taskinen et al, 1990). The cases were identified by linkage with a hospital discharge register and with clinical data on spontaneous abortions, and were compared with a sample of physiotherapists who had given birth to a normal child (Where a woman had had several abortions or births during the study period, one pregnancy was selected at random) Occupational exposures during the first three months of pregnancy were ascertained by postal questionnaire with response rates close to 90%. In an analysis based on 204 cases and 483 controls, spontaneous abortion was associated with use of ultrasound and physical exertion at work and abortion after ten or more weeks' gestation was associated with use of deep heat therapies (especially short-wave diathermy). However, in a multivariate analysis that included potential confounders, the last association was not statistically significant.

In another case-control study, 146 Danish physiotherapists who had suffered spontaneous abortion were compared with a reference group of 259 physiotherapists with completed pregnancies (larsen et al, 1991). No significant association was found with a time-weighted index of exposure to high frequency electromagnetic radiation from use of short-wave treatments during the first month of pregnancy (OR for highest vs lowest exposure category 1.4; 95% CI 0.7-2.8). Following a postal survey of 42403 female physiotherapists in the USA which collected information about pregnancy outcome and occupational exposures, a nested case-control study of spontaneous abortion was conducted in a subset of 6684 responders who reported ever having used microwave or short-wave diathermy at some time during employment (Ouellet-Hellstrom and Stewart, 1993). The 1753 case pregnancies were each matched with a control pregnancy in a mother of the same age (some mothers were sampled more than once as cases, controls or both). After adjustment for various potential confounders (including a variable for the number of previous fetal losses), there was an elevated risk of spontaneous abortion in women who were exposed to microwave diathermy during the six months before and three months after conception (OR 1.34; 95% CI 1.02-1.59). Moreover, risk increased with the number of exposures per month. However; no clear elevation of risk was apparent for exposure to short-wave diathermy during the same period (OR 1.07; 95% CI 0.91-1.24).

[A subsequent letter pointed out that microwave diathermy is less penetrating than short-wave therapy and therefore would give a lower dose to the uterus early in pregnancy (Hocking and Joyner, 1995). The 1994 Advisory Group report on VDUs reviewed nine epidemiological studies of spontaneous abortion (AGNIR, 1994). Six of these investigations found no elevation of risk even in heavy users, and the report concluded on the balance of evidence that VDU use does not increase the risk of spontaneous abortion. No new studies on the relation of spontaneous abortion to use of

VDUs have been published since 1994.

4.5.1 Conclusion

Although one case-control study has suggested a small elevation in the risk of spontaneous abortion among physiotherapists who used microwave diathermy around the time of conception, an association with short-wave or microwave therapy was not dearly apparent in two other investigations. Given the potential for recall bias in studies which ascertain exposures from subjects' personal recollection, the single positive finding is not a cause for concern. At the same time, current epidemiological evidence does not rule out the possibility that RF radiation could have a small effect on the risk of spontaneous abortion.

4.5.2 Bırth Outcome And Congenıtal Malformatıons

An early case-control study in Baltimore, USA, collected information about the parents of 216 children with Down's syndrome and an equal number of individually matched controls (Sigier et aI, 1965).The main Focus of the investigation was exposure to ionising radiation before the child was born, but, unexpectedly, there was a higher prevalence of exposure to radar among the case fathers (8.7% vs 3.3% of controls). This association disappeared, however, when the ascertainment of cases was extended to cover births over a longer period (Cohen et al, 1977).

A Swedish study compared the prevalence of birth outcomes in 2043 babies born to 2018 physiologists during 1973-78 with that expected from national rates (kallen et al, 1982). After adjustment for age, parity and hospital of delivery, the numbers of babies with gestation less than 38 weeks, birth weight under 2500g, and major malformations were all less than expected, and the frequency of all malformations was dose to expectation. However, in a nested case-control investigation that used a postal questionnaire to collect information about occupational exposures during pregnancy from 33 women whose babies were seriously malformed or died perinatally,33% reported use of short-wave equipment often or daily as compared with 14% of 63 controls ($p = 0.03$). There was no obvious pattern to the diagnoses of the exposed cases. Exposure to microwaves was too rare for meaningful analysis. A preliminary report of a register-based case-control study in Finland found no association between congenital malformations of the central nervous system, oral cavity, skeleton or cardiovascular system and exposure to non-ionising radiation (largely From microwave ovens) in restaurant staff during the First trimester of pregnancy (Kurppa et al, 1983). However, the authors indicated that their findings might be subject to revision because the classification of exposures had not yet been finalized. A later Finnish study used the national register of congenital malformations to identify cases born to mothers who were physiotherapists (Taskinen et al, 1990). Each case was matched with five normal births in the same cohort of women, and occupational exposures during the first three months of the relevant pregnancy were ascertained by means of a postal questionnaire (response rate close to 90%). In an analysis based on 46 cases and 187 controls that adjusted for several potential confounders, congenital malformations were associated with the use of short-wave equipment for over an hour per week (OR 2.3; 95% CI 1.1-5.2). However, there was no indication that risk increased with more frequent exposure. The observation of a case cluster prompted a similar study of female physiotherapists in Denmark (Larsen,1991). By linking union records with national registers of births, congenital malformations and hospital admissions, the investigators identified 57 cases of malformation and 267 referents randomly selected from non-cases. Information about occupational exposure to short-wave equipment during the first month of pregnancy was obtained through a blinded telephone interview (response rates above 90%). Positive associations were observed with duration and peak level of exposure, but these were weak and not statistically significant.

