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Faculty of Engineering

Department Of Electrical And Electronic Engineering

MOBILE PHONE AND ITS CAUSES TO HUMAN HEALTH

Graduation Project
EE- 400

Student: Ahmed Zourob (992100)

Supervisor: Mr. Jamal Fathi

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ABSTRACT

Mobile telephones have transformed the telecommunications industry. These devices can be used to make telephone calls from almost anywhere. There are two types - one has the antenna mounted on the handset and the other has the antenna mounted on a separate transmitter or, if the telephone is installed in a vehicle, mounted on the roof or rear window. Communication between a mobile telephone and the nearest base station is achieved by the microwave emissions from the antenna.

The first main objective of this thesis is to provide analysis of mobile phone system background, present and future uses and it also explain the benefit of using such a system and how it even work.

The second objective is to describe, how the radio frequency radiated from mobile telephone can affect on human health and can causes many dangerous the people that are using it.

Many studies have done in human and animals, which carried out by scientists to show or to measure the amount of trouble caused to them because of using such equipment.

And they also provide some methods or protection rules for reducing the effect of mobile telephone system radiation on human health such shields and hand-free kits.

INTRODUCTION

The telecommunication industry is experiencing rapid growth on a global scale. This a direct Consequence of technological development and has in turn facilitated the application of new technologies and a consequent increase in economic activity.

Within this thesis, one of the greatest growth areas of recent years has been the development of mobile or wireless Telecommunication is explained.

This thesis also summarizes what is known-and what remains unknown-about whether Mobil Phones can pose a hazard to health, and what can be done to minimize any potential risk.

The first chapter introduces an overview about Mobile Phone, benefit of mobile telecommunication Technology, GSM, Base Station, advantages of digital services and what happen when we call.

Chapter two represents the Mobile Cellular telecommunication system, limitation of conventional System, History of 800 MHz, Basic and types of Cellular system., Operation of Cellular system and finally it discussed the Cellular system in and out United States.

Chapter three is devoted to the Radio Frequency fields from Mobile phone, Radio Frequency Radiation usage, Electric and Magnetic fields intensities, fields from base station Antenna and fields penetration into the body-dosimetery.

Chapter four explain the effect of Electromagnetic Radiation on Human Health, sources of EM Radiation ,Effect of low and high frequency radiation. It also represent the information about uses of Mobile Phone by Consumers and methods of reducing the effect of EM on human health .It include also , definition of some technical words used in this thesis.

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CHAPTER 1

AN OVERVIEW OF MOBILE TELEPHONE SYSTEM

1.1 Introduction

Mobile phones are low power radio devices that transmit and receive microwave radiation at frequencies of about 900 Megahertz (MHz) and 1800 MHz .The first land mobile services were introduced into the UK in the 1940s, but the significant Expansion of services offered to the general public, including the introduction of mobile phones, began in the mid-1980s and rapidly attract a small but significant number of subscribers. Developments in the early 1990s, such as the introduction of digital networks and the Entry of additional services provides into the market, fuelled further increase in the numbers of subscribers.

It is now predicted that within a few years around half the population of the UK will be routinely using mobile telecommunication and that is will become the dominate technology for telephony and other applications such as Internet access. This wide use of a relatively new technology raises the question of weather there are many implications for human health, there are conflicting reports relating to possible adverse health effects and these have Understandably led to some concern. The minister telecommunication in a competitive environment for public Health recognized the importance of this issue and following consultation with the minister at the Department of Trade and Industry, decided to seek the advice of an independent group as to the safety of mobile telecommunication technology.

The Global System for Mobile Communication (GSM) and Code Division Multiple Access (CDMA) systems are digital mobile phone services consisting of base-station antennas, which communicate with the mobile phone via radio frequency (RF) transmission. In turn the base-station antenna is connected to the wired telephone system directly or via a further RF communication link.

The analogue mobile phone system is often referred to as cellular telephone technology because the regions being covered are broken up into cells each of which has their own localized service provided by a base station antenna. Currently the network includes both digital system is due to be closed down by the year 2000 and will be replaced by CDMA. This discussion will be limited to the digital system.

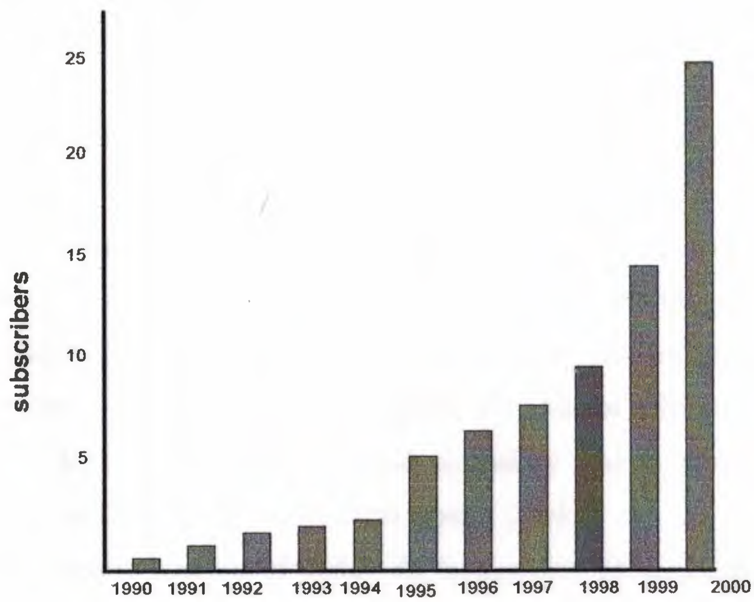

Figure 1.1 Growth in mobile phone subscribers in the UK between 1990 and 2000(based On data from Federation of Electronics Industry, FEI).

It presents the wide picture of mobile telecommunications on the general public, and recognizes the contribution of mobile telecommunications to the quality of life and to the UK economy. It considers the underlying and the characteristics of the RF fields generated by present and near future 3-5 years handsets and base stations, with particular reference to the magnitude of the fields.

It provides an appraisal of the experimental and theoretical work that has been carried out which has a bearing on human health, and makes a number of recommendations to Government. Background to the introduction of Mobile Telecommunication in the UK telecommunication system was initially developed and operated as a part of the general Post Office (GPO). In 1981, this situation changed with the passing of British Telecommunication Act, which effectively separated the telecommunication and postal businesses of the GPO, and led to the creation of British Telecom (BT). The next stage in the telecommunication development was a creation of a competitive marketplace governed by a new regulatory body, the Office of Telecommunication (OFTEL), which was established in 1984. These changes paved the way for the introduction of cellular telecommunications in a competitive environment.

In the UK, the new GSM networks become operational in July 1992(vodafone), September 1993(One 2 One), December 1993 (Cell net), and April 1994 (orange) the companies involved being referred on this report as a network operators. The original analogue networks are still operational, but the Government has indicated that analogue system should be removed from service by 2005.

However, in the late 1980s, there was a move to develop standards for a second generation of mobile telecommunication throughout Europe in order to provide seamless services for subscribers. This was achieved with the development and employment and deployment of a new operating standard called the Global System for Mobile Telecommunication (GSM), which employs digital technology and is now the operating system for 340 networks in 137 countries as shown in figure 1.2 below.

Although this system is now used worldwide, the European geographical area is still the dominant user, with more subscribers than any other region. It has, however, been widely accepted in other areas such as the Asia Pacific region.

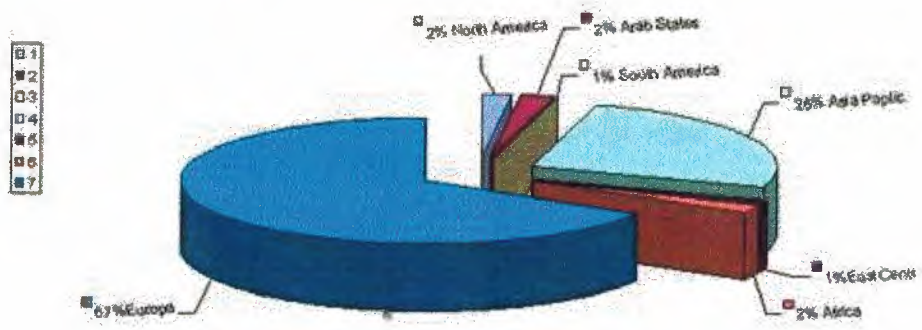

Figure 1.2 Distribution of GSM subscribers by geographical location (based on data from the GSM Association)

In Italy tow companies were granted operating license, Telecom Securicor Cellular Radio Limited (Cell net) and subsidiary of Racal Electronics P/C (Vodafone). In January 1985. Both these companies launched national networks based on analogue technology.

On a worldwide scale, there has been a rapid growth in both the numbers of countries with operational networks and the number of mobile phone operators as shown in figure 1.3. There are further 39 networks under construction for the GSM system alone

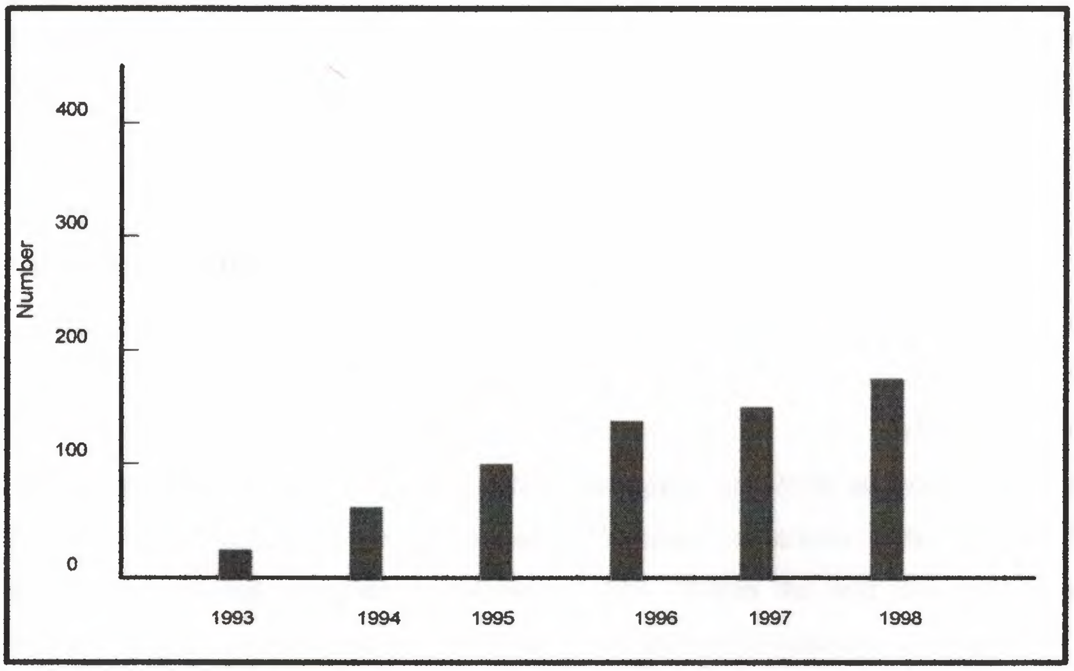

Figure 1.3 Growth of GSM networks throughout the world (based on data from the GSM association).

