NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

RADIATION HAZARDS

GRADUATION PROJECT
EE - 400

Name : Mutazz Hasan AL- Arouri (20011844)

Supervisor : Assoc. Prof. Dr. Sameer Ikhdair

Nicosia - 2005

TABLE OF CONTENTS

ACKNOWLEDGEMENT...i

ABSTRACT...ii

INTRODUCTION...iii

1. RADIATION HAZARDS 1

1.1 Types of Radiation...2

1.1.1 Electromagnetic Radiation...2

1.1.2 Ionizing Radiation 3

1.1.2.1 Ionizing Electromagnetic Radiation 4

1.1.2.2 Ionizing Particulate Radiation 4

1.1.3 Non-Ionizing Radiation 5

1.1.4 Alpha Radiation...5

1.1.5 Beta Radiation 5

1.1.6 Neutron Radiation...6

1.1.7 X Radiation and Gamma Radiation...6

1.1.8 Visible Radiation 6

1.1.9 Infrared Radiation...7

1.1.10 Microwave and Radio-frequency Radiation...7

1.1.11 Extremely Low Frequency Radiation...7

1.1.12 Background Radiation 7

1.2 Dose, Absorbed Dose and Dose Equivalents 8

1.2.1 Biological Studies...8

1.3 Radiation Sources 9

1.4 Monitoring...10

1.5 Work Processes and Procedures of Radiation 10

1.6 Radiation Control 10

1.6.1 Distance Control 11

1.6.2 Time Control...11

1.6.3 Shielding...12

1.6.3.1 Non-Ionizing Radiation Shielding...13

1.7 Contamination and Decontamination of Radiation 13
1.7.1 Contamination 14
1.7.2 Decontamination 15
2. ELECTROMAGNETIC FIELDS SOURCES AND EXPOSURE 16
2.1 Characteristics of Electromagnetic Fields 22
2.2 Modulation 23
2.1.1 Pulsing (Pulsed Modulation) 24
2.3 Source-Dependent Considerations 25
2.4 Far-Field Characteristics 26
2.5 Near Field Characteristics 26
2.6 Dissymmetry 26
2.7 Radio Frequency Sources and Exposure 28
2.8 Communications 28
2.9 Handheld Equipment 29
2.9.1 Mobile Phones 29
2.9.2 Cordless Phones 31
2.9.3 Bluetooth Technology 32
2.9.4 Wireless Local Area Network (Wireless LANs) 32
2.9.5 MF and HF Radio 33
3. BIOELECTROMAGNETICS DEVELOPMENTS TOWARDS 35
PHYSICAL BIOLOGY 35
3.1 Evidence for Role of Free Radicals in Electromagnetic Field Bioeffects 35
3.2 Calcium-Dependent Neuroregulatory Mechanisms Modulated by EM Fields 37
3.2.1 Sensitivity of Cerebral NeuroTransmitter Receptors 37
3.3 The Glutamate Receptor and Normal/Pathological Synthesis of Nitric Oxide, Sensitivity to Magnetic Fields 37
3.4 Neuroendocrine Sensitivities 38
3.4.1 Effects of Environmental EM Fields on Melatonin Cycling 38
3.4.2 Behavioral Teratology Associated with EM Field Exposure 39
3.4.3 Produces Melatonin 40
3.5 Melanoma of the Eye 41

3.6 Intrinsic and Induced Electric Fields as Threshold Determinants in Central Nervous Tissue, The Potential Role of Cell Ensembles 42

3.6.1 The Influence of High Frequency Mobile Communication Fields on Eeg and Sleep. 43

3.7 Animal Models of Brain Tumor Promotion 47

3.8 A Correlated Increase in the Incidence of Skin Cancer 48

4. NON-CANCER EPIDEMIOLOGY AND CLINICAL RESEARCH 49

4.1 Effects of Short-Term High Exposure 49

4.2 RF Radiation 49

4.3 Microwave Hearing 49

4.4 Cataract 50

4.5 Epidemiological Evidence 52

4.6 Male Sexual Function and Fertility 53

4.7 Female Sexual Function and Fertility 54

4.8 Spontaneous Abortion 55

4.9 Birth Outcome and Congenital Malformations 56

5. BIOLOGICAL EFFECTS OF RADIATION AND EFFECTS 59

OF ULTRAVIOLET RADIATION 59

5.1 Cellular Damage and Possible Cellular Processes 61

5.2 Linear Energy Transfer (LET) and Relative Biological Efficiency (RBE) ... 61

5.3 Ultra Violet Radiations as a Hazard in the Work Place 62

5.4 Health Risks Associated with Ultra Violet Radiation 63

5.4.1 Effects of UV Radiation on the Skin 63

5.4.2 Effects of UVR on the Eyes 63

5.4.3 Eye Protected from UV Radiation 64

5.5 UV Radiation Risks 65

5.5.1 Factors of Increasing the Risk 65

5.5.2 Effects UV Radiation on the Children 65

5.5.3 Manage Risks in the Work Place 65

5.6 Exposure Limits 66

5.7 Lasers Radiation **67**
5.7.1 Laser Safety Standard 68
5.7.2 Classify Laser Products 69
5.8 Beam Reflections **70**
CONCLUSION **72**
REFERENCES **73**

ACKNOWLEDGEMENT

First of all, I want to pay my regards and to express my sincere gratitude to my supervisor Assoc. Prof. Dr Sameer Ikhdair. And all persons who have contributed in the preparation of this project so to complete it successfully. I am also thankful to those who helped me a lot in my task and gave me full support toward the completion of my project.

I would like to thank my family who gave their lasting encouragement in my studies and enduring these all expenses and supporting me in all events, so that I could be successful in my life time. I specially thank to my father whose prayers have helped me to keep safe from every dark region of life. Special thank to my father who help me in joining this prestigious university and helped me to make my future brighter.

I am also very much grateful to all my friends and colleagues who gave their precious time to help me and giving me their ever devotion and all valuable information which I really need to complete my project.

Further I am thankful to Near East University academic staff and all those persons who helped me or encouraged me incompletion of my project. Thanks!"

ABSTRACT

In this project we discuss many topics well related to radiation hazards. We include fourteen types of radiations and each one of them has its own behavior and characteristics. In the context of the biological studies, they include whole animals and cultural experiments where animal studies are based on the premise that exposure to radiation will have similar health effects on animals and humans, cell or tissue culture experiments seek to learn how exposures affect the functions of individual cells or tissues.

Afterwards, we investigate source of electromagnetic fields sources and exposure where we talk, in general, about radio frequency fields. We also investigate the characteristics of electromagnetic fields and aspects of dissymmetry, shortly an electromagnetic field or wave consists of electric and magnetic fields that oscillate sinusoidally between negative and positive values at a frequency.

Afterwards, we also explain modulation, pulsing (pulsed modulation), source dependent considerations and several other topics. We figure electromagnetics' developments towards physical biology, on-cancer epidemiology and clinical research, biological effects of radiation and ultraviolet radiation.

Finally, the biological effects like radiation effects on the brain, skin, eyes....etc that people could have because of radiation and ultraviolet radiation are also presented.

INTRODUCTION

In this project we study many subjects related to radiation hazards. The radiation is the energy that comes from a source and travels through some material or through space. Light, heat and sound are types of radiation. The kind of radiation discussed is called ionizing radiation because it can produce charged particles (ions) in matter.

Ionizing radiation is produced by unstable atoms, unstable atoms differ from stable atoms because they have an excess of energy or mass or both. Unstable atoms are said to be radioactive, in order to reach stability these atoms give off or emit the excess energy or mass. Such emissions are called radiation.

Therefore, the kinds of radiation are electromagnetic (like light) and particulate (i.e., mass given off with the energy of motion). Gamma radiation and X-rays are examples of electromagnetic radiation, Beta and alpha radiation are examples of particulate radiation, and ionizing radiation can also be produced by devices such as X-ray machines.

In the first Chapter, we talk about radiation hazards in general including many topics related to radiation hazards like (types of radiations, dose, absorbed dose and dose equivalents, radiation sources, monitoring, work processes and procedures of radiation, radiation control, contamination and decontamination of radiation).

In the second Chapter we discuss the electromagnetic fields and exposure in general including many things related with main topic like characteristics of electromagnetic fields, general characteristics of electromagnetic field, modulation....etc, in addition we include one main figure that illustrates the radio frequency spectrum and sources and also two tables, the first one shows in detail the sources of radiofrequency radiation across the spectrum and typical field and the second one shows typical radiation exposures at high frequencies.

In the third Chapter, we study bio-electromagnetics' developments towards physical biology including the evidence for the role of free radicals in electromagnetic field bio-effects, calcium neuro-regulatory mechanisms modulated by electromagnetic fields the glutamate receptor and normal/pathological synthesis nitric oxide and the sensitivity of magnetic field.

In the fourth Chapter, we discuss non-cancer epidemiology and clinical research where the effects of short – term high exposure, RF radiation, microwave hearing, cataracts, male and female sexual functions, fertilities and some other related topics.

In Chapter five, the biological effects of radiation and ultraviolet radiation in which we talk about radiation's effects on eyes, the skin and many types of radiation effects caused generally to humans are also investigated.

Finally, we give our conclusion.

CHAPTER ONE

RADIATION HAZARDS

Radiation is a natural phenomenon. Scientists discovered it in the early 20th century, during investigations into the structure of matter. Many applications for the controlled application of radiation have since been developed, including television, computer monitor, radio, cellular telephone, microwave oven, X-rays and nuclear power. In spite of radiation's many uses, uncontrolled exposure is a very serious hazard that can cause illness or death. For this reason, every radiation hazard in the workplace must be identified, assessed and controlled. Recognition of radiation sources is relatively straightforward. Assessment is more complex, because the health effects of radiation exposure vary greatly among individuals. And the effects of many types of radiation are still under investigation. The control of radiation hazards is usually accomplished by applying one or more of three fundamental principles: shielding, distance and time. Shielding is a control at the source, which prevents the escape of radiation. Distance is a form of control along the path from the source to the worker, and time is a control at the worker. Although the principles of radiation control are similar to those for other hazards, they are specialized and must be carefully designed. They depend for their effectiveness on a detailed knowledge of the work processes by members of the joint health and safety committee, and on a commitment to health safety by everyone in the workplace.

Radiation is the emission or transmission of energy from a source. The energy travels in a rapidly moving stream of particles or as waves of pure energy. The mechanism of the energy transfer is different for each type of radiation, and there are a number of ways of classifying the various types. For example, radiation may be described as either particulate or nonparticulate, depending on whether or not it is made up of particles or waves of electromagnetic energy. It is also possible to distinguish between naturally occurring and man-made radiation. For safety recognition purposes, it will be convenient to classify radiation according to the frequency at which its waves are vibrating. All radiation with a frequency of less than 1016 Hertz will be referred to as non-ionizing radiation and all radiation with a frequency greater than that, plus all particulate radiation, will be classified as ionizing radiation. Radiation from naturally occurring sources is all around us. Various sources of man-made radiation combine with these natural sources to create the background radiation that spreads through the environment. In the workplace, additional radiation exposure comes from two sources: radioactive materials and equipment that emits radiation. Radioactive materials can be spilled and can contaminate work surfaces, tools and equipment. They can also be absorbed or ingested by workers. They are therefore especially hazardous. Electromagnetic radiation from equipment is a potential hazard in itself, but it cannot contaminate other objects, and does not pose a risk through ingestion or inhalation.