A further study based on the same cohort of Danish physiotherapists compared cases of birth weight under 2500g (44 cases), birth at less than 38 weeks' gestation (86) and stillbirth or death in the first year of life (18) with control births that did not meet these case definitions (Larsen et al, 1991). Again, occupational exposures during the first month of pregnancy were assessed from blinded telephone interviews. Exposure to short-wave diathermy was associated with a significant reduction in the ratio of male to female births, only 4 of the 17 children born to mothers with the highest time-weighted exposures being boys. However, associations for the other birth outcomes examined were based on small numbers of exposed cases and were not statistically significant.

In a postal survey completed by 2263 female members of the Swiss Federation of Physiotherapists (response rate *79.5%),* information was collected about the sex and birth weight of all children, and about the use short-wave and microwave equipment during the first month of each pregnancy (Guberan et al, 1994). In an analysis of 1781 pregnancies, neither category of exposure was associated with an unusual sex ratio. Nor was the use of short-wave equipment associated with a higher prevalence of low birth weight (under 2500 g). Data on work with microwave equipment and low birth weight were not reported.

As part of a case-control study of cardiovascular malformations in Finland, occupational exposure to microwave ovens was ascertained by interviewing the mothers of 406 cases and 756 controls (randomly selected from all births) approximately three months after delivery (Tikkanen and Heinonen, 1992). Daily exposure during early pregnancy was reported by 2.7% of case mothers and 1.9% of controls. For occasional exposure the corresponding proportions were 3.4% and 2.5%. Neither of these differences was statistically significant.

In a Dutch case-control study, the parents of 306 mentally retarded children and 322 controls with other congenital handicaps for which the cause was known (eg familial disorders and cerebral palsy) were interviewed about exposures from three months before conception to six months after the child was born (response rate 89.5%) (Roeleveld et al, 1993). Associations were found with maternal occupational exposure to non-ionising radiation during the last three months of pregnancy (OR 9.3; 95% CI 1.5-55.7) and also earlier in pregnancy and before conception.

CHATPTER FIVE

Epidemiological Studies Of Radiofrequency Field Exposure and cancer

5. Introduction

The emergent field of bioelectromagnetics encompasses two important scientific frontiers. On the one hand, it addresses studies in the physics of matter; and on the other, the search for essential bioenergetics of living systems. To carry this joint endeavor forward in future research, mainstream biological science is coming to recognize the essential significance of nonequilibrium processes and long range interactions ([Frohlich, 1988]). Historically, biology has been steeped in the chemistry of equilibrium thermodynamics. Heating and heat exchange have been viewed as measures of essential processes in the brain and other living tissues, and intrinsic thermal energy has been seen as setting an immutable threshold for external stimulation ([Adair, 1994]). Through the use of EM fields as tools, it is clear that heating is not the basis of a broad spectrum of biological phenomena incompatible with this concept. They are consistent with processes in nonequilibrium thermodynamics ([Adey and Lawrence, 1984]; [Binhi, 2002];[Scott, 1999). With the emergence of new knowledge on quasiparticles, solitonic waves and cooperative processes, many earlier postulates on the biological role of equilibrium thermodynamics have undergone extensive reappraisal ([Adey, 1992a][Adey, 1993]). Experimental evidence of biological effects of weak ELF magnetic fields is supported by theoretical models involving quantuminterference effects on protein-bound substrate ions. This ion-interference mechanism predicts specific magnetic-field frequency and amplitude "windows" within which the biological effect would occur, using the principles of gyroscopic motion ([Binhi, 2002]; [Binhi and Savin, 2002]