1.2 Mobile Phone Networks and Communication

Individual mobile phones operate by communication with fixed installation called base stations. These have a limited range and mobile phone operators have to establish national base station networks to achieve wide coverage. It takes many years to establish a network that will provide both complete coverage and adequate capacity across the country and, even today, none of the UK networks provides complete coverage. However, since operators invest a great deal of money to purchase licenses and establish networks and other infrastructure, they need to offer potential subscribers an effective communication system as quickly as possible. Moreover, operators were required, as a condition of there operating licenses, to provide a minimum level of coverage within a given time frame.

They established operational networks designed to allow most subscribers to access abase station most of the time. The initial phase of construction of such a network involves the installation of base station in urban areas with high population densities and along major transport routes as motorways these basic networks are then extended to provide coverage in more rural areas and increased capacity in urban areas. By developing networks in this way, operators can offer a functional system to the majority of the population. The more rural areas of the UK, particularly in the west of the country, still have rather poor coverage.

1.3 Present and Future Use of Mobile Phones

Initial market penetration by mobile phones was modest, with less than 1% of the UK population subscribing by the end of the 1980s. However, the advent of the more advanced GSM technology, in conjunction with greater competition in the market place, led to continuing growth in the number of subscribers throughout the 1990s as shown below in the Fig 1.4. At the present there are approximately 25 million subscribers in the UK, which is equivalent to a market penetration of around 40%. Within the next five years it is expected that this will have increased to 75% market penetration or 45 million subscribers.

At present it is estimated that around 45% of subscribers have a pre-paid mobile phone. Although it might be expected that many of these phones would not be used on a routine basis, the operators believe that around 90% of them are in regular use.

Within the next three years the "Third Generation" of mobile phone will be launched. This will employ a new operated standard called the Universal Mobile Telecommunication System (UMTS) and will enable operators to offer a full range of multimedia services. The introduction of these new services will required access to additional RF spectrum, (based on data from Mobile Tele branches) and the UK Government has recently auctioned licenses for the use of new spectrum. Five licenses are to be issued.

The growth in the mobile phone market that has been observed in the UK reflects similar trends in Europe and elsewhere in the world. In Europe the greatest market penetration has occurred in the Scandinavian countries and in Finland is approaching 60%. However, all Western European countries have experienced a rapid growth in mobile phone use in recent years Figure 1.4.

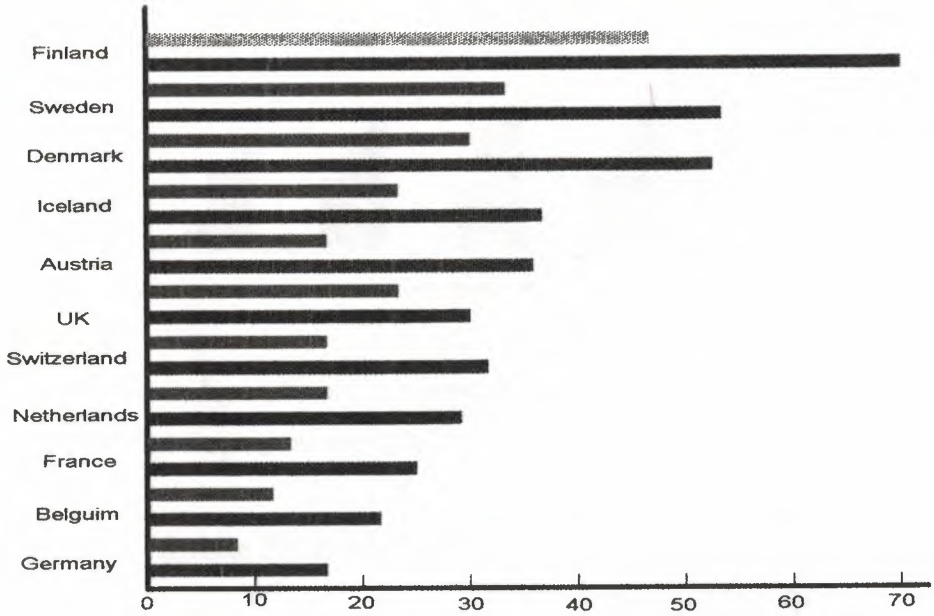

Figure 1.4 Increase in market penetration between 1996 and 1998 in European countries.

It is expected that the recent trends in the use of mobile phone technology will continue for the foreseeable future, with the number of GSM subscribers worldwide predicted to increase by a factor of three or more over the next five years (Figure 1.5).

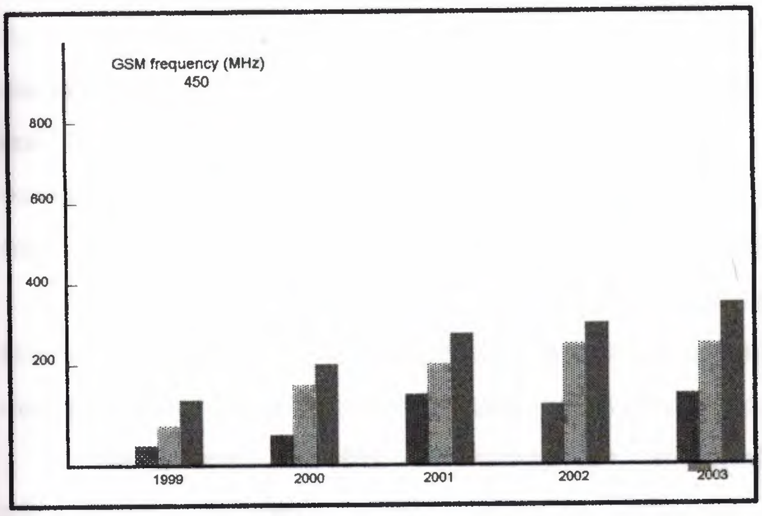

Figure 1.5 Predicted growths in the number of GSM subscribers worldwide. The different (GSM frequencies are used in different systems around the world).

1.4 Benefits of Mobile Telecommunications Technology

An active mobile telecommunications sector brings a number of economic benefits to the UK in terms of employment and tax revenue, There are also, however, a number of other advantages to be derived from application of this technology- Mobile telecommunications play an increasingly important role in general commercial activity arid thereby make an indirect contribution to the national economy. This is difficult to quantify, but is likely to be significant.

It is already apparent that mobile telecommunications also offer benefits in emergency situations. For example, the use of a mobile phone may reduce the time taken to notify the emergency services of road traffic accidents and other dangerous situations including crimes. An assessment of this aspect in Australia has recently been given by Chapman and School field (1998a,b) There have also been several accounts of individuals using mobile phones to alert rescue services following mountaineering or skiing accidents.
Mobile phone available may also be helpful during much rare large-scale emergencies. For example it is believed tat many lives were saved following the earthquake in Robe, Japan. Because those tapped under rubble wore able to use their mobile phones in alert rescue teams a few large multinationals. Although none of these is based in tile UK. Three of

them, Nokia, Motorola and Ericsson, all have a significant presence through both manufacturing and research and development (R&D) facilities Nokia and Ericsson bought out UK companies in the early 1990s and both have since expanded their operations. Other manufacturing companies that have invested in the UK include Lucent, NEC, Panasonic and Samsung. This is a rapidly changing sector and the above figures are indicative only.

The manufacturing base generates secondary manufacturing by companies such as Hewlett Packard and Racal, both of which make test equipment In addition; there is some manufacturing of components by companies such as Flirting Ltd.

The latest available information on manufacturing turnover values the telecommunications sector at £3.5 billion in 1997, but it is growing rapidly. Mobile telecommunications represent a significant and increasing element of this sector.

The UK provides significant input into mobile telecommunications R&D through universities and their spin-off companies. A consortium of UK universities has formed a Virtual Center of Excellence in this area to provide a focus for this work and ensure effective collaboration with industry. Funding for this virtual Center from industry and the Engineering and Physical Sciences Research Council totaled £3 million for the last three years and the budget for the next three is £4.5 million with industry providing 70%.

The mobile sector provides significant employment opportunities in the UK. It is difficult to obtain accurate data because the sector is developing so rapidly. However, taken together, the operators, manufacturers, and sales outlets probably employ about 100,000 people in the UK (industry estimate). This number seems likely to increase when mobile phones become more closely linked to the provision of Internet services.

1.5 GSM and how it is used by mobile telephony?

There are analogue and digital mobile telephony systems. GSM is the standard for digital mobile telephony systems. GSM stands for Global System for Mobile Communication. Analogue systems transmit the voice signal directly while digital systems convert the signals into numerical values for transmission; a digital mobile telephony system offers considerable advantages over the analogue system:

-Digital data are not sensitive to interference, similarly to data on music CD. Transmission errors can be conceded amid the reception quality is better.