1.1 Types of Radiation

1.1.1 Electromagnetic Radiation

Electromagnetic energy is absorbed by the body and deposits energy internally leading to thermal loads and temperature gradients. Since the 1950s the informally accepted tolerance dose in the US has been $(10\frac{mW}{cm^2})$.The American National Standards Institute (ANSI) officially adopted $(10\frac{mW}{cm^2})$.as the standard in 1966 for a five year term, and it was reaffirmed again in 1969 and 1974. It was concluded at the time that power densities in excess of $(100\frac{mW}{cm^2})$.were needed to produce any significant biological changes.

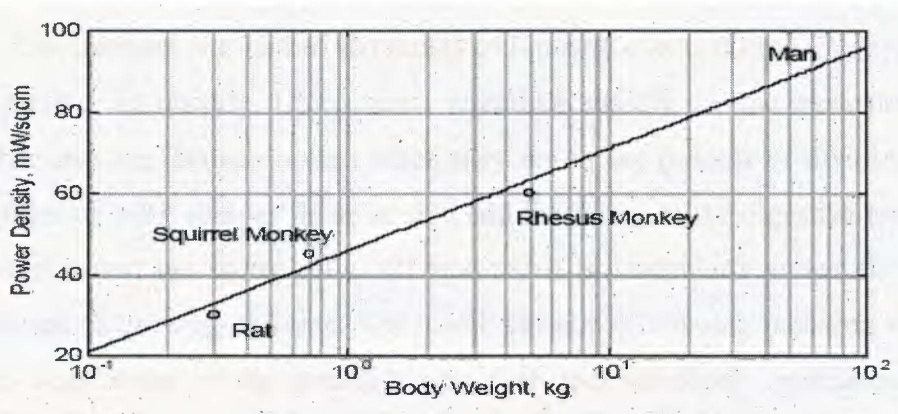

Figure 1.1: Threshold levels versus time for sensitive organs.

This is shown in the figure 1.1, revealed that certain body organs were more susceptible to the effects of electromagnetic heating than others. The testis power density safety curve assumes damage when the temperature increases by on 1.4 degrees C (which is less than a warm bath). Effects other than those due to heating have been alleged: changes in hormone levels, blood chemistry, neurological function, growth, etc. The vast majority of studies have been negative this is shown in the figure 1.1. Research on the effect of EM radiation on the immune system has been inconclusive.

1.1.2 Ionizing Radiation

In addition to high-energy electromagnetic radiation, ionizing radiation also includes all particulate radiation. Radiation, which is emitted as particles, has energy that is determined by the mass of the particle and its velocity. The energy level of particulate radiation is comparable to that of electromagnetic radiation with a frequency exceeding 3 x 1016 Hertz. Therefore, all particulate radiation has more than enough energy to dislodge electrons from atoms, causing ionization. When a particle of this type of radiation is absorbed by living tissue, it transfers its energy by ionizing a molecule of the tissue.

The health effects from exposure to ionizing radiation result from the disruption of molecules in body tissue. An ion is an atom, which has either lost one or more electrons or picked up extra electrons. Either way, it is electrically charged and can react with other particles in body tissue. This can result in significant damage to the body's genetic material, including DNA and RNA. The health effects of such radiation are cumulative, which means that the amount of damage increases as the exposure to radiation increases. The cumulative effect of thousands of ionizing events during every second of exposure mounts up quickly. Cells which reproduce rapidly are the most profoundly effected, because the damage occurs when they are in the process of dividing. These include epithelial cells, such as those in skin and the lining of the digestive tract, those in the bone marrow, and sperm cells. All fetal tissue is particularly vulnerable, as well as most tissues of growing children. The health hazards of ionizing radiation were first discovered when many of the scientists who first discovered and experimented with radiation began to die. Typically, their symptoms included burns on the skin, hair loss, and fluid loss from diarrhea, anemia and conditions resembling leukemia. These symptoms are all consistent with damage to cells, which reproduce rapidly. They can be caused by either inadvertent occupational exposure to radiation or excess exposure from diagnostic medical tests. Radioactive materials may be ingested, through eating contaminated food, or through contact between contaminated fingers and the mouth.

Radioactive materials can also be injected into the body, as part of a medical diagnostic procedure or by accident, as in a puncture wound. Once in the body, radioisotopes behave differently. Chemically, they behave exactly like their non-radioactive counterparts, and will take part in the body's metabolism. This brings the radioactive atoms into very close contact with tissues throughout the body. Radiation, which would normally be too weak to penetrate the skin, thus gets close enough to sensitive cells to be extremely harmful.

1.1.2.1 Ionizing Electromagnetic Radiation

The ionizing portion of the electromagnetic spectrum consists of very high energy X-rays and gamma rays, as well as the upper part of the ultraviolet

1.1.2.2 Ionizing Particulate Radiation

Different types of ionizing particles require different shielding techniques. Alpha radiation is relatively easy to shield. Most emissions can be stopped by two or three layers of paper, or by aluminum foil, and usually by the container in which the material is stored. Skin will also stop alpha radiation. Specific sources of alpha particles involve unique energy levels, ranging from 4 MeV to 8 MeV. Shielding should be appropriate for this entire range. Beta radiation is best shielded by dense materials such as lead. Unfortunately, one of the products of the absorption of high energy beta particles is X-rays. This is called Bremsstrahlung radiation, and is produced by the interaction of the beta radiation and the shielding material. The use of shielding material with a lower atomic number (such as glass, Lucite, water or wood) greatly reduces X-ray production, but increases the thickness of the shielding needed. Combinations of materials may be required in certain situations. Shielding neutron emissions requires a combination of materials. Some layers slow the neutrons down and others absorb their energy. Still others shield secondary gamma radiation produced by neutron absorption. Neutrons are slowed down effectively by materials with a high proportion of hydrogen, such as water, paraffin or polyethylene. The energy of gamma radiation is absorbed by layers of high atomic number elements. The shielding around nuclear power plants consists of concrete, water and steel. The needed amount of shielding can be calculated mathematically before the radioactive material is actually in the workplace. This ensures that controls can be put in place immediately.

1.1.3 Non-Ionizing Radiation

Non-ionizing radiation is found everywhere in the natural environment. It consists of energy waves rather than particles, and it is characterized by relatively low frequencies. Wavelengths range from 100 nanometers to thousands of kilometers. This part of the electromagnetic spectrum has been divided, somewhat arbitrarily, into a number of smaller bands. Visible light and infrared heat, which are the only part of the spectrum detectable by humans, are found in a small band of frequencies at this end of the electromagnetic spectrum. The bottom end of the spectrum is occupied by radiation with very long wavelengths (over 10,000 kilometers) and very low frequencies (less than 30 Hertz). These emissions are usually called extremely low frequency (ELF) emissions. At the high end of the non-ionizing portion of the spectrum are emissions with wavelengths of about 100 nanometers, with frequencies of up to 3,000 teraHertz.

1.1.4 Alpha Radiation

Some naturally occurring radioactive elements such as some of the isotopes of Uranium, Radium and Thorium, slowly disintegrate over time by emitting alpha particles an alpha particle consists of two protons and two neutrons, and it is very heavy. The velocity of alpha particles, however, is comparatively slow, and as a result, alpha radiation is not energetic enough to penetrate the skin. This means that alpha-emitting materials are not hazardous unless they are ingested or inhaled, in which case they are extremely hazardous.

1.1.5 Beta Radiation

Beta radiation consists of beta particles, which are electrons or positrons moving at velocities that can approach the speed of light. Common sources are radioactive isotopes. Isotopes are individual atoms of a substance which contain a varying number of neutrons in their nuclei. If isotopes are unstable, they are called radioactive, because they emit beta particles when they decay. Common radioactive isotopes found in workplaces include Carbon-14, Calcium-45, Sulphur-35 and Strontium-90. Each source of beta radiation produces particles of variable energy in a unique spectrum. The beta radiation from Tritium for example, is extremely weak and will not penetrate skin. But the beta radiation from Phosphorus-32 is very energetic and will penetrate more than 8 millimeters into tissue.

1.1.6 Neutron Radiation

Neutrons are uncharged particles. There are no significant naturally occurring sources of neutron radiation. Nuclear fission reactors produce neutron radiation in substantial quantities. The interaction between neutrons and body tissues is extremely complicated. Put simply, the neutron will penetrate tissue until it collides with the nucleus of an atom. The collision often results in the creation of charged particles, which travel at low speeds Causing ionization of the molecules in the tissue.

1.1.7 X Radiation and Gamma Radiation

X Radiation (X-rays) is electromagnetic (non-particulate) radiation, which is produced by machines. Gamma rays are naturally occurring. The X-ray and gamma ray bands of the spectrum overlap, because the distinction between the two is arbitrary. X-rays and gamma rays are defined differently because they were discovered independently, but for practical purposes, they can be considered essentially the same. Naturally occurring X-ray sources exist only outside the solar system. Artificial X-rays are usually produced in an X-ray tube by bombarding a charged heavy metal, such as tungsten, with a stream of accelerated electrons. As the electrons slow down, photons of X radiation are emitted. Other methods of producing X-rays involve the movement of electrons between the orbits of atoms. These transitions involve discrete changes in energy levels, and produce characteristic X-rays rather than the wide range of energies produced by acceleration methods. The penetrating power of X-rays depends upon their energy, which is variable. Their use in medical diagnosis is based on the fact that they can pass through the body to expose X-ray film. They are also used for inspecting welds, airport security inspections and for a variety of industrial purposes.

1.1.8 Visible Radiation

Radiation at wavelengths from 400 nanometers to about 1,000 nanometers (385 x 1012 Hertz to 750 x 1012 Hertz). is the part of the spectrum that human beings perceive as light. There is no indication that natural visible light is hazardous, but exposures at the extremes of the visible spectrum, (where violet light blends into ultraviolet, and where red light blends into infrared), should be treated with caution. Lasers are an exception to the general principle that visible light is not usually hazardous. Laser stands for light amplification by simulated emission of radiation. Lasers emit light at a single wavelength, in contrast with other sources of light that emit a spectrum of wavelengths. Lasers vary tremendously in power, and for this reason, some are more hazardous than others. Lasers that use the visible part of the spectrum are used for a wide variety of purposes, including land surveying, light shows, holography, bar code scanners and retinal surgery. Lasers used for surgery include Excimer lasers operating at wavelengths below 351 nanometers, as well as neodymium and carbon dioxide lasers operating at over 1,000 nanometers and over 10,000 nanometers respectively. These devices pose particular hazards because they emit invisible radiation.

1.1.9 Infrared Radiation

Infrared radiation is the name given to a broad range of electromagnetic radiation with frequencies from (30×109) to (38×1012) Hertz, which is immediately below the visible range. This radiation is perceptible by humans as heat. The penetrating power of this type of radiation is not great, although the mechanism by which it acts on most body tissues is not fully understood. Sources of occupational exposure include molten metals, molten glass, open arc processes (such as welding) and unshielded sunlight.