5.1 Evidence For Role Of Free Radicals İn Electromagnetic Field Bioeffects

Beyond the chemistry of molecules forming the fabric of living tissues, this experimental evidence suggests a biological organization based in far finer physical processes at the atomic level, rather than in chemical reactions between biomolecules ([Adey, 1997]). Physical actions of EM fields may regulate the rate and the amount of product of biochemical reactions, possibly through *free radical mechanisms* ([McLauchlan and Steiner, 1991];[Till et al., 1998]; [Timmel et al., 1998];), including direct influences on enzyme action ([Grissom, 1995]). Chemical bonds are magnetic bonds, formed between adjacent atoms through paired electrons having opposite spins and thus attracted magnetically. When chemical bonds are broken in chemical reactions, each atomic partner reclaims its electron and moves away as a *free radical* to seek another partner with an opposite electron spin. The brief lifetime of a free radical is about a nanosecond or less. McLauchlan points out that this model predicts a potentially "enormous effect" on the *rate* and *amount of product* of chemical reactions for static fields in the low mT range. For oscillating fields, the evidence is less clear on their possible role as direct mediators in detection of ELF frequency-dependent bioeffects. The highest levels of free radical sensitivities to imposed magnetic fields may reside in *spin-mixing* of orbital electron spins with nuclear spins in adjacent nuclei, where potential sensitivities may exist down to zero magnetic field levels. However, as a practical consequence, this sensitivity would hold only if occurring before diffusion reduced the probability of radical re-encounter to negligible levels (see [Adey, 2003a] for review) Lander (1997) has emphasized that we are at an early stage of understanding free radical signal transduction. "Future work may place free radical signaling beside classical intra- and intercellular messengers and uncover a woven fabric of communication that has evolved to yield exquisite specificity," but not necessarily through "lock and key" mechanisms. Lander speculates that certain amino acids on cell surface proteins may act as selective targets for oxygen and nitrogen free radicals, thus setting the *redox* potential of this target protein molecule as the critical determinant of its highly specific interactions with antibodies, hormones, etc. Magnetochemistry studies ([Grundler et al., 1992]) have suggested a form of cooperative behavior in populations of free radicals that remain *spin-correlated* after initial separation from a singlet pair. As discussed below, magnetic fields at 1 and 60 Hz destabilize rhythmic oscillations in brain hippocampal slices via as yet unidentified nitric oxide mechanisms (Bawin et al., 1996).

In a general biological context, these are some of the unanswered questions that limit free radical models as general descriptors of threshold events..

5.2 Calcium-dependent neuroregulatory mechanisms modulated by EM fields

5.2.1 Sensitivity of cerebral neurotransmitter receptors

Binding of neurotransmitters to their specific receptor sites is sensitive to weak modulated microwave fields. [Kolomytkin et al. (1994)] studied specific receptor binding to rat brain synaptosomes of three neurotransmitters, GABA, acetyl choline and glutamate, using 880 or 915 MHz fields at power densities of 10–1500 uW/cm2. Incident fields of 1500 μW/cm2 decreased GABA binding 30% at 16 pulses/s, but differences were not significant at 3, 5, 7, or 30 pulses/s. Conversely, 16 pulse/sec modulation significantly increased glutamate binding. For acetyl choline receptors, binding decreased 25% at 16 pulses/s, with similar trends at higher and lower frequencies. As a function of field intensity, sensitivities of GABA and glutamate receptors persisted for field densities as low as 50 μW/cm2 at 16 pulses/s with 915 MHz fields.

5.3 The Glutamate Receptor And Normal/Pathological Synthesis Of Nitric Oxide; Sensitivity To Magnetic Fields

An enzymatic cascade is initiated within cells when glutamate receptors are activated, leading to the synthesis of nitric oxide (NO). Receptor activation initiates an influx of calcium, triggering the enzyme nitric oxide synthase to produce nitric oxide from the amino acid arginine. As a gaseous molecule, NO readily diffuses into cells surrounding its cell of origin. It has been identified as a widely distributed neuroregulator and neurotransmitter in many body tissues ([Izumi and Zorumski, 1993]). Its chemical actions in brain appear to involve production of cGMP (cyclic-guanosine monophosphate) from GTP (guanosine triphosphate). The pathophysiology of NO links its free radical molecular configuration to oxidative stress, with a possible role in Alzheimer's and Parkinson's disease, and in certain types of epilepsy. Magnetic resonance spectroscopy (MRS) has suggested decreased levels of N-methylaspartate, an activator of the glutamate receptor, in the striatum of brains of patients with Parkinson's disease ([Holshouser et al., 1995]). Studies of the role of NO in controlling the regularity of EEG waves in rat brain hippocampal tissue have shown that inhibition of its synthesis is associated with shorter and more stable intervals between successive bursts of rhythmic waves. Conversely, donors of NO and cGMP analogs applied during blockade of NO synthesis lengthen and destabilize intervals between successive rhythmic wave bursts ([Bawin et al., 1994]). The rate of occurrence of these rhythmic EEG wave bursts in rat brain hippocampal tissue is also disrupted by exposure to weak (peak amplitudes 0.08 and 0.8 mT) 1 Hz sinusoidal magnetic fields ([Bawin et al., 1996]; Figure 1). These field effects depend on synthesis of NO in the tissue. They are consistent with reports of altered EEG patterns in man and laboratory animals by ELF magnetic fields ([Bell et al., 1992]; [Lyskov et al., 1993]). A sequence of functional steps have been described in mechanisms mediating this regulatory role of NO. The synthetic enzyme nitric oxide synthase is localized in the dendritic spines of hippocampal CA1 pyramidal cells ([Barette et al., 2002]} Long-term potentiation (LTP) in the hippocampus following electrical stimulation involves sequential activation by NO of soluble guanylate cyclase, cGMP-dependent protein kinase, and cGMP-degrading phosphodiesterase ([Monfort et al., 2002]). The post-stimulus time interval during which NO operated was restricted to less than 15 min, suggesting that NO does not function simply as an acute signaling molecule in induction of LTP, but may have an equally important role outside this phase(([Bon and Garthwaite, 2002]).