-GSM is an international standard. This is why (JSM mobile phones can be used
In many countries throughout the world.

-GSM mobile phones can be connected to computers. This means that when we are on the move with your laptop you can still send and receive faxes and e-mail messages.

Systems using the TACS standard have largely, although not entirely, been replaced by the European digital phone standard, GSM, the acronym for Global System for Mobil Communications (Peterson and Anderson, 1999; Steele and Hanzo, 1999), and mostly operate in either the 900 MHz or 1800 MHz band. This standard is now widely used in ninny pails of the world. The digital processing uses phase modulation that again results in only very small and essentially random changes in the amplitude of the carrier wave.

In the GSM system, each user requires a frequency channel of bandwidth 200 km so there is a maximum of 174 channels (175 minus one needed for technical reasons) within the 35 MHz bandwidth of the 900 MHz band and 374 within the 75MHz width of the 1800 MHz band available for allocation to network operators. The channels are distributed across the cells in a way that allows neigh boring cells to operate at different frequencies to avoid interference Cells are very often divided into three 120 sectors with different frequencies for each. These considerations limit the number of frequency channels available to users in a particular sector. Since the wavelengths at 900 MHz are twice as long as those at 1800 MHz, they are better at reaching the shielded regions behind buildings, etc as a result of diffraction (bending). So, to obtain the seine coverage, fewer base stations and hence fewer channels are needed at 900 MHz than at 1800 MHz. One 2 one and orange were in fact allocated 150 channels within the 1800 MHz band, and BT Cell net and Voda phone were allocated 113 channels within the 900 and 1800 MHz bands.

To increase the number of users that can communicate with a base station at the same time, a technique called Time Division Multiple Access (TDMA) is employed that allows each channel to be used by eight phones. This is achieved by compressing each 4.6 ms chunk of information to be transmitted into a burst or pulse 0.58 ms long (1 ms or millisecond is a thousandth of a second). So the phones and base stations transmit for 0.58 ms, every 4.6 ins, which results in a 217 Hz pulse modulation or variation in their output (217 Hz = ¼.6s). For technical reasons, there is, in fact, additional data Compression which leads to the phones and base stations transmitting 25 pulses hut omitting every 26Th., and so on. This produces thither pulse modulation of the power output at the lower frequency of 8.34 Hz (= 217 Hz/26). There is, however, no detectable amplitude modulation at the frequency of 271 kHz (every 4 micro second) at which the individual digits (zeros or ones) are transmitted since, this leads to a negligible change in amplitude.

The maximum powers that GSM mobile phones are permitted to transmit by the present standards are 2W (900 Hz) and 1 W (1800 Hz) - However, because TDMA is used, the average powers transmitted by a phone are never more than one-eighth of these maximum values (0.25 W and 0.125 W, respectively) and are usually further reduced by a significant amount due to the effects of adaptive power control and discontinuous transmission Adaptive power control (APC) means that the phone continually adjusts the power It transmits to the minimum needed for the base station to receiveacleaial. Although the power is likely to be appreciably marathon this in most situations. Discontinuous transmission (DIX) refers to the fact at the power is switched off when a user stops speaking either because he/she is listening or because neither user is speaking. So if each person in a conversation is speaking for about half the time, he/she is only exposed to fields from the phone for that half of the conversation. In summary, the largest output. From a phone occurs if it is mainly used at large distances from the base station or shielded by buildings, etc. In this situation, the peak powers could approach the values of2 W (900 Hz) and 1 W (1800 Hz) and the average powers could approach the values of 0.25 W (900Hz) and 0.125 W (1800 Hz).

Mobile telephony networks are designed to manage with extremely low transmission powers. For those with a special interest in technology we will explain how it is possible to place calls throughout the country and even throughout Europe using digital mobile telephony (GSM) despite the low transmitting power of antennas and mobile telephones. It is important to realize that the antennas of mobile phone transmitting stations do not simply broadcast in all directions, Instead they transmit only in one specific direction and within a specific angle of aperture. The waves are bundled; this reduces the necessary antenna power. The waves are of the same shape and are not sent in pulses. It's not a matter of "pulsed" beams as is often maintained.

1.6 Mobile Phone Base Stations

The mobile station (MS) consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to subscribed services irrespective of a specific terminal. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services.

The use of radio waves to carry information is an integral part of modern life and there are many different types of radio transmitter in the environment. These include the broadcast transmitters used for radio and television, the radio equipment used by the emergency services, mobile telephones and their associated base stations.

Mobile telephone base stations are low power radio transmitters with antennas mounted on either freestanding towers or on buildings. Radio signals are fed through cables to the antennas and then launched as radio waves into the area, or cell, around the base station. Two types of antennas are used for the transmissions; pole-shaped antennas are used to communicate with mobile telephones and dish antennas communicate to other base stations and link the network together.

There is a consensus among national and international expert bodies concerned with radiation protection that exposure guidelines for the protection of people should be based on sound scientific evidence relating to established effects on human health. Recommended limits on exposure to radio waves (including radio frequency and microwave radiation) in the United Kingdom and elsewhere are based on restricting whole and partial body heating. NRPB has published guidelines[1-3] advising restrictions on the rate at which energy is absorbed in the body. Compliance with the guidelines will ensure that temperature rises are sufficiently small not to be harmful.

The transmissions from any particular base station are variable and dependent upon the number of calls and the number of transmitters in operation. In general, the following points are relevant to the exposure of people to radio waves emitted by base stations.

1- The antennas are the sources of the radiated signals and operate at power levels consistent with their aim of communicating over short distances. Typical power levels are not more than a few tens of watts.

2- The power is radiated in conical fan-shaped beams, which are essentially directed towards the horizon with a slight downward tilt so the radio wave levels below the antennas and at the base of the towers will be considerably below exposure guideline levels.

3- Level at distances of greater than beams from the antennas spread out with distance and will be incident at ground few tens of meters from the antennas. The radio wave levels at these distances are much reduced from those directly in front of the antennas and will be below exposure guidelines levels.

4- Experience with typical installations has shown that there may be regions within a few meters, directly in front of the antennas, where radio wave levels can exceed UK exposure guideline levels.

When measurements are made of radio wave signal strengths at a given location, it is possible to detect the signals from many different radio transmitters, and all will contribute to a person's total exposure. NRPB measurements have shown that signals from less obvious, or more distant, transmitters can sometimes exceed exposures produced by a visually more prominent transmitter such as a mobile telephone base station. Nevertheless, at locations to which the public normally has access around base stations, the exposure from all radio sources combined is usually very many times below exposure guideline levels.

Base stations and mobile phones communicate in the frequency band around 1800 MHz. depending on the utilization load. One to a maximum of six closely adjoining frequencies is used. The radio link antennas transmit in frequency bands around 23 GHz and 38GHz, a lot of people have heard of 'pulsed' laser beams. Light, which is intensively bundled in this way, can be used for incredibly precise surgery, for example, on the human eye. The idea of 'pulsed' beams is therefore often associated with the hazards, which can arise from accidental exposure to such laser beams. But in the field of mobile telephony this term does not have any harmful meaning. Nevertheless as soon as pulsed beams are mentioned in connection with mobile phones a lot of people see something unpleasant to be afraid of. They imagine something like a pneumatic hammer assaulting tiny pinpricks, or us, which put holes in us without us noticing and causing us permanent damage. There are two points to remember about these pulsed beams.

First: a mobile telephone may transmit in so-called pulsed operation. It transmits during a time interval of (0.577 milliseconds) after which it goes 'silent' for seven time intervals before it transmits again. The fact that a short-pulsed transmission period is used for the phone link means that several subscribers can use the same frequency simultaneously. Second: the base stations send out electromagnetic waves of a constant strength. For these carrier waves to be able to carry signals the intensity (amplitude) of the waves is subjected to a very low amount of modification (modulation) at fixed time intervals (0.577 ms). This change in intensity is small in comparison to the intensity of the carrier wave. This is why although these amplitude-modulated waves can be referred to as 'pulsed' waves they are still not fundamentally any different from non-pulsed continuous waves, The relationship between the carrier wave and the additional signal can be clarified by the following image: a moving wave (our carrier wave) on the ocean is very powerful in comparison to the tiny wave (our signal) caused by us dropping our pebble into it.

The radio signals are received and sent via antennas Radio link antennas connect tire base stations together; other antennas provide the contact between base stations and the mobile phones located in a cell. The individual cells are divided into sections. Its own antenna, the so-called sector antenna, covers each of the sections, Radio link antennas and sector antennas calm bundle their signals. In this way less power is required for transmission.

1.6.1 Location of Base Stations

The location of base stations and the processes by which they are authorized appear to be the aspects of mobile phone technology that generate most public concert. Public telecommunications operators have been granted a number of rights similar to those enjoyed by gas, water and electricity companies. These include permitted development rights, which allow them to carry out certain developments, including the erection of masts less than 15 m high, without the need to make a full planning application. (A more detailed description of the current planning situation with respect to telecommunications is given in assessing the potential impact of a planned base station on health, the current approach in he UK is to determine whether it might cause exposures in excess of NRPB guidelines If this can be ruled out satisfactorily, risks to health are not considered further.

This approach is not optimal since it does not allow adequately for the uncertainties in scientific knowledge. Although it seems highly unlikely that the low levels of RE radiation from base stations would have significant, direct adverse effects on health, the possibility of harm from exposures insufficient to cause important heating of tissues cannot yet be ruled out with confidence, Furthermore, the anxieties that some people feel when this uncertainty is ignored can in themselves affect their well being.

Other aspects of the planning process for base stations are also unsatisfactory. Some citizens feel that the siting of base stations, and particularly of masts, can result in a loss of amenity and possibility a reduction in the value of property, and it is clear that, in the face of this threat, many feel excluded and disembowelled by the planning system now m operation. The resultant frustration also has negative effects on people's health and well being.

We conclude therefore, that changes to the regulation of base stations are necessary.