1.1.10 Microwave and Radio-frequency Radiation

Microwave and radio -frequency radiation occupies a band of the spectrum with frequencies ranging from 300 Hertz to 300 x 109 Hertz. Microwaves are in the upper portion of the range, above 300 x 106 Hertz. Natural levels of this type of radiation are low. Most workplace exposures are from communications devices, navigation instruments, radar, induction and dielectric heating devices and microwave ovens.

1.1.11 Extremely Low Frequency Radiation

Extremely low frequency radiation has a frequency range from almost zero (at least in theory) to about 300 Hertz. Wavelengths range from one meter to thousands of kilometers. Sources of this radiation include electric wiring, especially transmission and generation equipment, and all equipment, which uses electricity.

1.1.12 Background Radiation

Background radiation refers to the radiation that spreads through the environment from both natural and man-made sources. A great deal of radiation originates in the sun or other stars, and travels to earth in the form of virtually every wavelength in the electromagnetic spectrum. All of the light and heat, which makes life possible on earth, is a result of constant radiation from the sun. The atmosphere, including the ozone layer, screens out much of this radiation. But in the process, many new kinds of radiation sources are created. For example, the action of solar radiation on the upper atmosphere is the primary source of naturally occurring Tritium. Additional background radiation comes from radioisotopes contained in naturally occurring elements. There is no place on the earth that has no radiation from this source, and some places have very high levels. Finally, background radiation includes many man-made sources. These include artificially produced radioisotopes as well as radio-frequency emissions from all of the radio and television stations on the earth, visible radiation from lights, and a wide range of extremely low frequency radiation from electrical wiring.

1.2 Dose, Absorbed Dose and Dose Equivalents

The health effects of radiation are related to the amount of radiation received by the body, known as the absorbed dose. The measurement of doses is called dosimeter. The key issue in dosimeter is to quantify the amount of energy absorbed by body tissues. This energy is measured in Joules, and the standard dose units are called grays. One gray equals the absorption of one joule of energy by one kilogram of any material, including body tissue. The units used for energy and dose measurements were standardized in 1977. Previously, a number of other measurement systems were used. Some of the scientific literature, and some equipment manuals, still refer to rads and rems. Different types of radiation have different effects on the tissue that absorb sit. To simplify dosimeter, the concept of equivalent dose was developed This is measured in sieverts, with one sievert being the dose that is equivalent, in terms of biological damage, to one gray of X-rays. Most occupational exposures are expressed in millisieverts and microsieverts, which are one -thousandth and one-millionth of a sievert, respectively. The equivalent dose is calculated by multiplying the absorbed dose by factors, which correct for different types of radiation.

1.2.1 Biological Studies

Biological studies include whole animal and cell culture experiments. Whole animal studies are based on the premise that exposure to radiation will have similar health effects in animals and humans. Cell or tissue culture experiments seek to learn how exposures affect the functions of individual cells or tissues. This type of research has demonstrated that low-level electromagnetic fields can influence cell processes, including those involving genetic materials such as DNA and RNA. Exposure to radio-frequency radiation has been shown to cause slight temperature increases in tissue samples, whole animals and human subjects. But it has not been demonstrated that these biological outcomes affect human health in any significant way. Thus, the studies prove that workers exposed to many kinds of non-ionizing radiation are affected, but not that they are harmed. This research is on going. Meanwhile, it makes sense to limit exposure to non-ionizing radiation, especially at the high end of the range. Exposure to ionizing radiation should always be kept as low as possible. This principle is known as ALARA, an acronym for as low as reasonably achievable. While eliminating all exposure to radiation is not possible in the real world, the ALARA principle requires that all unnecessary exposures be eliminated or reduced as much as possible.

1.3 Radiation Sources

Devices, which are known to contain radioactive materials or produce radiation as their primary purpose, must be licensed by either the Atomic Energy Control Board or the Ministry of Labour of Ontario (X-Ray Safety Regulation 861) and Ministry of Health of Ontario (Healing Arts Radiation Protection Act). The employer must have an inventory of all such devices, and/or a list of areas where radioactive materials are used. Devices and procedures licensed by these bodies are strictly regulated, and the regulations are available for review by members of the JHSC. All sources of ionizing radiation should fall into this group. The hazards associated with ionizing radiation have been acknowledged for a relatively long time, and the sources of such radiation are almost entirely regulated. With a few exceptions, non-ionizing radiation sources are not as closely regulated as those that emit ionizing radiation. The major exception is lasers. Lasers emit very powerful, single wavelength, visible light. While visible light sources are not usually regulated, there are regulations, which require controls on lasers above a certain power level. In the workplace, lasers, which have the potential to endanger workers, are known and controlled. An inventory of these devices will be available to the joint health and safety committee. Workplace inspections by JHSC members may identify additional sources of radiation, which are not controlled.

1.4 Monitoring

Monitoring differs from measurement in that exposure data is cumulative and usually only available after the fact. The most common type of monitoring for exposure to radiation is the Thermo luminescent Dosimeter (TLD) Badge. This is a simple holder containing a radiation-sensitive film, which can be worn on the lapel, belt, wrist, or other part of the body. Different uses require the badge to be worn in different places, and reading the exposure accurately requires that the location of the badge be known. The film is normally replaced quarterly, and the exposures are known after the fact. Some direct-reading badges available. They can be read immediately, but they still record exposures only after they occur. In some cases, room monitors can be installed which will set off an alarm if the radiation level in a room exceeds a pre-set level.

1.5 Work Processes and Procedures of Radiation

Some equipment, such as X-ray machines and irradiators, are designed with shielding in place and must be operated that way. It is necessary to periodically verify that the shielding is still functioning according to design standards. Other equipment, such as welding machines and thermal sealers, emit radiation as a by-product of their normal function. In many cases, shielding requires special knowledge on the part of the operator. Equipment is sometimes needed to minimize exposure to workers other than the operator, such as curtains for welding operations. Proper assessment in these cases will require not only a review of the equipment used, but the procedures employed to carry out the work as well. Finally, in the use of radioactive materials, assessment will include a review of permanent and temporary shielding devices, procedures and operations. Emergency procedures including spill control and decontamination procedures will also be evaluated.

1.6 Radiation Control

Ideally, radiation hazards will be fully controlled, which means that it is physically impossible for any worker to be exposed to any radiation. Unfortunately, this is not always feasible. The goal of a radiation control program is to limit the exposure of workers to a level that is as low as reasonably achievable. This is known as the ALARA principle. Achieving this level of control requires a detailed knowledge of the workplace, combined with a systematic process of inspection and hazard assessment. A good understanding of exposure limits and the basis for them is also essential. These conditions are met only when all of the parties in the workplace, including the employer, supervisors, workers and the joint health and safety committee, are committed to radiation safety. The control of radiation sources is based on three principles: shielding, distance and time. Virtually all radiation controls are applications of one or more of these principles. They are discussed separately in the following sections.

1.6.1 Distance Control

Distance is a form of control along the path from the source to the worker. The intensity of radiation decreases as the square of the distance. This means that doubling the distance between the source and the worker reduces the intensity to one quarter, and increasing the distance by 10 times reduces the intensity by a factor of 100. A combination of shielding and distance can be a very effective form of radiation control. This is one area where there is no difference between particulate and nonparticulate radiation, or between ionizing and non-ionizing emissions. All radiation decreases with distance according to the same inverse-square rule. The geometry of the source, however, can reduce the effectiveness of distance as a control. Radiation which is emitted from a single point obeys the Inverse Square Law, while that emitted from linear or planar surfaces does not. This can be a problem when radioactive materials are transported by piping, or are fabricated into larger objects. Distance can be used as a control in a variety of ways. Dead space can be built into devices, so that they occupy more space than they actually require. Barriers can be constructed around some devices, keeping personnel at a specific distance from the source. Shielding can also ensure that workers maintain a safe distance. Finally, the physical location of some sources can ensure that workers are not in close proximity. An example is the location of radio-frequency antennas on the roofs of tall buildings.

1.6.2 Time Control

The effects of exposure to radiation are cumulative with time. As the time of exposure increases, the amount of energy absorbed into the tissue increases and so does the damage to that tissue. If the time that the worker is exposed to radiation is limited, so are the health effects. It is impossible to eliminate all radiation exposure, because of the significant level of background radiation. This makes it even more important to keep all occupational exposures as low as possible. Time is an example of a control at the worker, because it usually does nothing to eliminate the hazard. It is an administrative control, in that it requires a joint effort on the part of the worker and the supervisor to design the job so that the duration of exposure is kept low. For example, some work with radioisotopes must be done with the container opened. But procedures can be designed to minimize the time of exposure. Job rotation is another approach although this means that more workers

Will be exposed. Time works also works as a radiation control because of the fact that radioactive materials decay. This is relevant only for elements with short half-lives. A good example is P-32, which has a half-life of 14.2 days. Radioactive waste, contaminated with P-32, can be stored for six months, during which time 10 half-lives will have passed. This will reduce the radioactivity to less than 0.1 percent of the original amount. This way, the waste is handled only once, and it is virtually nonradioactive when removed from storage.

1.6.3 Shielding

Shielding is an example of control at the source. A shield surrounds the radioactive material or radiation-generating device, so that radiation is prevented from escaping and coming into contact with workers. The effectiveness of shielding depends upon the type of radiation and the shielding material. Shielding works by absorbing the energy of the radiation. It is not very effective for longer wavelengths (lower frequencies), because the shield cannot efficiently absorb the energy of these waves. In general, when electromagnetic radiation exceeds the wavelengths of microwaves, shielding becomes increasingly ineffective.

Different shielding materials vary in their ability to absorb radiation. Materials can be compared according to the so-called half-value layer. That is the thickness of material required to reduce radiation to one half of the intensity at its source. For example, consider a source of gamma radiation with energy of 3 MeV. For this type of radiation, a half-value layer of water would be 170 millimeters, while 80 millimeters of aluminum or 15 millimeters of lead would have the same shielding effect. It must be stressed that this applies only to gamma radiation and only to that particular energy level. It is very important to match the shielding material to the type and energy of radiation produced.

1.6.3.1 Non-Ionizing Radiation Shielding

The non-ionizing part of the electromagnetic spectrum is very broad, and shielding techniques vary considerably over this range. Ultraviolet, visible (non-laser) and infrared radiation all behave very much like visible light. Any opaque solid barrier, of almost any thickness, will block the transmission of this type of radiation. In certain cases, it is not practical to shield the source with an opaque material. For example, in welding operations, the material must be seen by the welder. In these cases, protective eyewear must by used to reduce the intensity of radiation reaching the eyes. Lasers are a special case, because laser light may contain sufficient energy to damage a shield. Another potential hazard from laser light is the possibility of reflection. All visible light can reflect and thereby defeat shields. An example is the sunburn that can result from light reflected from sand or water, defeating a hat. Lasers pose a particular hazard if they reflect from polished metal surfaces in laboratories or machine shops. Eye protection for lasers must be specifically designed to block or attenuate the exact frequency of the laser being used. There are two special considerations. First, eye protection must be used even when the laser is in the non-visible range. Second, the manufacturer of the laser should be involved in the design of the eye protection. It is very difficult to shield non-ionizing radiation below 106 Hertz in frequency. The longer wavelengths are not easily absorbed by the shielding materials. Attenuation can be achieved using wire mesh cages, but this is not true shielding.