5.4 Neuroendocrine sensitivities

5.4.1 Effects of environmental EM fields on melatonin cycling in animals and man

Brain neuroendocrine sensitivities to ELF fields have centered around the pineal gland, where synthesis and secretion of the hormone melatonin exhibits a strong circadian rhythm. There is a nocturnal peak around 2.0 a.m. in man and animals ([Reiter and Richardson, 1990]). The cycle is variably sensitive to the day/night ratio of light exposure in different species. Its possible susceptibility to a changing EM environment has been the subject of intense study ([Semm, 1983]; [Wilson et al., 1986][Wilson et al., 1990]). Evidence for modulation of human melatonin cycling by environmental EM field exposure remains unclear ([Juutilainen et al., 2000];[Stevens et al., 1997]), and although aspects of these studies remain unclear within and between species, the most consistent findings in animal models have been in the Djungarian hamster ([Yellon, 1994]). Acute exposure of long-day (16 h light/8 h dark) animals to a 60 Hz magnetic field (0.1 mT, 15 min) 2h before light off suppresses the night-time rise in melatonin in the pineal gland and in the blood. In short-day (8 h light/16 h dark) animals, acute exposures produced similar results, but daily exposures for as long as 3 weeks had no effect. Beyond diurnal activity rhythms, melatonin is key to a broad range of regulatory mechanisms ([Reiter, 1992]), including the immune system, reducing incidence of certain cancers in mice, and inhibiting growth of breast cancer cells ([Hill and Blask, 1988]; [Liburdy et al., 1993]). This inhibitory action of melatonin is reported to be blocked by 60 Hz magnetic fields at a 1.2 μT threshold level in MCF-7 human breast cancer cells ([Liburdy et al., 1993]; [Blackman et al., 1996]). Further studies ([Ishido et al., 2001]) have confirmed the original observation of an oncostatic action of melatonin on MCF-7 cells at physiological concentrations. Also, this oncostatic action was inhibited by exposures to 50 Hz magnetic field at 1.2 ∝T through an action on melatonin type 1A receptors on the cell membranes. Since other enzymes involved in the melatonin signaling pathway, such as GTPase and adenylyl cyclase, were unaffected by the exposures, it is hypothesized that the magnetic fields may uncouple signal transduction from melatonin receptors to adenylyl cyclase. Patients with estrogen receptor-positive breast cancer have lower nocturnal plasma melatonin levels ([Tamarkin et al., 1982]). Epidemiological studies also suggest a relationship between occupational exposure to environmental EM fields and breast cancer in women and men ([Stevens et al., 1992]). Women in electrical occupations have a 40% higher risk of breast cancer than other women in the workplace ([Loomis et al., 1994]). An increased incidence of breast cancer has also been reported in men in a variety of electrical occupations ([Demers et al., 1991]; [Matanoski et al., 1991]).

5.4.2 Behavioral teratology associated with EM field exposure in animals and man

In animal models, periods have been delineated in early development when hormones most readily affect long-lasting changes in sexual and other behaviors. In the rat, for example, the time of greatest susceptibility to the organizational action of the gonadal steroids occurs during the last week of gestation and continues for 4 or 5 days after parturition. Complete masculinization of the brain during this period is dependent on normal secretory patterns of testosterone, as well as on normal ontogenic development of brain regions sensitive to steroid action, such as the amygdala and hypothalamus. Prenatal exposure of rats to an ELF magnetic field has been reported to demasculinize adult scent marking behavior and to increase accessory sex organ weights ([McGivern et al., 1990]).