1.6.2 National register of base stations

The first requirement is for reliable and openly available information about the location and operating characteristics of all base stations. Easy access to such information would help to reduce mistrust among the public. Furthermore, the data would be useful when applications for new base stations were being considered, and night also be of value in epidemiological investigations.

A national database be set up by Government giving details of all base stations and their emissions. For each this should list: the name of the operating company; the grid reference; the height of the antenna above ground level; the date that transmission started; the frequency range and signal characteristics of transmission the transmitter power; and the maximum power output under the Wireless Telegraphy Act. Moreover, this information should be readily accessible by the public, and held in such a form that it would be easy to identify for example, all base stations within a defined geographical area, and all belonging to a specified operator

1.6.3 Exclusion zones

Although exposures to RF radiation from base stations well generally be well below exposure guidelines, the need remains to prevent access by workers or the public to places where the relevant guidelines might be exceeded. Therefore, we endorse the practice of defining clear exclusion zones around base stations.

The establishment of clearly defined physical exclusion zones around base station antennas, which delineate areas within which exposure guidelines may be exceeded. The incorporation of exclusion zones should be part of the template of planning protocols that we advocate.

A physical barrier should define each exclusion zone and a readily identifiable nationally agreed sign with a logo. This should inform the public and workers that inside the exclusion zone there might be RE emissions that exceed national guidelines. We recommend that the design of the logo should be taken forward by the British Standards Institute and implemented within 12 months.

The warning signs should be incorporated into micro cell and Pico cell transmitters to indicate that they should not be opened when in use.

1.6.4 Audit base stations

There is a need to ensure that base stations are operating within the parameters specified when they were approved.

An independent, random, ongoing audit of all base stations be carried out to ensure that exposure guidelines are not exceeded outside the marked exclusion zone and that the base stations comply with their agreed specifications. If base station emissions. Are found to exceed guideline levels, or there is significant departure from the stated characteristics, then the base station should be decommissioned until compliance is demonstrated. The particular attention should be paid initially to the auditing of base stations near to schools and other sensitive sites. The audit should include appropriate checks to ensure that base stations conform to the operational parameters specified when they were approved, end that exclusion zones are properly demarcated and signed.

1.6.5 Planning process

As described in the annex to this chapter, the erection of base stations for mobile phone networks is not subject to such stringent planning procedures as some other types of construction project. In particular, masts less than 15 m high can be built without the planning permission that would normally be required. The lack of public consultation is a major cause of grievance in people who suffer a loss of amenity when base stations are erected and we consider the current situation to be unacceptable.

For all base stations, including those with masts under 15 m, permitted development rights should be revoked, and that the sitting of all new base stations should be subject to the normal planning process. This planning process should also apply when a change to an existing base station will increase its power output.

At national Government level, a template of protocols be developed, in concert with industry and consumers, which can be used to inform the planning process and which must be assiduously and openly followed before permission is given for the sitting of a base station.

Consider that the protocol should cover the following points:

1-All telecommunications network operators must notify the local authority of the proposed installation of base stations. This should cover installations for macro cells, micro cells and Pico cells.

2- The local authority should maintain an up-to-date list of all such notifications, which should be readily available for public consultation.

3- The operator should provide to the local authority a statement for each site indicating its grid reference, the height of the antenna above ground level, the frequency and signal characteristics, and details of maximum power output.

4- Any change to an existing base station that increases its size, or the overall power radiated, should be subject to the normal planning process as if it were a new development.

A robust planning template is set in place within 12 months of the publication of this report. It should incorporate a requirement for public involvement, an input by health authorities/health boards and a clear and open system of documentation, which can be readily inspected by the general public.

In making decisions about the sitting of base stations, planning authorities should have power to ensure that the RE fields to which the public will be exposed pill be kept to the lowest practical levels that will be commensurate with the telecommunications system operating effectively.

1.7 Base Station Antennas

The mobile phone system has limitations, similar to the radio and television systems, in that the number of frequencies available restricts the number of handsets or users within each cell. To enable a large number of users, regions are divided up into cells each with its own set of frequencies (GSM system). Adjacent cells have different frequencies to prevent interference and power levels are kept to a minimum to ensure no interference with non-adjacent cells, which use the same frequency. The size of the cell varies depending on the number of users. In rural areas, which typically cover large regions due to the sparse population, more power has to be generated to cover the larger area. This can lead to higher radiation exposure.

The use of a large number of antennas to service a densely populated area does not necessarily equate with greater RF exposure. The number of frequencies available within a cell varies from one to twelve with each frequency able to accommodate up to eight different users.

Maximum power will be transmitted only when a frequency has all eight users operating at the same time. In figure 1.6 below the non-adjacent cells labelled A can use the same frequencies. Cells A and B share boundaries and so must use different frequencies.

In the CDMA system all cells use the same spectrum and transmitting a code, which repeats at constant time intervals, prevents interference. These time intervals vary from one base station to another and thus enable interference to be prevented. Transmitted power levels are kept to the minimum necessary to maintain good communications.

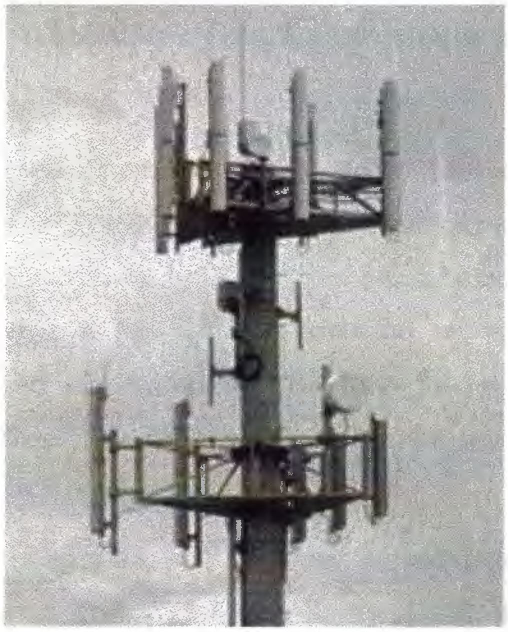

Figure 1.6 Base station antenna.

Antennas must be elevated and located clear of physical obstruction to ensure wide coverage and reduce the incidence of dead spots. The radiation from these antennas is beamed horizontally at the horizon with a slightly downward tilt, which causes the maximum exposure to occur at distances of about 100 meters. The picture shows two sets of three high gain sector antennas - two receive and one transmits - each set of three antennas would service a single cell. The power output from an antenna will vary depending on the number of people using the facility at a given time. A typical antenna will operate at about 60 Watts. Dead spots, due to shadows caused by obstructions such as tall buildings are covered by micro cells that have an antenna power output of about 1 Watt. A base station will usually cover three cells in an arrangement similar to those labelled 'B' in the diagram below. RF exposures from CDMA base stations will be less than those experienced from GSM installations.

The sitting Guidelines for base station antennas is described in Australian Standard (AS 3516.2-1998) titled Sitting of Radio communications Facilities: Part 2: Guidelines for Fixed, Mobile and Broadcasting Services Operating at Frequencies above 30 MHz. This

Standard deals with sitting which will minimize interference between other broadcasting facilities, electrical and telephone facilities and also includes environmental considerations. The sitting of mobile phone base stations is now subject to State and Territory planning laws as a result of the 1997 Telecommunications Act which came into operation on 1 July 1998.

Limitations on the RF power emitted by base station antennas are described in the Australian Standard AS/NZS 2772.1(INT) 1998 titled Radio frequency Radiation Part1: Maximum Exposure Levels - 100kHz to 300 GHz. This Standard expired on 30 April 1999 when the interim period ended: it has not been extended or replaced. The Australian Communications Authority used this Standard as the basis for regulating exposure under section 162 of the Act. These Standards are available for purchase from Standards Australia.

Base station can be categorized into merciless, microcells and piccolos depending on their size and power output. There are approximately 20,000 merciless in the UK at present and, in general, all the major operators can now offer coverage to over 97% of the population. The number of merciless is continuing to rise as operators seek to complete their geographical coverage and improve capacity. Since

Each base station can only handle a limited number of connection at any one time, operators need to install more base station units in densely populated areas to cope with increasing demand, it seems likely that these will mainly be micro cells and piccolos. The overall number of base station is likely to double within the next few years.

1.7.1 Antenna transmission

Both sector antennas and radio link antennas bundle the waves they transmit, sending them in just one specific direction or at one specific angle. This means the waves can be sent only where they are actually required. Less power is therefore
Required for transmission.

Sector antennas only transmit within a horn-shaped aperture of 65 degree or 50 degree. Outside this angle the transmitting power of the antenna immediately drops by more than half below, above amid behind the antenna the power will actually be as little as less than one hundredth of the power in the angle of aperture. This value is considerably below the permitted limit values. Radio link antennas bundle the transmitted waves to an extraordinary degree. They can thus transmit to the next antenna in linear fashion and virtually without scatter,

1.7.2 The maximum transmitting power of the antennas

Sector antennas have a maximum power output of only 21 watts. They do however release their bundled power in the direction of a foresight (or main beam). This is the beam, which is transmitted in the shape of an acoustic bin. This bundling allows the sector antenna to achieve a range and transmission power, which an omni directional dipole antenna could only manage by transmitting at 710 watts. The high effective transmitting power of the sector antenna is not even exhausted. However, even when it does transmit at full power in the direction of the foresight, the delivered power remains below the limit value, provided a distance of more than 3 meters or so from the antenna is maintained. Nevertheless in the main transmission direction a distance of at least 30 meters it observed from sites where people tend to spend any time, Radio link antennas have an output power of *0.03* W (at a transmission frequency of 23 GHz) and 0.04 W (at 38 GHz). This low transmitting power depends entirely on the exceptional degree of bundling of the transmitted waves these bundling enables radio link antennas to achieve an effective output, *which* would correspond to as much as 1000 W with an omni directional dipole antenna. It should however be noted that this effective power only applies to the zone linking the transmitting point and the receiving point. The antennas do not release any undirected enemy to the environment.