1.7 Contamination and Decontamination of Radiation

Sources of electromagnetic emissions can be turned off. The radiation stops when the emission is no longer generated or when the electrical current stops flowing through the wires. Radioactive materials, on the other hand are always radioactive. Because this source of radiation is a physical material, it can contaminate other objects. Most radioactive materials are used in medical research and health care, although there are a few industrial applications as well. All equipment, apparatus or other objects, which come into direct contact with radioactive materials, become contaminated. This must be understood and planned for as part of the job. Provision must be made for the safe use, storage and decontamination of these items.

1.7.1 Contamination

There are two cases of contamination that require special procedures. One is the handling of spills of radioactive material, and the other is contamination of workers. Spills of radioactive material are particularly dangerous, especially if the non-radioactive form of the material is hazardous in itself. For example, if the substance evaporates easily or is especially caustic, then the radioactive forms pose a double threat. As it evaporates or eats into the floor tiles, it carries the radioactivity with it, contaminating an even wider area. For this reason, it is wise to limit the use of radioactive materials to the smallest volume possible. Work with such materials should also be done only in areas with proper spill containment facilities and with easy access to cleanup procedures. Workers can become contaminated while handling radioactive materials. The best method of control is prevention. Prevention of contamination depends upon the correct use of personal protective equipment, including gloves, coats and eye protection. Different substances require different protective equipment, and the choice must be reviewed for each material

Used. Nonetheless, spills, or the generation of aerosols (suspensions of the material in the air), are possible even in the best circumstances, and contamination can occur very easily. The most common type of contamination is for material to be deposited on the outside of a glove. Since the droplets of liquids can be very small, the worker may not know that the glove is contaminated. Subsequently, every item in the workplace that is touched by the glove will also be contaminated. This might include, for example, doorknobs, light switches and computer keyboards. A more serious problem is direct contamination of the skin. This can occur if a worker does not wear gloves, if the glove tears or develops a hole, or if the wrong kinds of gloves have been provided. The proper technique for decontaminating skin depends upon the material involved including both its radioactive and chemical properties. Washing with soap and water may be appropriate in some cases, but it will not be effective for chemicals, which are rapidly absorbed through the skin. For this reason, workers must be trained in proper responses to skin contamination. Medical attention should always be obtained following a case of radioactive contamination.

1.7.2 Decontamination

If contamination is found, the first priority is to determine the extent of the problem and to warn other workers to avoid the area. All surfaces should be checked for contamination. The best decontamination method depends upon both the chemical and radioactive properties of the contaminant. Some isotopes have a very short half-life, and closing the area or locking out the piece of equipment for a period of time may be the simplest solution. This will also prevent exposure to radiation that could occur during the Clean-up process. Materials with relatively long half-lives will require active decontamination measures. This may include washing, scrubbing, or irrigating. The choice of cleaning agent will depend upon the form of the radioactive substance. Some can be easily washed away with soap and water, while others might require the use of a solvent. In some cases, it may be impossible to decontaminate the area. For example, material can get into cracks in surfaces. Or, the chemical may bind irreversibly with the surface material. In these cases, the options are to completely remove the surface or to install temporary or permanent shielding to prevent the continued exposure of workers in the area. The best choice depends on individual circumstances. In very rare instances, workers may ingest radioactive materials. This is especially hazardous, because this brings radioactive materials into very close proximity to delicate tissues and organs. Radioactive sources which are not normally a hazard, such as alpha emitters, are extremely toxic when ingested, as the radiation is delivered directly to the tissues. In all cases of ingestion of radioactive materials, qualified medical attention must be sought.

CHAPTER TWO

ELECTROMAGNETIC FIELDS SOURCES AND EXPOSURE

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. RF Spectrum and Sources is shown in Figure 2.1, together with the International telecommunications Union (ITU) bands. Even at the highest frequency of the range. 300GHz, the energy quantum, *h f*, 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.

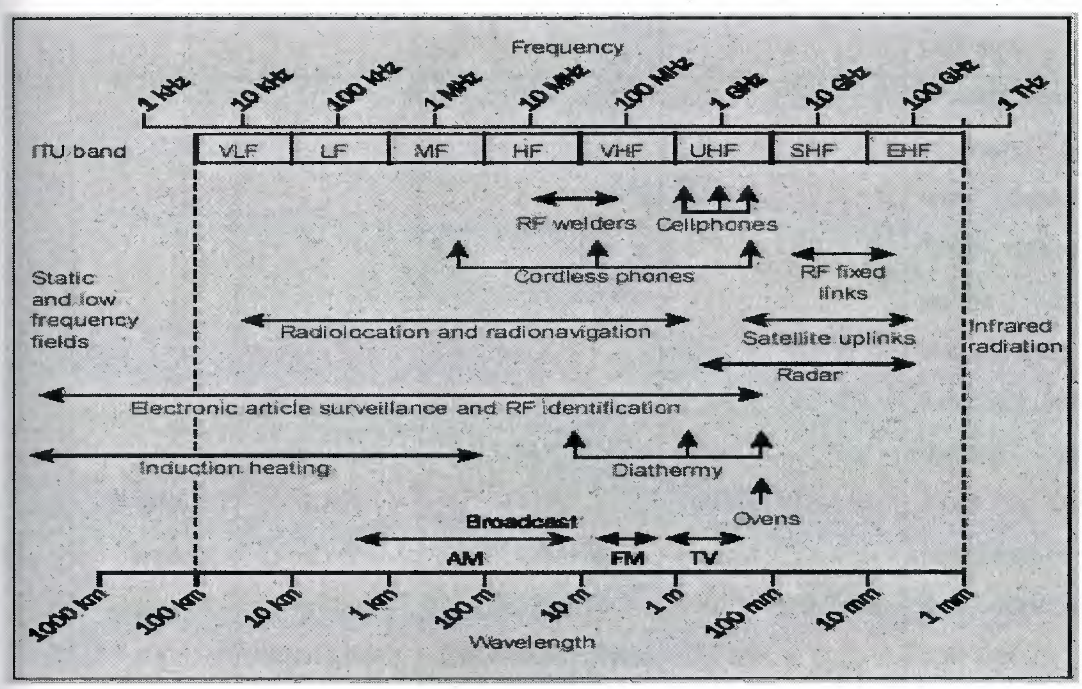

Figure 2.1: RF spectrum and sources

Frequency band	Description	Source	Frequency	Typical exposure	Remarks
3 KHZ	VLF (very low frequency)	Introduction Heating (TV/DVU)	Up to 25KHZ 15 _ 30 KHZ	12-1000/AM, 1-10V/M, 0.16/AM	Occupational exposures at close_approach to coils, 0.1-1M Public sitting at 30Cmfrom VDU
30 KHZ	LF(low frequency)	Introduction heating ,electronic article surveillance	100 KHZ 130 KHZ	800 /AM, UP TO 20 / AM	Limb exposures at clos approach (0.1m) to coils, public midway between panels when entering or leaving premises
300 KHZ	MF (medium frequency)	AM radio , introduction heating.	415KHZ- 1.6_MHZ ,300KHZ -1MHZ	450V/m , 0.2-12/AM 0.2-12A/m	Occupational exposure at 50 m from Am broadcast mast occupational exposure
3 MHZ	HF high frequency	short-waves broadcast EAS PVC welding wood gluing \CB radio	3.95-26.1 MHZ 8MHZ 27.12MHZ 27012MHZ 27Mhz(less10w)	0.2A/m body: 100V/m*0.5A/m Hands: 1500V/m*0.7A/m 170V/m 1kV/m*0.2A/m	occupational exposure beneath wire feeders of 750kw transmitter public exposure close to a tag detecting system operate position close to wending plat form of 10kV dial citric heater operator body exposure at 50Cm

					of 2k W wood gluing public exposure close to antenna radio
30 MHZ	VHF Very high frequency	FM radio	8-108MHZ	4V/M	public exposure at 1500m from a 300 300kw FM mast

Table 2.1: Sources of RF radiation across the spectrum and typical field

Frequency Band	Description	Source	Frequency	Typical Exposure	Remarks
300 MHZ	transmission digital signals and analog video	TV analogs GSM handsets GSM base station terminal (VSAT very small aperture) satellite earth station microwave	470-854 MHZ 900 MHZ 1800MHZ 900 and 1800MHZ 1.5/1.6 GHZ 2.45 GHZ	3V/m 400V/m*0.8A/m 00V/m*0.8A/m 1mw*m^-2 0.5W*m^-2 8W*m^-2 (0.6V/m*1.6mA/m)	Publicexposure (maximum at ground level) from a high power 1Mw effective radiated power TV transmitter mast At 2.2Cm from 2W phone At 2.2Cm from a 1W phone Public exposure 50m from a mast operating at maximum of 50W per channel main beam direction

		cooking			leaking at BSI emission limit Public exposure at 50Cm from an over
3 GHZ	SHF super high frequency	radar air traffic control VSAT traffic radar satellite news gathering	1-10 GHZ 2.8 GHZ 4-6 GHZ 11-14 GHZ 9-35 GHZ	0.5-10W*m^-2 0.16W*m^-2 less 10W *m^-2 less 10W *m^-2 less 1W*m^-2 less 2.5 W*m^-2	Exposure at 100m from ATCradar operating over a range a frequencies Maximum in the main beam maximum in the main beam from 100mW speed check radar public exposure distances of 3m and 10m
30 GHZ-300 GHZ	EHF frequency extra high	transmission digital signals and analog video	38GHZ/ 55GHZ	less 10^-4W*m^-2	beam of microwave dish public exposure at100 m out side main

Table 2.2: These are typical exposures at high frequencies

In contrast to ionizing and ultraviolet radiation, where natural sources contribute the greater proportion of the exposure to the population, man-made sources tend to dominate exposure to time-varying electromagnetic fields over the spectrum shown in the table 2.1. 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 potential 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 necessarily present a source of material exposure except to specialist maintenance workers or engineers. Millions of people, however, approach to within a few centimeters 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 (Figure2.2). Modem digital radio communication systems can use more than one of these types of modulation in the same signal shown in the table 2.2, Many industrial sources produce waveforms with high harmonic content resulting in complex waveforms (Figure 2.3). 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 following tables and graphs:

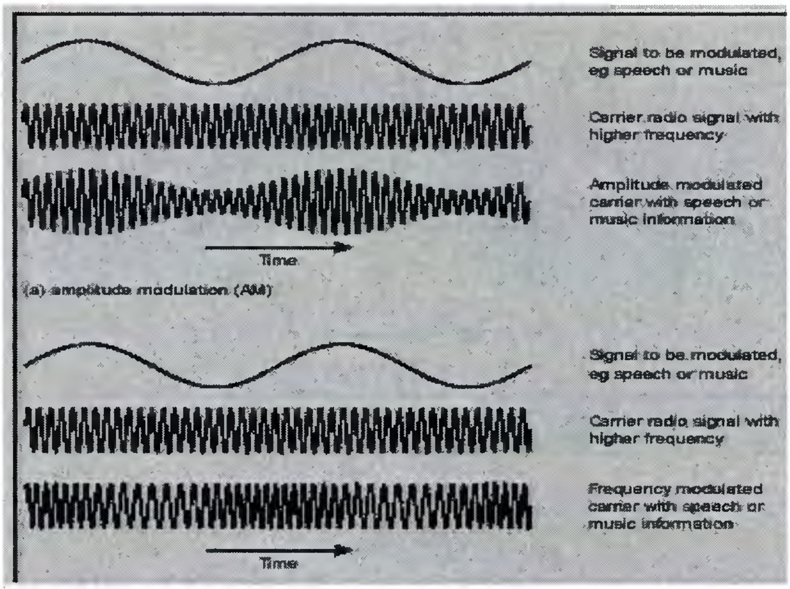

Figure 2.2: Different forms of analogue modulation commonly applied to radio signals

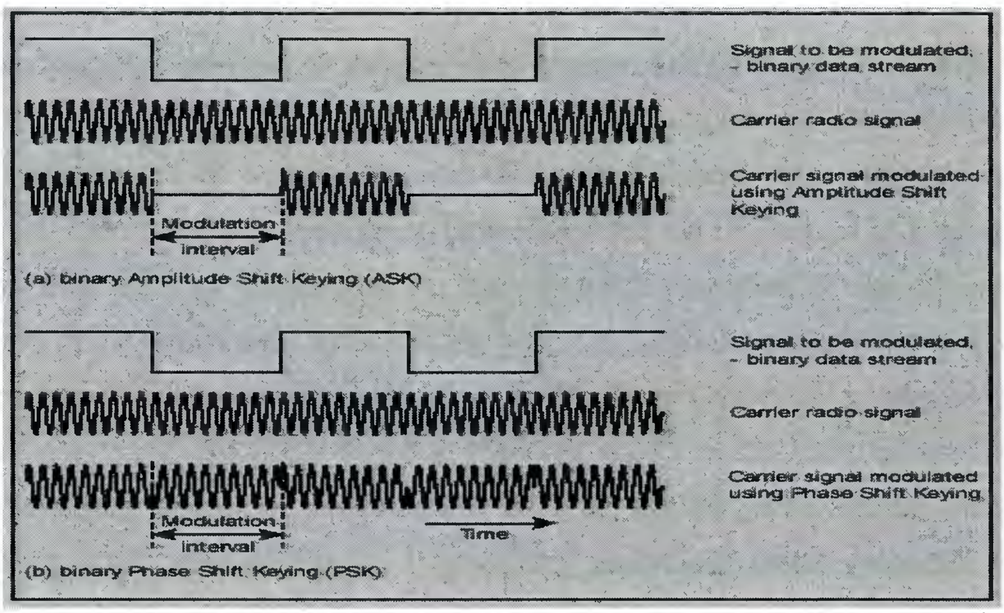

Figure 2.3: Examples of two simple digital modulation schemes

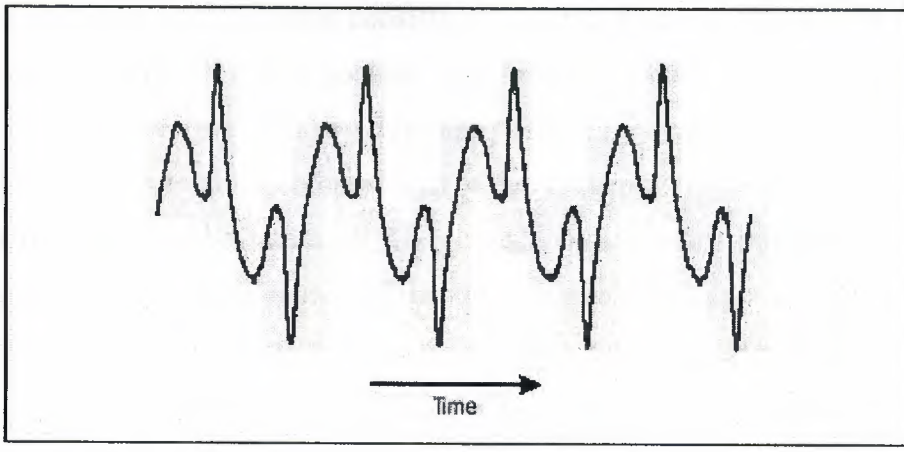

Figure 2.4: Industrial magnetic field wave form with high harmonic content

2.1 Characteristics of Electromagnetic Fields

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 solenoid 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.

An electromagnetic field or wave consists of electric, *E*, and magnetic, *H,* fields that oscillate sinusoid ally 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 rams, or root mean square, value (the square root of the average of the square of the field). For a sinusoid ally 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 meter, the power density is $1Wm^{-2}$.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, $S = EH$.

2.2 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, while in frequency modulation (FM) the frequency changes by small amounts proportional to the size of the low frequency signal at that time. 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. 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.

2.1.1 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 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 that occur at a rate of 1500Hz will cause this component to `color` 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.

2.3 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: radioactive and reactive. The radioactive component is that part of the field which propagates energy away from the source. While the reactive com-potent 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 radioactive 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 the source 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 Dies 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 radioactive 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 (or1m 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.

2.4 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 $100 Wm^{-2}$.

2.5 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, i.e. they are out of phase. Hence, the simple relation between S, E and H given 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

Table 2.3: Examples of far-field (plane wave) relation ships

2.6 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 dissymmetric 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.

2.7 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 a microwave cooking. Many of the measurements reported here are `spot measurements', i.e. 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 analyzed 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.

2.8 Communications

Antennas generate electromagnetic fields across the spectrum At very low frequencies 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 may b encountered within the boundary defined by the antenna structures. Magnetic field strengths in the range ($2-15Am^{-1}$) have been measure close to VLF antenna feeds and ($0.2-52Am^{-1}$) close to LF towers. In transmitter buildings magnetic field strengths were in the range <0.1 $mm^{-1}-11Am^{-1}$. 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 am per Vm^{-1}. at the resonance frequency of around 35MHz for an electrically grounded adult Measurements indicate that under more normal grounding conditions, e.g. when wearing shoes, the current is reduced to about 6-8 am per Vm^{-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 Vm^{-1} have been measured at 5cm from 4W CB transmitters, whereas at 60cm the field strengths fall to less than 60 Vm^{-1}.

In the USA, long before the advent of mobile telephony a study of population exposure to background fields from VHF and UHF broadcast transmitters that the median exposure for 15 cities was 50 μWm^{-2} (0.14 Vm^{-1}), although some cities had median exposures of 200 μWm^{-2} (0.3 Vm^{-1}). Maximum exposures, which were from local FM radio stations, were about 0.1 Wm^{-2} (6 Vm^{-1}), these values are all well within the ICNIRP reference levels of about 25 to 60 Vm^{-1}).for this frequency range.

2.9 Handheld Equipment

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

2.9.1 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 (2.4) 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 2.4: Mobile phone systems and handset powers

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 (2.5) 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, egg any six-minute period.

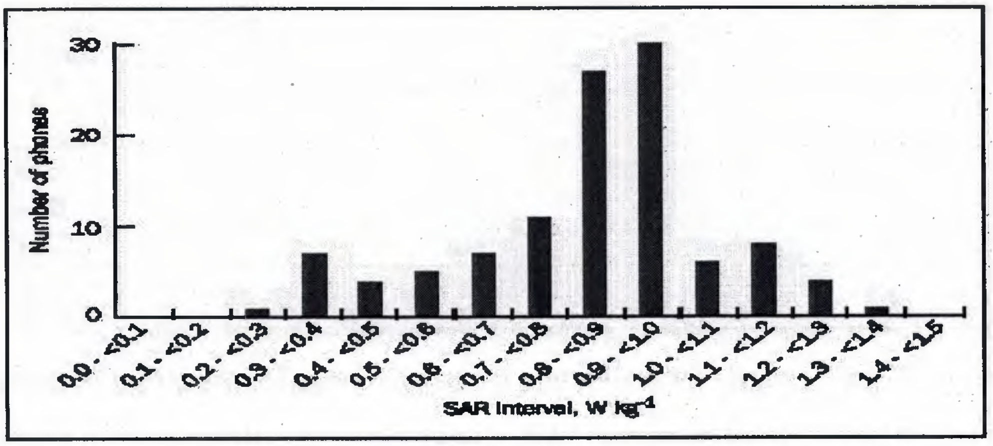

Figure 2.5: Distributions of SARs produced by 111 mobile phone handsets

2.9.2 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 400 μs bursts. Average powers are thus ten or more times smaller than those from mobile phones operating at their highest power level (see Table 2.5a). 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 favorably located with respect to a base station would reduce their output power and therefore the SAR below that of cordless phones.

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 (2.5B).

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	1g averaged	10g averaged	Spatial peak	1g averaged	10g 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 2.5: (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 3w tetra hand portables.

2.9.3 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.

2.9.4 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. egg 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.

2.9.5 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 rn^{-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 dosimeters 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$V m^{-1}$ beneath the antenna feeders. Fields in excess of 1500 $V m^{-1}$ 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 (Manti ply et al, 1997) with operating powers from 1 to 50kW over the frequency range from 500kHz to 1.6MHz. Within a meter or two of the towers electric field strengths were between 95 and 720V m^{-1} and magnetic field strengths ranged from 0.1 to 9.3A m^{-1}. At 100m the electric and magnetic field strengths varied over an order of magnitude to 20 mV m^{-1} and 76 am m^{-1}, respectively. A review of general population exposure (Hankins, 1986) revealed that the median exposure of the urban population to AM broadcast in the USA was 280mV m^{-1} and 98% of the populations were exposed to levels above 70 mV m^{-1}.