Pregnant Sprague–Dawley rats were exposed to a pulsed magnetic field (15 Hz, 0.3 ms, peak intensity 0.8 mT) for 15 min twice daily on days 15–20 of gestation. No differences in litter size, number of stillborns, or body weight were observed in offspring from field-exposed dams. At 120 days of age, field-exposed male offspring exhibited significantly less scent marking behavior than controls. Accessory sex organ weights, including epididymis, seminal vesicles and prostate, were significantly higher in field-exposed subjects at this age. However, circulating levels of testosterone, luteininizing hormone, and follicle-stimulating hormone, as well as sperm counts, were normal. Defective glycosaminoglycan formation at cell surfaces in the developing chick brain has been proposed as a mechanism of action of weak magnetic fields ([Ubeda et al., 1983]). Subtle defects in behavioral and motor performances have been reported in children exposed to high intensity pulsed radar fields from conception through adolescence ([Kolodynski and Kolodynska, 1996]). For more than 25 years, a Latvian early warning radar has operated in a populated area, at frequencies of 154–162 MHz (pulse repetition frequency 24.5/s, pulse width 0.8 ms). The study involved 966 children (425 M, 541 F), aged 9–18 years, all born in farming communities, and many living under conditions of chronic radiofrequency exposure. A computerbased psychological test battery evaluated neuromuscular coordination, reaction time, attention and recent memory. As compared with unexposed controls, and with children living at the margins of the antenna beam, children exposed to the main lobe of the radar beam had less developed memory and attention, slower reaction times, and less sustained neuromuscular performance.

5.4.3 Produces Melatonin

a time regulator for the body, and therefore it is still a major subject of discussions regarding field effects on humans, be it low or high frequency ranges. For some time now, it has been known that in humans and in animals calcium deposits form in this organ, these deposits consist of hundreds of micrometer sized structures in the shape of mulberries and small 10-20 micrometer sized crystals, which look completely different. The latter have been for the first time crystal graphically analysed and identified as octagonal single crystals, whose characteristics can be ascribed as piezo-electric. Even though they cannot be compared to the magnets Krischvink described, the idea in this case that there could be non-thermal mechanisms of high frequency fields, should be carefully considered.

This concept seems to be far-fetched, since there are many other piezo-electric structures all over the body and besides that the effects of weak HF-fields on melatonin production is highly unlikely

Type of Radiation[1]	Approximate Wavelength	Approximate Frequency
Ionizing Radiation		
X-rays and gamma rays	0.03 nm	10^{10} GHz
Non-ionizing Radiation		
Radar	3 cm	10 GHz
Microwave oven	12 cm	2.45 GHz
Cellular telephone	30 cm	1 GHz
Electrical power lines	5,000 km	50-60 Hz

Table 5.1 Characteristics of ionizing and non -ionizing radiation

5.5 Melanoma of the Eye

Two incidence case-control interview studies were conducted in Germany on occupational risk factors for 8 rare cancers, including uveal melanoma, and results were pooled (Stang et al. 2001). A total of 118 cases of uveal melanoma and 475 matched controls were evaluated (Table 3). Workers had been asked "Did you use radio sets, mobile phones, or similar devices at your workplace for at least several hours per day?" Based on a subsequent evaluation of this response and categorization by one of the authors, a significant four-fold increased risk of malignant melanoma of the eye was reported for "probable or certain exposure to mobile phones", based on 12 exposed cases. This study is largely non-informative with regard to cellular phone use because it was not designed to address cellular phone exposures. Exposure assessment was extremely limited and did not include personal (non-occupational) use of phones, responses were not validated, it is unclear how mobile phone use could be separated from "radio sets or similar devices" based on "author review", tumor laterality with regard to side of phone use was not considered and important confounders, such as UV exposure, were not taken into account. If use of cellular phones increases the relative risk of uveal melanoma by a factor of four as reported in the German study, it was postulated that increases in incidence over time should be observable (Inskip 2001). To test this hypothesis, the incidence rates of ocular melanoma 1943- 1996 were correlated with the number of mobile phone subscribers in Denmark (Johansen et al. 2002). No increasing trend in the incidence rates was observed, which was in sharp contrast to the exponentially increasing number of mobile phone subscribers (Figure 1). In addition to the absence of an increasing trend in incidence of melanoma of the eye, no association between this cancer and cellular phone use was observed in the Danish cohort study of over 420,000 users of mobile telephones between 1982 and 1995 (Johansen et al. 2001). Eight cases of ocular cancer were observed compared with 13.5 cases expected (SIR 0.59; 95 % CI 0.25 – 1.17). Thus the Danish studies provide no support for an association between mobile phones and ocular melanoma. Further, an association seems somewhat improbable given the very low level of exposure to the eye from RF signals emanating from mobile phones (Rothman et al. 1996b, Anderson and Joyner 1995).