1.8 Batteries

Properly used batteries make a big difference in the amount of time you can talk or standby to receive calls. When your phone battery is dead, you're out of touch. There are three kinds of rechargeable batteries that are popular for portable and micro-portable phones: Nickel-cadmium (NiCd) commonly called NiCad, Nickel-metal hydride (NiMH). And Lithium-ion.

1.8.1 Nickel-cadmium batteries.

NiCad rechargeable batteries are the, least expensive. If properly handled they last for 300 to 500 charge discharge cycles to 80% of rated capacity.

If not, they can get a problem called "memory affect". Unless a NiCad battery is fully discharged before recharging, it loses its ability to filly discharge while maintaining full voltage. You can prevent NiCad memory by fully discharging before recharging, then filly recharging the battery before you use it again. You can recover from memory affected by turning on your phone and leaving it on standby until the batteries are fully discharged. NiCad batteries, which seem to be fully discharged usually, recover some additional charge if left off for a period of time. You can more fully discharge your batteries by letting them rest after they stop working, and then turn your phone back on and let it discharge again. Do this until there is absolutely nothing left; Recharge your batteries for about 24 hours before use. If you do this five or six time, you will be amazed at the results, if this doesn't work, then your batteries need replacing or you have some other problem.

1.8.2 Nickel-metal hydride batteries

Nickel-metal hydride batteries do not suffer from memory. They generally carry more charge for the same weight giving them a 30 to 40% longer run-time per cycle. You don't have to *recharges as often. You can also charge any time you want, even just a few* minutes, without reducing the battery's performance. These will last for more charge cycles than NiCads. The main disadvantage is the cost.

1.8.3 Lithium-ion batteries

Lithium-ion batteries are the newest in the cellular telephone battery world. They are the latest technology and can endure a tremendous number of cycles. A lithium-ion battery can last for up to 1000 charge cycles or more. They are also Lightweight for the amount of power they can store. You have to pay more for the batteries arid more for the phone to use them, not all phone manufacturers offer these, and they are not available for all models. Overall they are great if you can afford them

1.9 Advantages of a digital service

The most promising advancement in cellular service is the change from today's analogue communications to digital services; the many advantages include clearer conversations, new data and messaging services, and greater security from eavesdroppers.

Clearer conversations are the result of the elimination of extraneous noise or hiss that is common with analogue systems. In addition, digital communications are clear even with diminishing signal strength. That means hat communications through the modem become clear. Now you can hook up to a data service like MLS and have cellular modems with a PCMCIA card.

New data and messaging services include text messaging, caller ID, and battery conservation; Text messaging automatically transmits messages to your cell phone, similar to two-way paging. With Caller ID, you can decide whether to pick up the phone or leave it to voice mail, Battery conservation works by haying the phone broadcast its position to the nearby cellular network for only a few milliseconds out of every second instead of continuously. That will increase stand-by battery time dramatically. Greater security from eavesdroppers occurs because digital frequencies are much harder to pick up with a scanner.

1.10 What happens when I call?

When you turn on your cell phone it continuously sends digital information to the transceivers, telling them where you are and that you are ready to receive a call or send one, The information sent is called the electronic serial number (ESN) and the Mobile Identification Number (MIN). The former is a unique serial number programmed into the cellular phone by the manufacturer, The MIN is a code given by the cellular provider to identify the caller.

One of the most common Points of cellular telephone fraud is "cloning" the electronic serial number (ESN). According to the Cellular Telecommunications Industry Association, the cellular industry lost $482 million in 1994 to fraud, One way the ESN is cloned is by capturing the ESN-MIN with a device called an FSN reader, The captured ESN-Man is then reprogrammed into a computer chip of another cellular telephone. Digital cellular telephones provide more security against cloning because scanners do not as readily pick up digital frequencies.

All the transceivers have a set-up channel that handles these data signals. The Mobile Telephone Switching Office (MTSO) analyses the ESN-MIN. signal strength coming from your phone, which is the computerized centre that all the cells are connected to, the location of your phone is stored in the Home Location Register, and it is updated when necessary.

So when you call someone's cell phone, not all cells look for the phone. Only one does, if the network can't find the phone at first, then it will try the other locations. Pretty smart, when you are receiving a call or placing one, the cell assigns a voice channel on a discrete frequency to you. Then you just talk like normal.

So what happens if you are driving and you have to switch cells? This 'handing off' between cells is pretty tricky to explain, so 191 take it step by step.

1. The MTSO's computer is continuously monitoring the voice signal strength of all the cells.
2. Each nearby cell site monitors your voice signal with a scanning receiver,
3. If the strength at the cell you are using drops below a certain level, the cell sends a "hand-off" signal to the phone through the voice channel. This signal tells the phone what frequency to change to.
4. The new cell picks up the new frequency. All this takes 150 to 400 milliseconds,
5. What's even cooler is that if the signal gets too strong, the cell tells the phone to cut back on output power. Using 6 unidirectional antennas spaced 60 degrees apart on a cell, the network can tell exactly where you are using computers.

With more efficient systems such as digital networks, the loads that the cells can carry will increase as well as the quality of service.

CHAPTER 2

MOBILE CELLULAR TELECOMMUNICATION SYSTEM

2.1 Features of mobile cellular system

Cellular is one of the fastest growing and most demanding telecommunications applications. Today, it represents a continuously increasing percentage of all new telephone subscriptions around the world. Currently there are more than 45 million cellular subscribers worldwide, and nearly 50 percent of those subscribers are located in the United States. It is forecasted that cellular systems using a digital technology will become the universal method of telecommunications. By the year 2005, forecasters predict that there will be more than 100 million cellular subscribers worldwide. It has even been estimated that some countries may have more mobile phones than fixed phones by the year 2000.

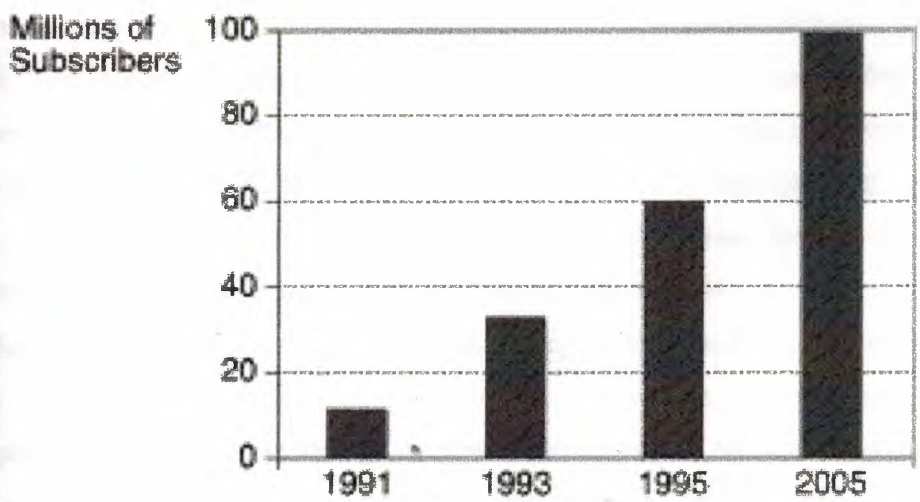

Figure 2.1 Cellular Subscriber Growth Worldwide

The concept of cellular service is the use of low-power transmitters where frequencies can be reused within a geographic area. The idea of cell-based mobile radio service was formulated in the United States at Bell Labs in the early 1970s. However, the Nordic countries were the first to introduce cellular services for commercial use with the introduction of the Nordic Mobile Telephone (NMT) in 1981.

Cellular systems began in the United States with the release of the advanced mobile phone service (AMPS) system in 1983. Asia, Latin America, and Oceanic countries adopted the AMPS standard, creating the largest potential market in the world for cellular.

In the early 1980s, most mobile telephone systems were analogue rather than digital, like today's newer systems. One challenge facing analogue systems was the inability to handle the growing capacity needs in a cost-efficient manner. As a result, digital technology

2.1.1 Limitations of conventional mobile telephone systems

Developing a cellular mobile telephone system and deploying it in many cities was intended because of the operational limitations of conventional mobile telephone systems: limited service capability, poor service performance, and inefficient frequency spectrum utilization.

1-Limited service capability: A conventional mobile telephone system is usually designed by selecting one or more channels from a specific frequency allocation for use in autonomous geographic zones as shown in Fig.2.2. The communications coverage area of each zone is normally planned to be as large as possible, which means that the transmitted power should be as high as the federal specification allows. The user who starts a call in one zone has to reinitiate the call when moving into a new zone (see Fig. 2.2) because the call will be dropped. This is an undesirable radiotelephone system since there is no guarantee that a call can be completed without a handoff capability.