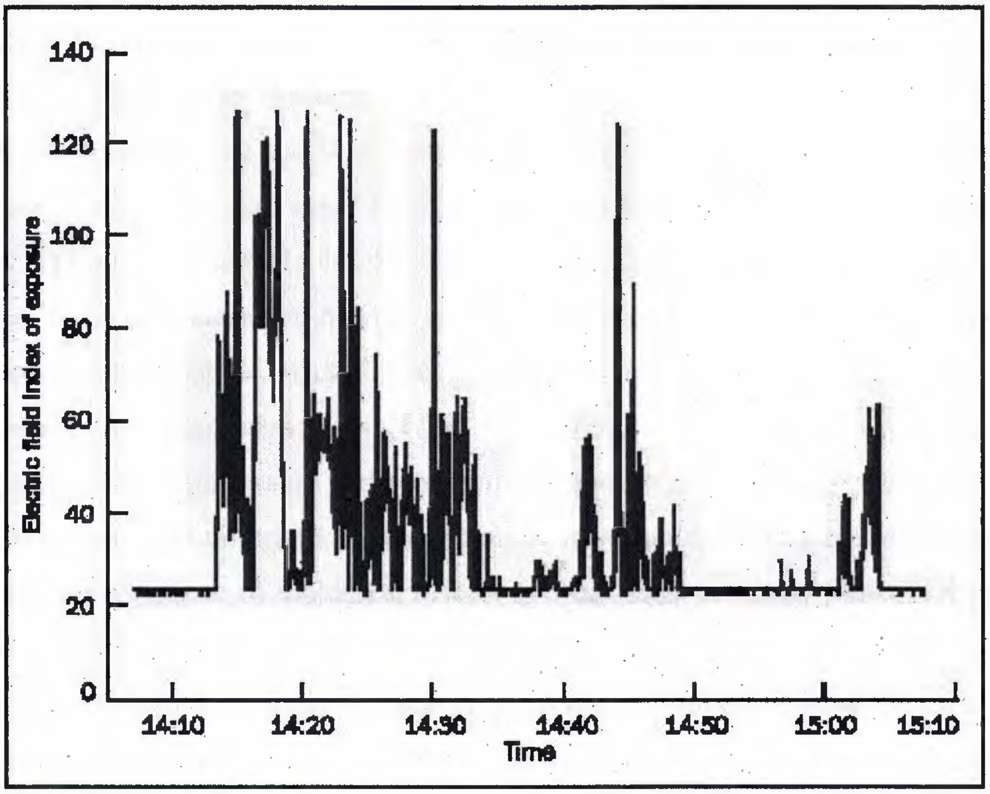

Figure 2.6: Trace acquired from a body-mounted personal exposure meter worn by a worker at an HF broad cast site

CHATPTER THREE

BIOELECTROMAGNETICS DEVELOPMENTS TOWARDS PHYSICAL BIOLOGY

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 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 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 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. 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

3.1 Evidence for Role of Free Radicals in 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 Physical actions of EM fields may regulate the rate and the amount of product of biochemical reactions, possibly through free radical mechanisms including direct influences on enzyme action 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.

3.2 Calcium-Dependent Neuroregulatory Mechanisms Modulated by EM Fields

3.2.1 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.

3.3 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).

3.4 Neuroendocrine Sensitivities

3.4.1 Effects of Environmental EM Fields on Melatonin Cycling

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).

3.4.2 Behavioral Teratology Associated with EM Field Exposure

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.

3.4.3 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 3.1: Characteristics of ionizing and non -ionizing radiation

3.5 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 3.1). 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).

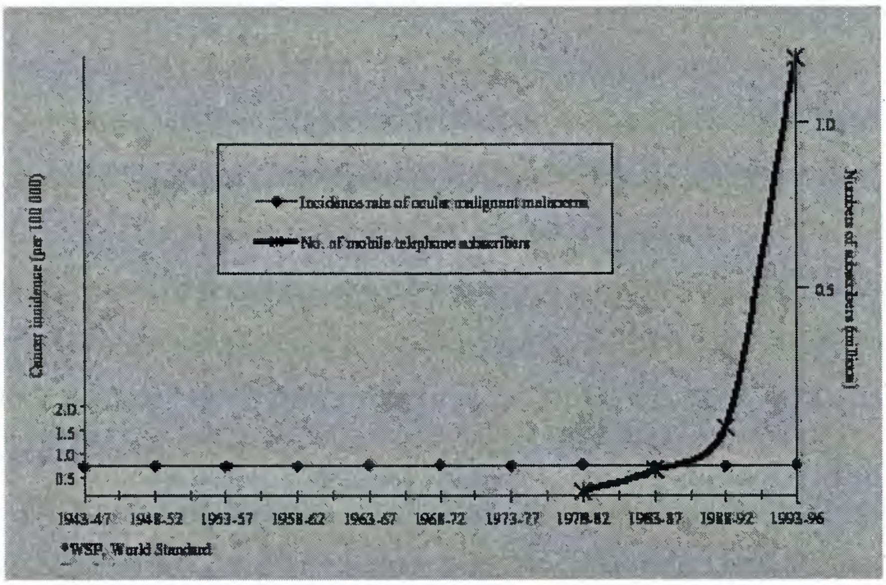

Figure 3.1: Age standardized (WSP) annual incidence (cases per 100,000) of ocular malignant melanoma in denmark 1943-96 and number of subscribers to cellular telephones, denmark 1982-96* (Johansen et al. 2002).

3.6 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.

3.6.1 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:

1. Charge motion,
2. The triggering of dipole motion,
3. 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.

3.7 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).

3.8 A Correlated Increase in the Incidence of Skin Cancer

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.

CHAPTER FOUR

NON-CANCER EPIDEMIOLOGY AND CLINICAL RESEARCH

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.

4.2 RF Radiation

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.

4.3 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 m^{-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.

4.4 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 micro-waves (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 (2-60$W\,m^{-2}$) 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 linemen 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 Wm^{-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.

4.5 Epidemiological Evidence

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.

4.6 Male Sexual Function and Fertility

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 $(1.3\times10^{7}\frac{1}{mL} vs 3.5\times10^{7}\frac{1}{mL})$, 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.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.

4.7 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).

4.8 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.

4.9 Birth Outcome and Congenital Malformations

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.

CHAPTER FIVE

BIOLOGICAL EFFECTS OF RADIATION AND EFFECTS OF ULTRAVIOLET RADIATION

The discovery or x-rays and radioactivity resulted from scientific inquiry into electrical discharges in gases. At that time not much was understood about what was happening in the gas and there was great curiosity about the beautiful electrical displays that were observed in the partially evacuated discharge tubes. On November 8, 1895. Professor Wilhelm Conrad Roentgen discovered x-rays. He was investigating the penetrability of cathode rays in his darkened laboratory. Lying about on his lab bench were several scraps of metal, covered with barium platinocyanide, a fluorescent material. At the time he was operating the Hittorf vacuum tube inside a light-tight box. From the corner of his eye, he noticed that some of these barium platinocyanide scraps were glowing while the tube was energized. Further investigation showed these scraps stopped glowing when he turned the tube off and glowed more intensely when he brought them close to the box. From this he concluded that whatever caused the glowing originated from inside of his vacuum tube. Professor Roentgen realized that he had discovered a new phenomenon, a new kind of radiation which he called x-rays because it was a previously unknown type of radiation. Within a few days of Roentgen's announcement of this "new kind of ray," experimenters all over the world were producing x-rays with equipment that had been in their laboratories for years. Within a few weeks, the French scientist Henri Poincarj reasoned that there might be some connection between the rays from Roentgen's tubes that made certain minerals glow and something in the same minerals that would spontaneously produce the same glow or phosphorescence. A colleague of Poincarj, Henri Becquerel, undertook a systematic study of such minerals, including those containing uranium and potassium. The initial experiments entailed exposing the material to sunlight to stimulate fluorescence. In March 1896, during a period of bad weather, Becquerel stored some uranium and the photographic plates in a drawer. When he developed the plates, he found dark spots and the image of a metal cross which had been between the uranium and the plate. He soon realized that he had discovered a type of radiation that was similar to Roentgen's x-rays. Becquerel had, in fact, discovered natural radioactivity, and he reported this in April 1896, about four months after Roentgen's discovery. When x-rays (and radiation) were first discovered there was no reason to suspect any particular danger. After all, who would believe that a ray similar to light but unseen, unfelt or otherwise undetectable by the five senses could be injurious? Early experimenters and physicians set up x-ray generating equipment and proceeded about their work with no regard for the potential dangers of radiation. The use of unshielded x-ray tubes and unshielded operators were the rule in 1896, with predictable results. Not only some patients, but many roentgenologists were exposed to the mysterious ray because the equipment was built without protection for the operator. The tube was often tested by placing the hand into the beam. The newness and fascination caused the operators to demonstrate the equipment to interested colleagues and nervous patients. Because researchers initially did not suspect damage from radiation, many clinical and experimental procedures resulted in workers and patients suffering prompt, somatic effects such as erythematic, skin burns hair loss, etc. Often these injuries were not attributed to x-ray exposure, in part because there was usually a several week latent period before the onset of injury, but also because there was simply no reason to suspect x-rays as the cause, and now regarding the effects of ultraviolet radiation ultraviolet radiation is a known cause of skin cancer, skin ageing, eye damage, and may affect the immune system.

People who work outdoors are the most likely of all workers to suffer health damage from exposure to UV radiation. Other people may be exposed to UV radiation at work from non-solar sources such as arc welding, the curing of paints, inks etc and the disinfection of equipment in hospitals and laboratories amongst others.

In relation to non-solar sources of ultraviolet radiation, well designed engineering and administrative controls and in the case of arc welders, personal protective equipment can keep the risks to a minimum.

However with outdoors workers who are regularly exposed to the sun for long periods of time, a more comprehensive strategy is required to minimize risks. This is because the sun (exposure source) cannot be controlled like other workplace exposure hazards.

5.1 Cellular Damage and Possible Cellular Processes

The principal difference between nuclear radiation and other types of electromagnetic radiation (e.g., heat, light, RF, etc.) is that nuclear radiation ionizes (i.e., produces ion pairs) as it passes through matter. Chapter 1 (Figures 1-17 &1-19), discussed range and penetrability of radiation: have long ranges and are very penetrating while x-/c-rays particulate radiation has a short range and does not penetrate deeply into tissues before expending all of its energy. Mass, charge, and velocity of a particle all affect the rate at which ionization and energy deposition occurs.

5.2 Linear Energy Transfer (LET) and Relative Biological Efficiency (RBE)

The amount of energy a radiation deposits per unit of path length (i.e., kilo electron volts/micron - keV/mm) is defined as the linear energy transfer, LET, of that radiation. Mass, charge and velocity of a particle all affect the rate at which ionization occurs and is related to range. Heavy, highly charged particles (e.g., a-particle) lose energy rapidly with distance and do not penetrate deeply. In general, radiation with a long range (e.g., x-/g-rays, high-energy ß particles) usually has a low LET, while large particulate radiations with short range (e.g., □particles, neutrons, protons) have a high Additionally, LET increases with the square of he charge on the incident p values of LET and RBE in water for various radiations. When ionizing radiation interacts within cells, it deposits ionizing energy in the cell (Figure 2-1). The higher the charge of the particle and the lower the velocity, the greater likelihood to produce ionization. In tissue, the biologic effect of a radiation depends upon the amount of energy transferred to the tissue volume or critical target (i.e., the amount of ionization) and is therefore a function of LET.

In radiation biology research, many different types and energies of radiation are used and it become difficult to compare the results of the experiments based on the let, and a more general term, the relative biologic effectiveness, article.