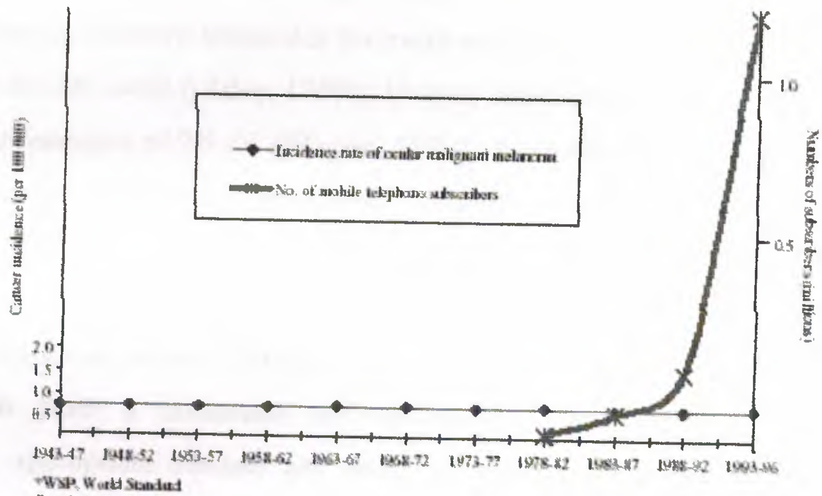


Figure 5.1 Age Standardized (WSP) annual incidence (cases per 100,000) of ocular malignant melanoma in Denmark 1943-96 and number of subscribers to cellular telephones, Denmark 1982-96* (Johansen et al. 2002).

5.6 Intrinsic and Induced Electric Fields As Threshold Determinants In Central Nervous Tissue; The Potential Role of Cell Ensembles

The intact nervous system might be expected to be more sensitive to induced electric fields and currents than *in vitro* preparations, due to a higher level of spontaneous activity and a greater number of interacting neurons. However, these fields induced in the body are almost always much lower than those capable of stimulating peripheral nerve tissue ([Saunders and Jefferys, 2002]). Weak electric field effects, below action potential thresholds, have been demonstrated in *in vitro* brain slice preparations ([Faber and Korn; 1989]; [Jefferys, 1995]}.Behavioral sensitivities in sharks and rays may be as low as 0.5 nV/mm for tissue components of electrical fields in the surrounding ocean ([Kalmijn, 1971]), or 100 times below measurable thresholds of individual electroreceptor organs ([Valberg et al., 1997]). Research in sensory physiology supports the concept that some threshold properties in excitable tissues may reside in highly cooperative properties of a population elements, rather than in a single detector ([Adey,1998, 2003a, 2003b]). Seminal observations in the human auditory system point to a receptor vibrational displacement of 10-11m, or approximately the diameter of a single hydrogen atom ([Bialek, 1983]; [Bialek and Wit, 1984]). It is notable that suppression of intrinsic thermal noise allows the ear to function as though close to 0o K, suggesting system properties inherent in the detection sequence. Human olfactory thresholds for musk occur at 10-11 M, with odorant molecules distributed over 240 mm2 ([Adey, 1959]). Human detection of single photons of bluegreen light occurs at energies of 2.5 eV ([Hagins, 1979]). In another context, pathogenic bacteria, long thought to function independently, exhibit ensemble properties by a system recognizing colony numbers as an essential step preceding release of toxins. These *quorum sensing* systems may control expression of virulence factors in the lungs of patients with cystic fibrosis ([Erickson et al., 2002]).

Although far from a consensus on mechanisms mediating these low-level EMF sensitivities, appropriate models are based in nonequilibrium thermodynamics, with nonlinear electrodynamics as an integral feature. Heating models, based in equilibrium thermodynamics, fail to explain a wide spectrum of observed nonthermal EMF bioeffects in central nervous tissue. The findings suggest a biological organization based in physical processes at the atomic level, beyond the realm of chemical reactions between biomolecules. Much of this signaling within and between cells may be mediated by free radicals of the oxygen and nitrogen species. Emergent concepts of tissue thresholds to EMF sensitivities address ensemble or domain functions of populations of cells, cooperatively "whispering together " in intercellular communication, and organized hierarchically at atomic and molecular levels.

5.6.1 the influence of high frequency mobile communication fields on eeg and sleep.