The handoff is process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the conversation cart is continued in *a* new frequency zone without redialling. Another disadvantage of the conventional system is that the number of active users is limited to the number of channels assigned to particular frequency zone

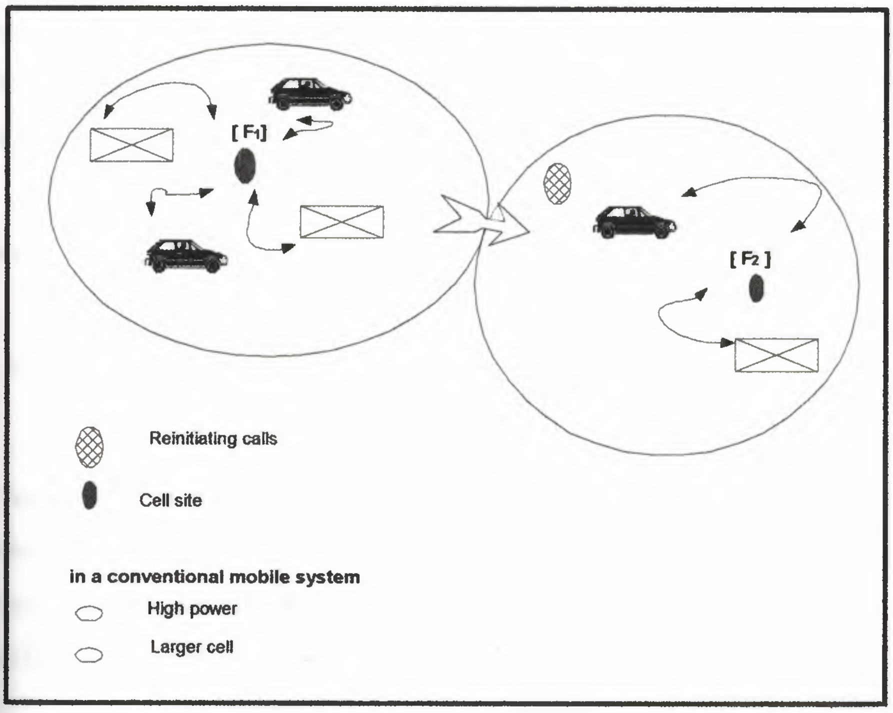

Figure 2.2 conventional mobile systems

2-Poor service performance. In the past, a total of 33 channels were allocated to three mobile telephone systems: Mobile Telephone Service (MTS), Improved Mobile Telephone Service (IMTS) MJ systems, and Improved Mobile Telephone Service (IMTS) MK systems. MTS operates around 40 MHz and MI operates at 150 MHz both provide 11 channels; IMTS MX operates at 450 MHz and provides 12 channels. These 33 channels must cover an area 50-ml in diameter. In 1976, New York City bad 6 channels of MJ serving 320 customers, with another 2400 customers on a waiting list.

New York City also had 6 channels of MK string 225 customers, with another 1300 customers on a waiting list. The large number of subscribers created a high blocking Probability during busy hours. The actual number of blocking will be shown later. Although service performance was undesirable, the demand was still great. A high-capacity system for mobile telephones was needed.

3- **Inefficient frequency spectrum utilization**: In a conventional mobile telephone system, the frequency utilization measurement Mo is defined as the maximum number of customers that could be served by one channel at the busy hour. Eq. (2.1-I) gives the 1976 New York City data cited earlier.

$$M_o = \text{No of Customer/Channel} \qquad (2.1\text{-}2)$$

Or

$M_o =$ → 53 customer/channel (MJ system)
→ 37customer/channel (MJ system)

Assume an average calling time of 1.76 mm and apply the Erlang B model (lost-calls - cleared conditions). Calculate the blocking probability as follows: Use 6 channels, with each channel serving the two different numbers of customers shown in Eq. (2.1-1) The offered load can then be obtained by Esq. (2.1-2)

$$A = \frac{\text{Av. calling time (min)} \times \text{total consumer}}{60 \text{ min}} \text{ erlang s} \qquad (2.1\text{-}2)$$

$$A_1 = \frac{1.7 \times 33 \times 6}{60} = 9.33 \text{ erlangs} \quad \text{(MJ system)} \qquad (2.1\text{-}3)$$

$$A_1 = \frac{1.7 \times 37 \times 6}{60} = 6.51 \text{ erlangs} \quad \text{(Mk system)} \qquad (2.1\text{-}4)$$

Given that the number of channels is 6 and the offered loads axe A1= 9.33 and A_{2}= 6.51, read from the table in Appendix 2.1 to obtain the blocking probabilities B_1= 50 percent (MJ system) *and* B_2 =*30* percent (MK system), respectively. It is likely that half the initiating calls will be blocked in the MJ system, a very high blocking probability. If the actual average calling time is greater than 1.76 min, the blocking probability *can be* even higher. To reduce the blocking probability, we must decrease the value of the frequency spectrum utilization measurement Mo. as shown in Eq. (2.l-l). As far as the frequency spectrum utilization is concerned, the conventional system does not utilize the spectrum efficiently since each channel can only serve one customer at a time in a whole area. A new cellular system that measures the frequency spectrum utilization different from Eq. (2.1-1) and proves to be efficient is discussed in sec. (2.1-2).

2.1.2 Spectrum efficiency considerations

A major problem facing the radio communication industry is the limitation of the available radio frequency spectrum. In setting allocation Policy the federal Communications Commission (FCC) seeks systems, which need minimal bandwidth but provide high usage and consumer satisfaction .The ideal mobile telephone system would operate within a limited assigned frequency band and would serve an almost unlimited number of users in unlimited areas.

Three major approaches to achieve the ideal are:

1. Single-sideboard (SSB), which divides the allocated frequency band into maximum numbers of channels
2. Cellular, which reuses the allocated frequency band in different geographic locations
3. Spread spectrum, frequency-hopped, which generates many codes over a wide frequency band

2.1.3 Technology, feasibility and service affordability

In 1971, the computer industry entered a new era. Microprocessors and minicomputers are now used for controlling many complicated features and functions with less power and size than was previously possible. Large-scale integrated (LST) circuit technology reduced the size of mobile transceivers so that they easily fit into the standard automobile. These achievements were a few of the requirements for developing advanced mobile phone systems and encouraging engineers to pursue this direction.

Another factor was the price reduction of the mobile telephone unit. LSJ technology and mass production contribute to reduce cost so that in the near future art average-income family should be able to afford a mobile telephone unit.

On Jan. 4, 1979, the FCC authorized Illinois Bell Telephone Co. (IBT) to conduct a developmental cellular system in the Chicago area and make a limited commercial offering of its cellular service to the public. In addition, American radiotelephony Services, Inc., (ARTS) was authorized to operate a cellular system in the Washington, D.C. -Baltimore, Md., and area. These first systems showed the technological feasibility and affordability of cellular service.

2.1.4 History of 800-MHz Spectrum Allocation

The FCC's decision to choose 800 MHz was made because of severe spectrum *limitations at lower frequency bands. FM broadcasting services operate in the vicinity of* 100 MHz. The television broadcasting service starts at 41 MHz and extends up to 960 MHz.

Air-to-ground systems use '15 to 136 MHz; military aircraft use 225 to 4410 MHz. The maritime mobile service is located in the vicinity of 160 MHz. Also fixed station services are allocated portions of the 30-to 100-MHz band. Therefore, it was hard for the FCC to allocate a spectrum in the lower portions of the 30- to 400-MHZ band since the services of this band had become so crowded. On the other hand. Mobile radio transmission cannot be applied at 100 MHz or above because severe propagation path loss, multi path fading, and rain activity make the medium improper for mobile communications.

Fortunately, 800 MHz was originally assigned to educational TV channels. Cable TV service became a big factor in the mid-70s and shared the load of providing TV channels Th_5 situation opened up the 800-MHZ band to some extent, and the FCC allocated a 40 MHz system at 800 MHz to mobile radio cellular systems.

Although 800 MHz is not the ideal transmission medium for mobile radio, it has been demonstrated that a cellular mobile radio system that does not go beyond this frequency band can be deployed. Needless to say, the medium of transmitting an 800-MHz signal, although it is workable, is already very difficult.

In 1958, the Bell System (FCC Docket 11997) proposed a 75-MHz system at 800 MHz, quite a broadband proposal. In 1970, the FCC (Docket 18262) tentatively decided to allocate 75 MHz for a wire-line common carrier 1st December 1971 the Bell System assured technical feasibility by showing how a cellular mobile system could be designed. In 1974, the FCC allocated 40 MHz of the spectrum, with one cellular system to be licensed per market. There was considerable uncertainty in predicting the cellular market. However, the FCC strategically placed spectrum reserves totalling 20 MHz in proximity to the cellular allocation. In 1980, the FCC reconsidered its one-system-per market strategy and studied the possibility of introducing competition into the previous one-carrier markets. Although cost savings make one cellular system per market attractive, balancing the benefits of economies of scale against the benefits of competition, two licensed carriers per service area was more in line With emerging FCC policies.

Trunking efficiency degradation using two corners per service area will be discussed in Sec. 2.4. It was the FCC's view that such an approach, while not gaining the foil competitive market structure, would provide some competitive advantages. The frequencies will be assigned in 20-MHz groups identified as block A and block If, or called band A and band B.

Table 2.1 Mobile and basic transmission frequency

Band	Mobile	Base	Two systems/market
A	824-235,845,846.5	869-880,890-891.5	Non-wire-line
B	835-845,846.5,849	880-890,891.5-894	Wire- line

Two bands serve two different groups in the standard situation: one for wire-line (telephone) companies and one for non-wire-line (non-telephone) companies. Each company designs its own system and divides the area into geographic areas, or cells. Earth cell operates within its own bands (see table 2.1) since 30 kHz ate specified bandwidth; each band operating nowadays consists of 333 channels. How to utilize test limited resources to provide adequate voice quality and service performance to an unrestricted population size presents a challenge.

2.2 Types of Cellular Phones

2.2.1 Mobile phones -in your car

-Permanently installed in the vehicle.

-A full 3 watts of power and an outside antenna provides the best possible reception.

-Standby and talk times are unlimited because the phone is powered from the cars battery.

- Great for people who need to use their phone only in their car.

2.2.2 Transportable phone - in or out of your car

-Semi-permanent vehicle installation or portable capability.

-Phone has its own battery, which is usually large arid heavy.

-Full 3 watt models that car be connected to an outside antenna will provide the best possible reception.

-Used by people who need the best transmission when away from their car or who frequently travel in a fringe area.

2.2.3 Portable Phones - in your hand or on your hip

-Designed for portable use but can be adapted for automobile use

-Powered from a rechargeable battery

-Can be charged at home with an overnight charger or in the car with a vehicle power adapter

-Six tenths of a watt of power is enough in most areas

-Used by people who want the freedom to use their phone out of their car and don't want to carry a heavy bag phone

2.2.4 Micro portable Phones - in your pocket

-Same as a portable but even smaller

-Usually purchased by a business user who will to take fill advantage of the features.