5.3 Ultra Violet Radiations as a Hazard in the Work Place

Ultraviolet (UV) radiation is a known cause of skin cancer, skin ageing eye damage and may affect the immune system. People who work outdoors are the most likely of all workers to suffer health damage from exposure to UV radiation. Other people may be exposed to UV radiation at work from non-solar sources such as arc welding, the curing of paints, inks etc and the disinfection of equipment in hospitals and laboratories amongst others In relation to non-solar sources of UV radiation, well designed engineering and administrative controls and in the case of arc welders, personal protective equipment can keep the risks to a minimum However with outdoor workers who are regularly exposed to the sun for long periods of time, a more comprehensive strategy is required to minimize risks. This is because the sun (exposure source) cannot be controlled like other workplace exposure hazards Factors that affect UV radiation include the following:

1. Sun elevation: The higher the sun in the sky, the more intense the UV radiation. Therefore the UV radiation levels are highest around solar noon and in summer.
2. Latitude: The closer to equatorial regions, the higher the UV radiation levels.
3. Cloud cover: Solar UVR can penetrate through light cloud cover, and on lightly overcast days the UV radiation intensity can be similar to that of a cloud-free day. Heavy cloud can reduce the intensity of UV radiation. Scattered cloud has a variable effect on UV radiation levels, which rise and fall as clouds pass in front of the sun.
4. Altitude: At higher altitudes, the atmosphere is thinner and absorbs less UV radiation.
5. Ozone: Ozone absorbs some of the UV radiation that would otherwise reach the Earth's surface.
6. Ground reflection: Grass, soil and water reflect less than 10% of UV radiation; fresh snow reflects as much as 80%; dry beach sand about 15% and sea foam about 25% As UV radiation can neither be seen nor felt, it is important therefore that workers who have the potential to be exposed to intense levels of UV radiation are aware of the risks and are regularly reminded to take prompt, appropriate protective action.

5.4 Health Risks Associated with Ultra Violet Radiation

UV radiation is known to cause adverse health effects that can manifest over both the short and long term. UV radiation is absorbed in the skin and the adverse health effects are mostly confined to the skin and eyes. In most cases it is considered that shorter wavelengths (UVB) are more harmful than longer wavelengths (UVA).

5.4.1 Effects of UV Radiation on the Skin

Short-term exposure to UV radiation causes reddening of the skin, sunburn and swelling which may be very severe. In some people this sunburn is followed by increased production of melanin, and is recognized as a suntan. Tanning is a sign that damaged skin is attempting to protect itself from further harm. A suntan is not an indication of good health and offers only minimal protection against further exposure. The most serious long-term effect of UV radiation particularly for white skinned populations is the induction of skin cancer. The non-melanoma skin cancers (NMSCs) are basal cell carcinomas and squamous cell carcinomas. They are relatively common in white people, although they are rarely fatal. They occur most frequently on sun-exposed areas of the body such as the face and hands and show an increasing incidence with increasing age. The findings from epidemiological studies indicate that the risk of both of these skin cancers can be related to cumulative UV radiation exposure, although the evidence is stronger for squamous cell carcinomas Malignant melanoma is the main cause of skin cancer death, although its incidence is less than NMSC. A higher incidence is found in people with large numbers of naive (moles), those with a fair skin, red or blond hair and those with a tendency to freckle, to sunburn and not to tan on sun Exposure. Both acute burning episodes of sun exposure and chronic occupational and recreational exposure may contribute to the risk of malignant melanoma chronic exposure to solar radiation also causes photo ageing of the skin and actinic kurtosis. Photo ageing is characterized by a leathery, wrinkled appearance and loss of skin elasticity while actinic kurtosis is a known precursor to squalors cell carcinomas.

5.4.2 Effects of UVR on the Eyes

Responses of the human eye to acute overexposure of UV radiation include photokeratitis and photo conjunctivitis (inflammation of the cornea and the conjunctiva, respectively) more commonly known as snow blindness or welders flash. Symptoms range from mild irritation to sever pain and possibly irreversible damage. There is evidence that chronic exposure to intense levels of solar radiation is a contributory factor in the development of age-related macular degeneration of the retina and cortical cataracts, both a cause of blindness.

5.4.3 Eye Protected from UV Radiation

Ultraviolet radiation reaches the eye not only from the sky above but also by reflection from the ground, especially water, snow, sand and other bright surfaces. Protection from sunlight can be obtained by using both a brimmed hat or cap and UV absorbing eyewear. A wide-brimmed hat or cap will block roughly 50% of the UV radiation and reduces UV radiation that may enter above or around glasses. Ultraviolet absorbing eyewear provides the greatest measure of UV protection, particularly if it has a wraparound design to limit the entry of peripheral rays. Ideally, all types of eyewear, including prescription spectacles, contact lenses and intraocular lens implants should absorb the entire UV spectrum (UV-B and UV-A). UV absorption can be incorporated into nearly all optical materials currently in use, is inexpensive, and does not interfere with vision. The degree of UV protection is not related to price. Polarization or photosensitive darkening are additional sunglass features that are useful for certain visual situations, but do not, by themselves, provide UV protection. For outdoor use in the bright sun, sunglasses that absorb 99-100% of the full UV spectrum to 400 nm are recommended. Additional protection for the retina can be provided by lenses that reduce the transmission of violet/blue light. Such lenses should not be so colored as to affect recognition of traffic signals. The visible spectrum should be reduced to a comfortable level to eliminate glare and squinting. Individuals who also wear clear prescription eye wear outdoors should consider using lenses which absorb 99-100% of the UV radiation to 380-400 nm.

There is presently no uniform labeling of sunglasses that provides adequate information to the consumer. Labels should be examined carefully to insure that the lenses purchased absorb at least 99-100% of both UV-B and UV-A. Consumers are advised to be wary of claims that sunglasses “block harmful UV” without saying how much.

5.5 UV Radiation Risks

Everyone is at risk. No one is immune to sunlight-related eye disorders. Every person in every ethnic group in developed and developing nations alike is susceptible to ocular damage from UV radiation that can lead to impaired vision.

5.5.1 Factors of Increasing the Risk

Any factor that increases sunlight exposure of the eyes will increase the risk for ocular damage from UV radiation. Individuals whose work or recreation involves lengthy exposure to sunlight are at greatest risk. Since UV radiation is reflected off surfaces such as snow, water and white sand, the risk is particularly high on the beach, while boating or at the ski slopes. The risk is greatest during the mid-day hours, from 10 AM to 3 PM and during summer months. Ultraviolet radiation levels increase nearer the equator, so residents in the southern US are at greater risk. UV levels are also greater at high altitudes. Since the human lens absorbs UV radiation, individuals who have had cataract surgery are at increased risk of retinal injury from sunlight unless a UV absorbing intraocular lens was inserted at the time of surgery. Individuals with retinal dystrophies or other chronic retinal diseases may be at greater risk since their retinas may be less resilient to normal exposure levels.

5.5.2 Effects UV Radiation on the Children

Children are not immune to the risk of ocular damage from UV radiation. They typically spend more time outdoors in the sunlight than adults. Solar radiation damage to the eye may be cumulative and may increase the risk of developing an ocular disorder later in life. It is prudent to protect the eyes of children against UV radiation by wearing a brimmed hat or cap and sunglasses. Sunglasses for children should have lenses made of plastic rather than glass for added impact protection.

5.5.3 Manage Risks in the Work Place

There are a number of measures that can be put in place to control risks
In the workplace this would involve:

1. Engineering controls. For outdoor workers this would include the provision of shade cover or canopies. In the context of non-solar sources of UV radiation, suitable engineering controls measures would include opaque barriers, UV radiation blocking filters and door interlocking power supplies.

2. Administrative controls. For outdoor workers this would include rescheduling outdoor work programs where possible to be performed outside the peak UV radiation period (2 hours either side of solar noon), moving where possible the jobs indoors or to shady areas or rotating workers between indoor and outdoor tasks to lessen each employees total UV exposure. In the context of non-solar sources of UV radiation, administrative controls would include warning signs, keeping staff at a safe distance and limiting the time during which UV radiation sources are switched on. Training of supervisors and
3. Employees should be undertaken for workers exposed to solar adnoun-solar sources of radiation.
4. Personal protective equipment (PPE). If necessary, outdoor workers should be provided with protective clothing that is loose fitting, made of close weave fabric and provides protection to the neck and preferably to the lower arms and legs. Hats should shade the face,
5. Neck and ears and have a wide brim (8-10cm). If hard hats have to be worn, they should have attached neck flaps. Sunscreen should be a minimum SPF 15, and be broad-spectrum, that is blocking UVA and UVB, and is applied regularly and liberally to exposed skin. Sunglasses should be close fitting, of a wrap-round design and block at least 99%
6. UV radiation. In the context of non-solar sources of UV radiation, arc welders in particular need to be provided with purpose-specific protective equipment.
7. Training should be offered to all employees exposed to medium to very high levels of UV radiation at work so that they understand the risks and what is expected of them while at the workplace.

5.6 Exposure Limits

Exposure limits for UV radiation for the avoidance of acute health effects have been published by bodies such as the International Commission on Non-Ionizing Radiation Protection and the American Conference of Governmental Industrial Hygienists These limits are based on the concept of thresholds below which acute effects will not be observed in a normally sensitive lightly pigmented adult population. It is believed that there is no lower threshold for induction of chronic affects such as

skin cancer the published limits will limit the additional risk of these effects from occupational exposure by virtue of an overall reduction in exposure.
Acute overexposure to the sun can result in sunburn, skin blistering headaches, nausea, vomiting, or dizziness. The latter 4 symptoms are those of sunstroke which is caused by dehydration and overheating and is not necessarily a direct effect of the UV radiation. If such cases occur, protect the worker's skin from further direct sun exposure and apply cold water to the affected areas and then seek medical attention. For UV radiation overexposure to the eye, place a sterile dressing over the eye and seek medical attention. When such incidents of overexposure occur, it is important to identify the causes and adjust work practices or controls to prevent future incidents.

5.7 Lasers Radiation

Exposure of the body to laser radiation at all wavelengths can cause injury, often in the form of serious burns, to the skin, and also to the outer layers of the eyes (to the cornea the conjunctiva and other ocular tissues) where the consequences can be particularly severe At certain wavelengths, laser radiation can penetrate further into the eye and be focused to form a very small spot (which may be no more than 20 or 30 μm across) on the retina at the back of the eye. This can result in retinal exposure levels that can be up to 100 000 times greater than at the surface. This focusing effect is illustrated in figure 5.1, the retina is the light-sensitive layer that transmits visual information to the brain, and it is particularly susceptible to damage. For the retina to be at risk, laser emission must lie within the transmission band of the eye.
This extends, not just across the visible band (from 400 to 700 nm), but also into the near infrared as far as 1400 nm. The wavelength region between 400 and 1400 nm, the extent of this transmission band, is therefore known as the retinal hazard region. Laser radiation in this region is particularly hazardous, and can be especially so when the emission lies in the near infrared and is thus invisible. Serious damage to the interior tissues of the eyes (especially the sensitive retinal layer), including permanent visual function loss, can result from the viewing of even quite low power lasers within the visible and near-infrared band. This can occur with exposure levels that, at the front of the eyes and at the skin, are completely harmless figure 5.1, Focusing of laser radiation by the eye.