A Swiss group presented the results of investigations, which also included measurements taken on regional cerebral blood flow by means of Positronen Emissions Tomography (PET). It could be shown with great significance that probands who had been exposed for half an hour on the left side with GSM similar pulsed fields (900 MHz, 1 W/kg), exhibited after 10 minutes an increase in local circulation in the exposed half of the brain. With regard to non-pulsed fields of the same intensity, these effects could not be established. The authors came to the conclusion that the effect could not be attributed to an increase in temperature. (Is the space-time temperature gradient in both irradiation modes really identical?) In a further experiment the effects on sleep were investigated with an identical irradiation plan. A EEG frequency analysis done before falling asleep showed an increase in the intensity of the alpha-spectral range, which only occurred after irradiation with pulsed fields. Even when the sleep phase itself was not significantly effected by irradiation, with pulsed fields a similar EEGchange was also measured in the NREM sleep phase, which even increased during the course of the night. The authors stressed that the measured effects were slight and no conclusions could be drawn with regard to health but their results should not be disregarded. Hamblin and A.W. Wood from the Swinburne University of Technology in Melbourne, Australia analysed in an exhaustive and meticulous study on current research pertaining to the effects of mobile phone emissions on brain activity and sleep parameters. Basically, since 1995 up to the point when this paper was concluded in January 2002 there were only18 publications on the subject. Low frequency effects have been investigated investigated in the past and these types of publications are more frequent, however it must be emphasized and rightly so that these results are at most relevant with regard to the magnet fields which originate from the working currents of mobile phones. An overview of the study shows that there is little consistency regarding the results. Occasionally, the same authors could not reproduce their results in a second series of experiments which they obtained in the first study. What could be the cause of this? A series of methodical limitations has been discussed: e.g. differences in frequencies and intensities, as well as antenna configurations; differences in measurement time schemes and in irradiation and differences in how the results are statistically worked out. While some authors investigated changes during irradiation, only some registered such changes at different times after irradiation. The number of groups investigated did not always allow for reliable statistical statements. What was generally criticised was that all of the measurements were carried out on young healthy probands and therefore, it is not possible to make any direct statements concerning children or the elderly. In any case it seems as if fields of a maximum mobile phone intensity range held to the head can temporarily have an effect, especially on the alpha-waves of EEG. How can this be explained? Are they subtle thermal effects, which promote blood flow, or must a cellular mechanism be held responsible, this is always discussed over and over again, (but never proven) namely calcium efflux? Could it be that perhaps the effects can not be attributed to HF-fields but attributed much more to the circa 7,5 microtesla, 8Hz magnet fields of the working currents of mobile phone? Other methods proving brain activity should be incorporated, e.g. the positron-emissionstomography (PET), which can provide information information on blood flow changes (please see the report by Borbely et al. in this review of scientific publications).

Are there any "non thermal" effects stemming from high frequency electromagnetic fields, effects that occur below the intensity-level, which can be proven as thermal? Robert K. Adair has quoted from two 1996 studies where it was established that such supposed effects have been proven to be the result of measurement errors. As far as the experiments are concerned, we may question from a biophysical point of view if such effects can be expected to occur at all. Robert Adair, who has repeatedly critically analysed publications on this subject by various authors, systematically analyses the problem. A focal point is of course thermal noise. A physiological primary reaction is only possible when a special mechanism has been found where the absorbed energy exceeds the thermal energy. It should not be forgotten that in the range of the HF-fields the effect of the magnetic field vectors, e.g. through the radicalpair recombination mechanism, has to be ruled out. Even with a power flow density of 10 mW/cm2 the magnetic field is still four powers of 10 smaller than what is required for this mechanism. The author categorised conceivable electric mechanisms into three classes:

A – charge motion,

B – the triggering of dipole motion,

C - electro restrictive effects. With regard to category A he calculated charge movement and molecular rotation. Even when coherent behaviour is considered, it would be many powers of ten below thermal noise. In the process a power flow density was respectively presupposed at 10mW/cm2, which corresponds to an Efield of 200 V/m. Category B was assigned the concept that a field could affect the dipole of a transport protein and, therefore, effect the excitation process of the membrane. What speaks against this is not only the time constant of this process but the lack of energy as well. However with regard to electrostriction, about one cell (class C) in fields of this dimension effects occurred, but on the other hand, these were concealed by thermal membrane oscillations. Resonance-effects have to be ruled out because of the viscosity characteristics of the cell. The Fröhlich theory of coherent excitement is also being discussed and it has been established that even when the vixcose loss is not considered, this mechanism placed in class B, cannot function. On the other hand the experiment and the theory seem to be in agreement that athermal reactions of this kind do not exist and they cannot possibly exist. Nevertheless, the author refers to the electrostrictions as the only possibility, at least with regard to energy that cannot be completely ruled out. Comprehending this train of thought is well worth it (in spite of a few printing errors in formulas and in the text). (Adair, R. K.: Biophysical limits on athermal effects of RF and microwave radiation. Biolectromagnetics. 24, 39-48. 2003). While directly deducting nerve impulses with the aid of micro-electrodes, it was found out how cells in the cerebrum and the cerebellum of zebra finches react to weak GSM-signals (900 MHz, 217 Hz-Pulse, 0.1 m W/cm2, 0.05 W/ kg). For this purpose the birds were anaesthetized and were irradiated in a tuned wave guide. The microelectrodes were put into place through a 4 mm hole in the skull. From the 133 cells which were examine, 52% exhibited under field effects a circa 3.5 fold increase in spontaneous impulse rate and 17% showed a slight decrease. The effects occurred after switching on the field with a latent time of 104±197 seconds and faded out with a time constant of 308±68s after turning off the field again. Nonpulsed fields triggered no reaction. The authors are aware of the possibility of artefacts, which among others, could occur when the measuring electrode under the effects of the field could turn into a stimulus electrode. This is avoided with the corresponding field orientation. A reproduction of the results done with independent methods seems to be required here. (Beason, R. C. and Semm, P.: Responses of neurons to an amplitude modulated microwave stimulus. Neuroscience Letters; 333, 175-178. 2002). K.A. Hossmann and D.M. Hermann at MPI for neurological research published a literature overview on the possible effects of mobile radio emissions on the central nervous system. The results of in-vitro investigations, animal experiments, investigations with probands and epidemiological evaluations were critically assessed and refereed. The authors came to the conclusion that some of the material has to be more closely examined. For instance, the effects that were found on sleep and cognitive functions, which are very difficult to reproduce, should be pursued further. However, all together there is a slight possibility that pulsed or continuous mobile radio emissions can effect the functional and structural integrity of the human brain. Only in thermal cases is the effect consistent, but this is beyond the normal mobile phone exposure. On the other hand, there are indirect effects for instance the increase in the number of traffic accidents caused by using a mobile phone while driving. This has to be taken into account and how to avoid such accidents has to be more intensely discussed.