-Some of these units provide battery times comparable to portables, but at a lot less weight and size

- These are the most convenient and some of the most popular phones on the market today as welcomed. The advantages of digital systems over analogue systems include ease of signalling, lower levels of interference, integration of transmission and switching, and increased ability to meet capacity demands. *Table 1* charts the worldwide development of mobile telephone systems.

2.3 Trucking Efficiency

To explore the trucking efficiency degradation inherent in licensing two or more earners rather than one compares the trucking efficiency between one cellular systems per market operating 666 channels and two cellular systems per market each operating 333 channels. Assume that all frequency channels are evenly divided into seven Subaru's called cells. In each cell, the blocking probability of 0.02 is assumed. Also the average calling time is assumed to are 1.76 min Look up the table of Appendix 2.1 with N1= 666/7=95 and B = 0.02 to obtain the offered load A1= 83.1 and with N_2= 333/7=47.5 and B = 0.02 to obtain A_2 = 38. Since two carriers each operating 333 Channels are considered, the total offered load is $2A_2$. We then realize that.

$$A_1 >= 2A_2 \qquad (2.3\text{-}1)$$

By converting Eq. (2.3-1) to the number of users who can be served in a busy hour, the average calling time of 1.76mm is introduced. The number of calls per hour served in a cell can be expressed as

$$Q_i = \frac{A \times 60}{1.76} \qquad = 8.5\% \qquad (2.3\text{-}2)$$

Qi = 2832.95 calls/h (1carrier/market)

11295.45 2 = 2590.9 calls/h (2 carriers/market)

The trounking efficiency derogation factor can be calculated as.

2832.95 -2590.9

$$\eta = \frac{\qquad\qquad}{2832.95} = 8.5\% \qquad (2.3\text{-}3)$$

For a blocking probability of 2 percent. Figure 2.3 shows η by comparing one earner per market with more than one earner per market situations with different blocking probability conditions. The degradation of trunking efficiency decreases as the blocking probability increase. As the number of carriers per market increases the degradation increases However, when a high percentage of blocking probability, say more than 20 percent, occurs, the performance of one carrier per market is already so poor that further degradation becomes insignificant as Fig- 2.3 shows.

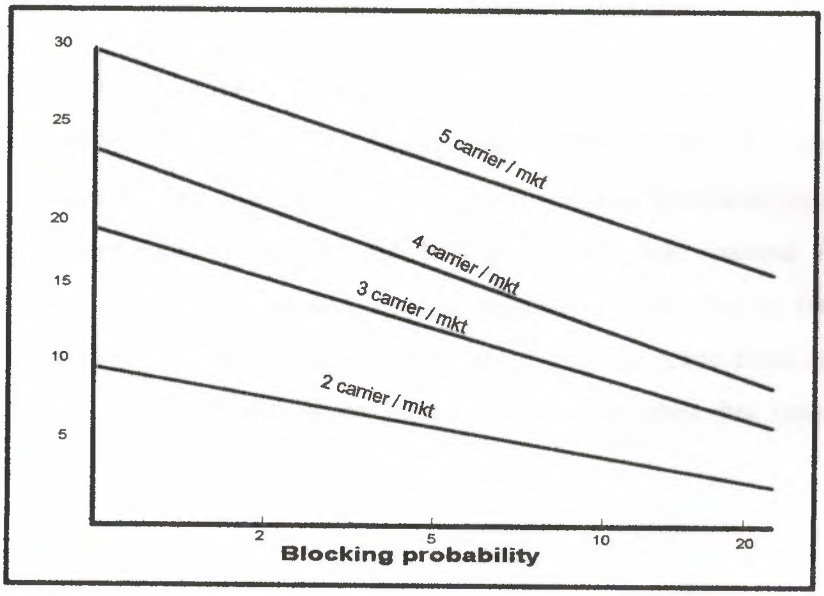

Figure 2.3 Degradation of trucking efficiency-comparing one carrier/market and than-one-carrier/market

For a 2 percent blocking probability trunking efficiency of one carrier per market does show a greater advantage when compared to other scenarios.

2.4 A Basic Cellular System

A basic cellular system consists of three parts: a mobile unit, a cell site, and a mobile telephone switching office (MTSO), as figure (2.4) shows with connections to link the three subsystems.

1. **Mobile unit**. A mobile telephone unit contains a control unit, transceiver, and an antenna system.

2. **Cell site** The cell site provides interface between the MTSO and the mobile units. It has a control unit, radio cabinets, antennas, power plant, and data terminals.

3. **MTSO**. The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. I interface with telephone company zone offices; controls call processing, and handles billing activities.
4. **Connections.** The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link But the channel is not fixed; it can be any one in the entire band assigned by the serving area, with each site having multi channel capabilities that connect simultaneously to many mobile units.

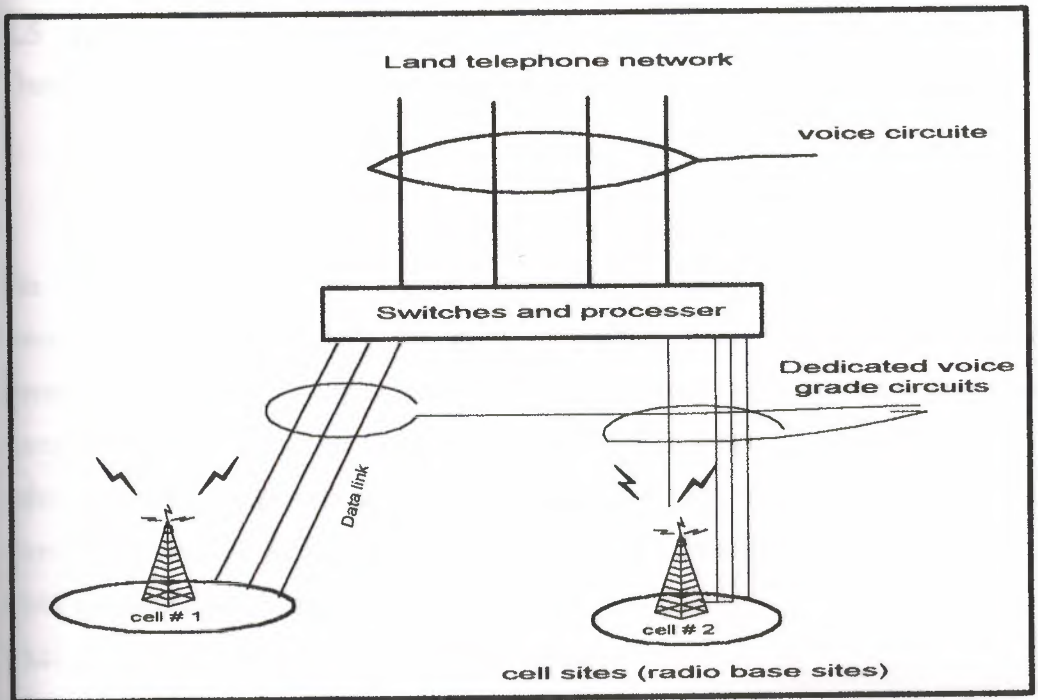

Figure 2.4 A basic Cellular System

The MTSO is the heart of the cellular mobile system. Its processor provides central coordination and cellular administration.

The cellular switch, which can be either analogue or digital, switches calls to connect mobile subscribers to other mobile subscribers and to the nationwide telephone network. It uses voice trunks similar to telephone company interoffice voice trunks. It also contains data links providing supervision irks between the processor and the switch and between the cell sites and the processor. The radio link carries the voice and signalling between the mobile unit and the cell site. The high-speed data links cannot be transmitted over the standard telephone trunks and therefore must use either microwave links or T-carriers (wire lines). Microwave radio links or T-carriers carry both voice and data between the cell site and the MTSO.

2.5 Performance Criteria

There are three categories for specifying performance criteria.

2.5.1 Voice quality

Voice quality is very hard to judge without subjective tests from users' Opinions. In this technical area engineers cannot decide how to build a system without knowing the voice quality that will satisfy the users. In military communications the situation differs: armed forces personnel must use the assigned equipment. For any given commercial communications system, the voice quality will be based upon the following criterion: a set value x at which y percent of customers rate the system voice quality (from transmitter to receiver) as good or excellent, the top two circuit merits of the five listed below.

CM5 excellent (speech perfectly understandable)

CM4 good (speech easily understandable some noise)

(DM3 fair (speech understandable with a slight effort, occasion repetitions needed)

(DM2 poor (speech understandable only with considerable effort, frequent repetition needed)

CMI unusable (speech not understandable)

As the percentage of customers choosing CM4 and CM5 increases, the cost of building the system rises.

2.5.2 Service quality

Three items are required for service quality.

1. **Coverage.** The system should serve an area as large as possible. With radio coverage. However, because of irregular terrain configurations, it is usually not practical to cover 100 percent of the area for two reasons:

a. The transmitted power would have to be very high to illuminate weak spots with sufficient reception, a significant added cost factor.

b. The higher the transmitted power, the harder it becomes to control interference. Therefore, systems usually try to cover *90* percent of an area in flat terrain and *75* percent of an area in hilly terrain. The combined voice quality and coverage criteria m AMPS cellular systems state that 75 percent of users rate the voice quality between good and excellent in 90 percent of the sewed area, which is generally fiat terrain. The voice quality and coverage criteria would be adjusted as per decided various terrain conditions In hilly terrain, 90 percent of users must rate voice quality good or excellent in 75 percent of the served area. A system operator can lower the percentage values stated above for a low-performance and low-cost system.

2. Required grade of service. For a normal start-up system the grade of service is specified for a blocking probability of -02 for initiating calls at the busy hour. This is an average value. However, the blocking probability at each cell site will be different. At the busy hour, near freeways, automobile traffic is usually hea4y so the blocking probability at certain cell sites may be higher than percent, especially when car accidents occur. To decrease the blocking probability requires a good system plan and a sufficient number of radio channels.

3. Number of dropped calls. During Q calls in an hour, if a call is dropped and Q 1 calls are completed, then the call drop rate is 1K). This drop rate must be kept low. A high drop rate could be caused by either coverage or handoff problems related to inadequate channel availability.