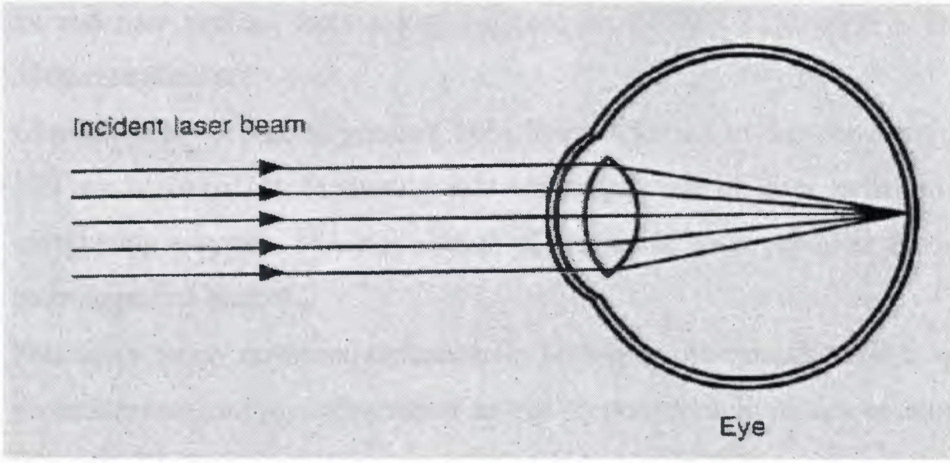

Figure 5.1: Focusing of laser radiation by the eye

These hazards to the eyes and the skin can arise from beam reflections as well as from direct exposure (called intra-beam exposure) to the beam itself. A summary of the tissues at risk from different wavelengths is given in figure 5.1. In addition to the radiation hazards of lasers, other hazards may also exist, depending on the type of laser and the particular application. Many lasers use high voltages for excitation of the active medium. Pulsed lasers often employ large capacitor banks that can store significant amounts of electric charge, even after the equipment has been switched off and disconnected from the main supply Electrical hazards can be life threatening, and accidents with laser power supplies have indeed had fatal consequences.

Tissue			
Waveband	Skin	Outer layers of eye	Retina
Below 700 nm	X	X	
700-1400 nm	X	X	X
Above 1400 nm	X	X	

Table 5.1: Wavelengths

5.7.1 Laser Safety Standard

Requirements placed on those who manufacture laser products, and can define the safety measures that should be adopted by those who use laser equipment.

Australian and new zealand laser safety standard is AS/NZS 2211.1:1997. The main objects of this standard are:

1. Classification to protect persons from laser radiation in the wavelength range 100 nm to 1mm* by indicating safe working levels of laser radiation and by introducing a system of classification of lasers and laser products according to their degree of hazard.
2. Precaution to lay down requirements for both user and manufacturer to establish procedures and supply information so that proper precautions can be adopted.
3. Warning To ensure adequate warning to individuals of hazards associated with accessible radiation from laser products through signs, labels and instructions.
4. Injury reduction To reduce the possibility of injury by minimizing unnecessary accessible radiation, to give improved control of the laser radiation hazards through protective features, and to provide safe usage of laser products by specifying user control measures.
5. Protection to protect persons against other hazards resulting from the operation And use of laser products.

5.7.2 Classify Laser Products

The product classification is the primary indication of the potential hazard. It is the Responsibility of the manufacturer to label and provide information about their laser product in accordance with Section 2 of AS/NZS 2211.1:1997 A guide for the implementation of safe practice for the user is set out in Section 3 of AS/NZS 2211.1:1997. It is therefore necessary that both the manufacturer and its shown in the figure 5.2. Where a hazard exists, the user, understand the system of classification. The details of the classification system are set out in Section 2 of AS/NZS 2211.1:1997, and the philosophy behind it is described below. The classes and their hazards for CW lasers operating at visible wavelengths (400 nm – 700 nm) are shown schematically below: Note that in terms of hazards this diagram is applicable for repetitively pulsed or modulated lasers and for lasers with invisible radiation (Infrared to far infrared with the wavelength greater than 700nm).

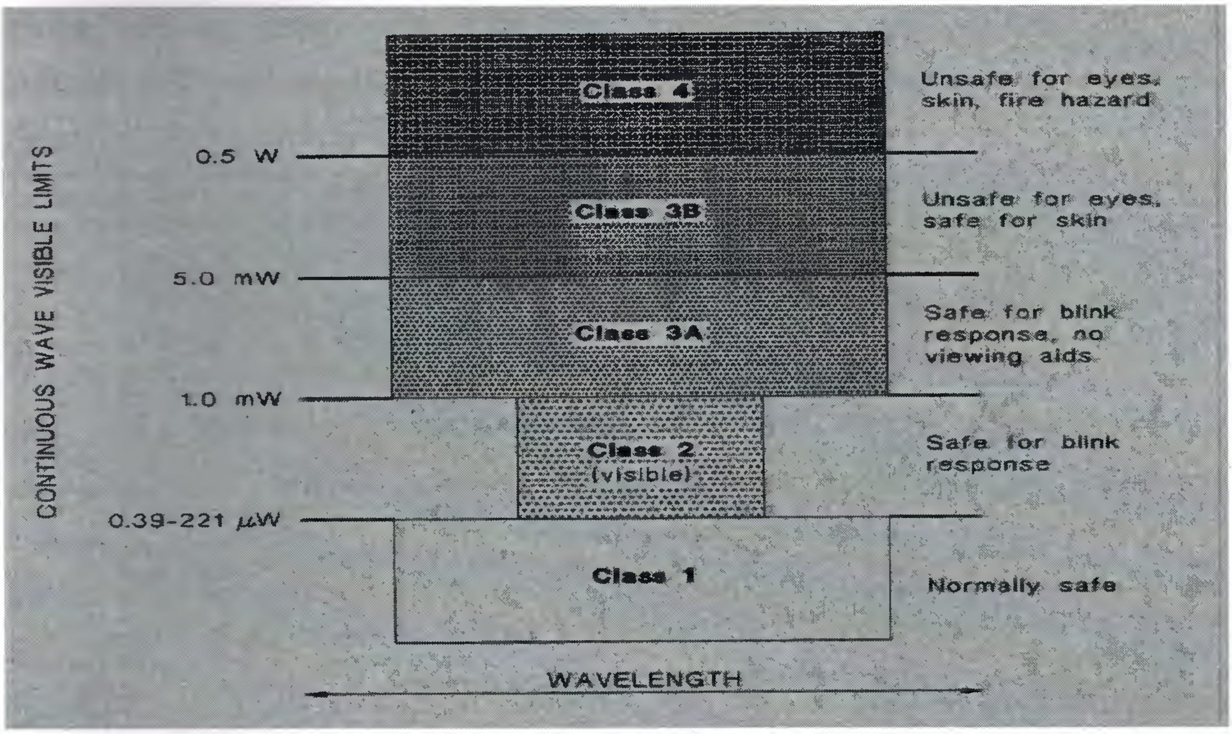

Figure 5.2: Accurate values are given in AS/NZS 2211.1.

5.8 Beam Reflections

Laser hazards may arise not only from the direct beam but as a result of its reflection from a surface on which it impinges (whether accidentally or intentionally). There are secular and diffuse reflectors. The illustration of both processes is given Below A plane secularly reflective surface would merely redirect the beam without changing the characteristics of the beam see figure 5.3.

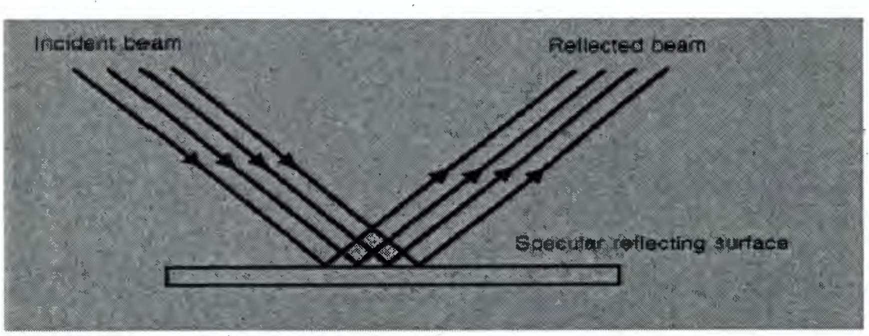

Figure 5.3: Seculars reflection

Diffuse reflecting surface would redistribute the reflected radiation in all directions, hence destroying the original geometrical properties of the incident beam shown in the figure 5.4, Diffuse Reflection

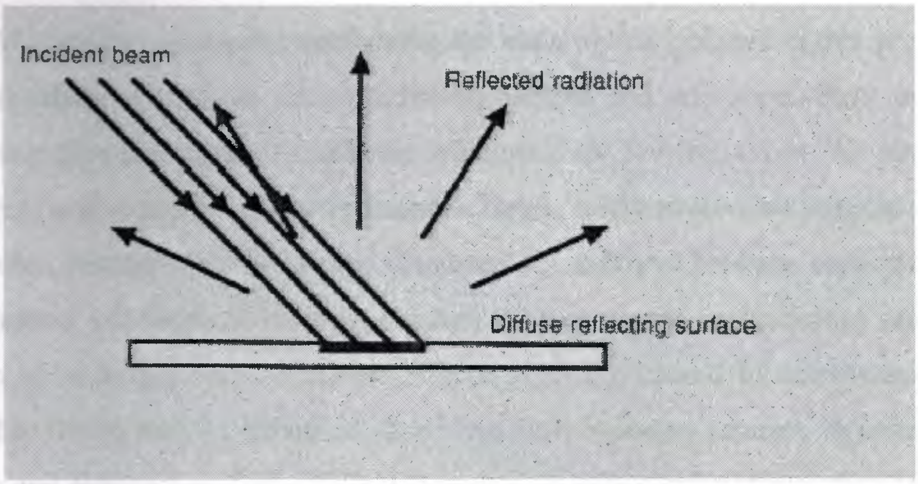

Figure 5.4: Diffuse reflection

CONCLUSION

We briefly summarize mentioning the main topics included in this project (five chapters) where at first we define radiation hazards and talk about them in general, mentioning the main types of radiations which include fourteen types. We investigated the sources and exposure of electromagnetic fields, safety procedures against radiations or radiation hazards. We have also discussed the relation between electromagnetics' developments and physical biology. Further, the non-cancer epidemiology and clinical research in including some exposure effects generally caused by microwaves (being exposed to them) such as effects of short term-high exposure cataract, exposure effects on male and female functions, birth outcomes and congenital malformations caused by exposure.

Finally we presented the main biological effects caused by the radiation and ultraviolet radiation that most people working in x-ray-radiation work places have like cellular damage and ultraviolet radiation effects on the eyes, brain and skin. Also we include some unique type of radiation called (laser radiation) that plays a vital role in effecting on people and hurting them by causing them real injuries often in the form of serious burns to the skin and also to the outer layers of the eye and so forth. Thus, we have covered mostly the main aspects of radiation hazards.

REFERENCES

[1] Ian Hymes, The Physiological and Pathological Effects, NewYork, 1996.

[2] B.L. Diffey, Evaluation of Ultraviolet Radiation Hazards in Hospitals, Los Angeles,1994.

[3] by Bruce Fife, Health Hazards of Electromagnetic Radiation, NewYork, 1998.

[4] Edelstyn and Oldenshaw, The acute effects of exposure to electromagnetic field emitted by mobile phones on human attention, england, 2002.