5.7 Animal Models of Brain Tumor Promotion

There are few accepted animal models of spontaneous malignant central nervous system (CNS) tumors, although there has been increasing use of the Fischer 344 rat, with a reported incidence of spontaneous malignant tumors as high as 11%. Two life term studies using this rat model have compared exposures to the North American Digital Standard (NADC) digital phone field using Time Division Multiple Access (TDMA) modulation pulsed at 50 "packets"/sec, with comparable exposures to the older type of FM (analog) phone fields ([Adey et al., 1999]; [Adey et al., 2000]). Rats were exposed in utero to a single dose of the short-lived neurocarcinogen ethylnitrosourea (ENU), and thereafter, exposed intermittently to either TDMA or FM fields for 23 months. In the TDMA study, when compared with rats receiving ENU but unexposed, rats that died from a primary CNS tumor before termination of the study showed a significant reduction in tumor incidence ($P<0.015$). A similar but non-significant reduction in spontaneous tumor incidence occurred in rats field-exposed but not receiving ENU ($P<0.08$). In the balanced design of this experiment, consistent non-significant differences in survival rates were noted between the four rat groups, with higher death rates in a progression: sham/field:sham/sham:ENU/field:ENU/sham. By contrast in the FM study, no field-related effects were observed in number, incidence or types of either spontaneous or ENU-induced CNS tumors. These observations of an apparent protective effect against ENU-induced and spontaneous CNS tumors are not isolated. Low dosage of X-rays in fetal rats at the time of ENU dosage sharply reduce subsequent incidence of induced tumors ([Warkany et al., 1976]), through activation of AT (alkylguanine-DNA-alkyltransferase) enzymes that participate in DNA repair ([Stammberger et al., 1990]). Other studies with nonionizing (microwave) fields also suggest their actions in mechanisms of DNA repair. Modulation of levels of single-strand breaks in brain cell DNA has been reported following low-level, long-term microwave exposure in mice ([Sarkar et al., 1994]) and in acute experiments in rats ([Lai and Singh, 1995]).

5.8 A Correlated Increase in The Incidence of Skin Cancer With The Number of Surrounding Transmitter Masts And Even With The Transmission Frequency

concede that in the former east-block countries which transmitted low FM-frequencies (70 MHz) had fewer problems since these frequencies were further away from the resonance frequencies of the human body than those in countries where 87-108 MHz are transmitted. Nevertheless, it is surprising that as an antenna measurement arm-leg and torso were used and not the entire length of the body because when measurements are taken in this way the conclusions would not be correct. Since most transmitters are horizontally polarized, the most dangerous position for humans would be a horizontal horizontal one and the most dangerous time would be during the night. Correspondingly, one would recommend placing one's bed in the direction of the weakest fields. The section on confounders is very short and only states that an increase in traffic density has been observed or recently more attention has been paid to the diagnose of melanoma. The effects of UV were only marginally mentioned. Changes in holiday and travel habits, which will certainly have a sustained effect on northern Europeans or an increase in the number of visits to solariums was not dealt with in this paper.

CONCLUSION

The available epidemiological evidence on microwave radiation and cataract is of variable quality. Many of the published reports do not provide quantitative data on exposures, or on the reliability of the methods by which pathology in the lens was a Several studies have reported an increased risk of congenital malformations Following maternal occupational exposure to RF radiation during pregnancy, principally in physiotherapy.ssessed.

In some investigations, associations may have occurred spuriously as a consequence of biased ascertainment of health outcomes or failure to take adequate account of confounding variables.

In addition, the apparent inconsistency of findings from one country to another raises the possibility that the occurrence of such symptoms is psychologically induced and determined by cultural influences and health beliefs rather than a direct effect of RF radiation. It is possible that localised heating occurs as a consequence of radiation from the phone's antenna or through conduction from the handset.

The mechanism underlying symptoms and associated clinical abnormalities is uncertain, but in some cases, at least, could be psychological.

It is possible that localised heating occurs as a consequence of radiation from the phone's antenna or through conduction from the handset The mechanism underlying symptoms and associated clinical abnormalities is uncertain, but in some cases, at least, could be psychological.

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