2.5.3 Special features

A system would like to provide as many special features as possible, such as call forwarding, call waiting, voice stored (VSR) box, automatic roaming, or navigation services. However, sometimes the customers may not be willing to pay extra charges for these special services.

2.6 Uniqueness of Mobile Radio Environment

2.6.1 Description of mobile radio transmission medium

The propagation attenuation. In general, the propagation path loss increases not only with frequency hut also with distance. If the antenna height at the cell site is 30 to 100 in and at the mobile unit about 3 m, and the distance between the cell site and the mobile unit is usually 2 km or more, then the incident angles of both the direct wave and the reflected wave are very small, as figure (2.5) shows the incident angle of the direct wave is Or, and the incident angle of the reflected wave $\theta_2 . \theta_1$, is also called the elevation angle. The propagation path loss would be 40 dB/dec., where "dec." is an abbreviation of decade, i.e., a period of 10. This means that a 40-dB loss at a signal receiver will be observed by the mobile unite as it moves from Ito 10km Therefore C is inversely proportional R^4.

$$C\alpha R^4 = C\alpha R^{-4} \qquad (2.6\text{-}1)$$

Where

C= received carrier power

R= distance measured from the transmitter to the receiver.

α = Constant

The difference in power reception at two different distances RI and *R2* will result in

there is an equation here

And the decibel expression of Eq. (2.6-2) is

$$\Delta C \text{ (in dB)} = C_2 - C_1 \text{ (in dB)} \qquad (2.6\text{-}2)$$

$$= 10 \log \frac{C_2}{C_1} = 40 \log \frac{R_1}{R_2} \qquad (2.6\text{-}2b)$$

When $R_2 = 2R_1$ =-12dB; when $R_2 = 10R_1$, ΔC =-40dB (2.6-3)

This 40 dB/dec. is the general rule for the mobile radio environment and easy to remember and to compare to flee-space propagation rule of 20 dB/dec. The linear and decibel scale expressions are

$$C\ \alpha R^{-2} \quad \text{(free space)} \qquad (2.6\text{-}3a)$$

$$\Delta C = C_2(indB) - C_1(indB)$$

$$=20 \log \frac{R_1}{R_2} \qquad (2.6\text{-}3b)$$

In real mobile radio environment the propagation path-loss slope varies as.

$$\mathbf{C\alpha R^{-\gamma}} = \alpha \mathbf{R}^{-\gamma} \qquad (2.6\text{-}4)$$

γ Usually lies between 2 and S depending on the actual condition of course γ cannot be lower than 2,which is the free-space condition. The decibel scale expression of Eq. (2.6-4) is

$$C = 10 \log \alpha - 10 \gamma \log R \text{ dB} \qquad (2.6\text{-}5)$$

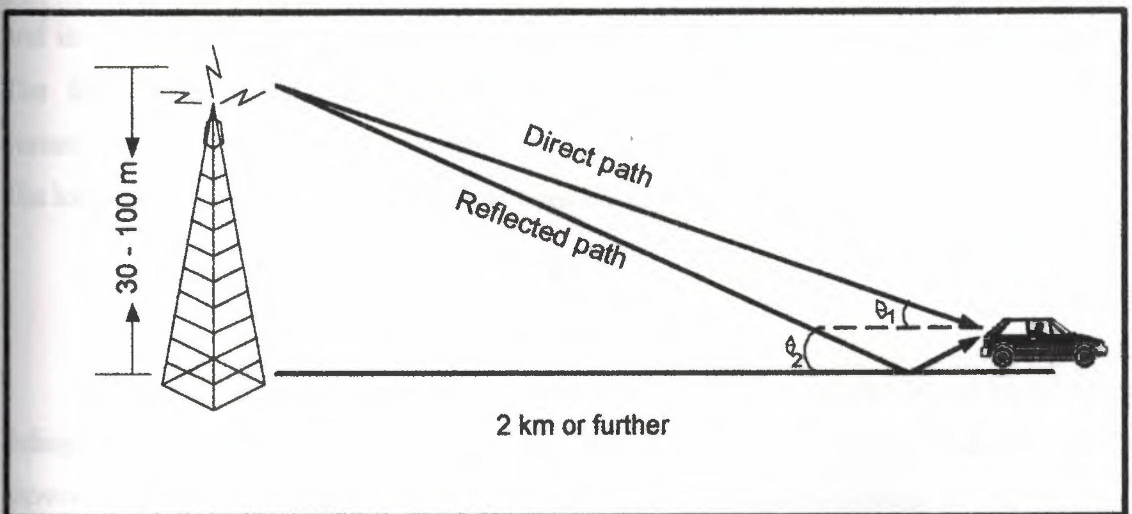

Figure 2.5 Mobile radio transmission model

Severe fading. Since the antenna height of the mobile unit is lower than its typical surroundings, and the carrier frequency wavelength is much less than the sizes of the surrounding structures multi path waves are generated. At the mobile unit, the sum of the multi path waves causes a signal-fading phenomenon. The signal fluctuates in a range of about 40 dB (10 dB above and 30dB below the average signal). We can visualize the nulls of the fluctuation at the baseboard at about every half wavelength in space, but all nulls do not occur at the same level, as If the mobile unit moves fast, the rate of fluctuation is fast. For instance, at *850 MHz*, the wavelength is roughly 0.35 m (1 ft). If the speed of the mobile unit is 24km/h (15 mi./h) or 6.7 m/s, the rate of fluctuation of the signal reception at a 10-dB level below the average power of a fading signal is 15 nulls per second.

2.6.2 Model of transmission medium

A mobile radio signal r (t), illustrated in figure 2.6, can be artificially characterized by two-component m (t) arid ro (t) based on natural physical phenomena,

$$r(t) = m(t)\, r_0(t) \qquad (2.6\text{-}6)$$

The component m (t) is called local mean, long-term fading, or log-normal fading and its variation is due to the terrain contour between the base station and the mobile unit. The factor r_0 is called multi path fading, short-term fading, or Raleigh fading and its variation is due to the waves reflected from the surrounding buildings and other structures. The long-term fading m (t) can be obtained from Eq. (2.6-7a).

$$m(t_1) = \frac{1}{2T} \int_{T-T_1}^{t_1+T} T - T_1 r(t)dt \qquad (2.6\text{-}7a)$$

Where 2T is the time interval for averaging r (t). T can be determined based on the fading rate of r (t), usually 40 to 80 fades. Therefore, m **(t) is** the envelope of r (t). As shown in figure 2.6a. Equation (2.6-ia) also can be expressed in spatial scale as

$$m(X_1) = \frac{1}{2L} \int_{X_1-L}^{X_1+L} r(X)dt \qquad (2.6\text{-}7b)$$

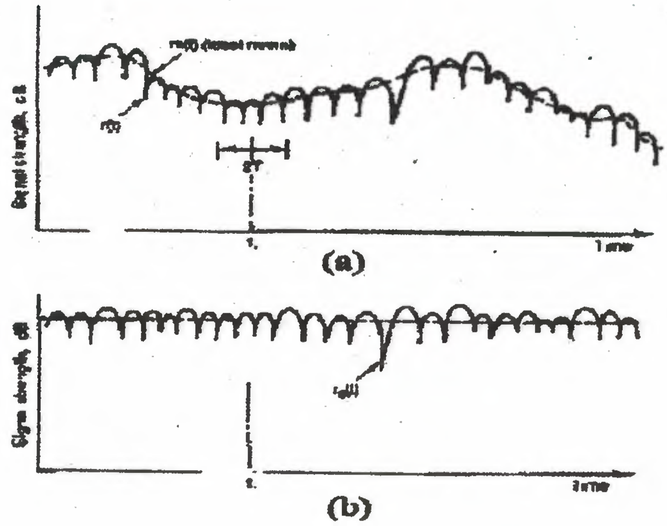

Figure 2.6 a mobile signal fading representation. (a) A mobile signal fading. (b) A short-term signal fading.

The length of 2L has been determined to be 20 to 40 wavelengths. Using 36 or up to 50 samples in an interval of 40 wavelengths is an adequate averaging process for obtaining the local means. The factor m (t) or m (x) is also found to be a lognormal distribution based on its characteristics caused by the terrain contour. The short-term fading r_0 is obtained by

$$r_0 \text{ (in dB)} = r(t) - m(t)\text{dB} \qquad (2.6\text{-}8)$$

As shown in figure 2.6b. The factor ro (t) follows a Raleigh distribution, assuming that only reflected waves from local surroundings are the ones received (a normal situation for the mobile radio environment). Therefore, the tern, Raleigh fading is often used.

2.6.3 Mobile fading characteristics

Raleigh fading is also called multi path fading in the mobile radio environment. When this multi path waves bounces back and forth due to the buildings and houses, they form many standing-wave pairs in Space, as shown in figure 2.7. Those standing-wave pairs are summed together and become an irregular wave-fading structure. When a mobile unit is standing still, its receiver only receives signal strength at that spot, so a constant signal is observed. When the mobile unit is moving, the fading structure of the wave m the space is received. It is a multi path fading. The recorded fading becomes fast as the vehicle moves faster.

-The radius of the active scattered region.

The mobile radio multi bath fading shown in Fig. 2.6 explains the fading mechanism. The radius of the active scattered region at *850* MHz can be obtained indirectly. The radius is roughly 100 wavelengths. The active scattered region always moves with the mobile unit as its centre, it means that some houses were inactive scatters and became active as the mobile unit approached them; some houses were active scatters and became inactive as the mobile unit drove away from them.

-Standing waves expressed in a linear scale and a log scale.

We first introduce a sine wave in log scale

$$y = 10 \, \text{Cos} \, \beta x \, \text{dB} \qquad (2.6.9)$$

A log plot of the sine wave of Eq. (2.6-9) is shown, figures 2.8b the linear expression of Eq. (2.6-9) then is shown in figure 2.8a the symmetrical waveform

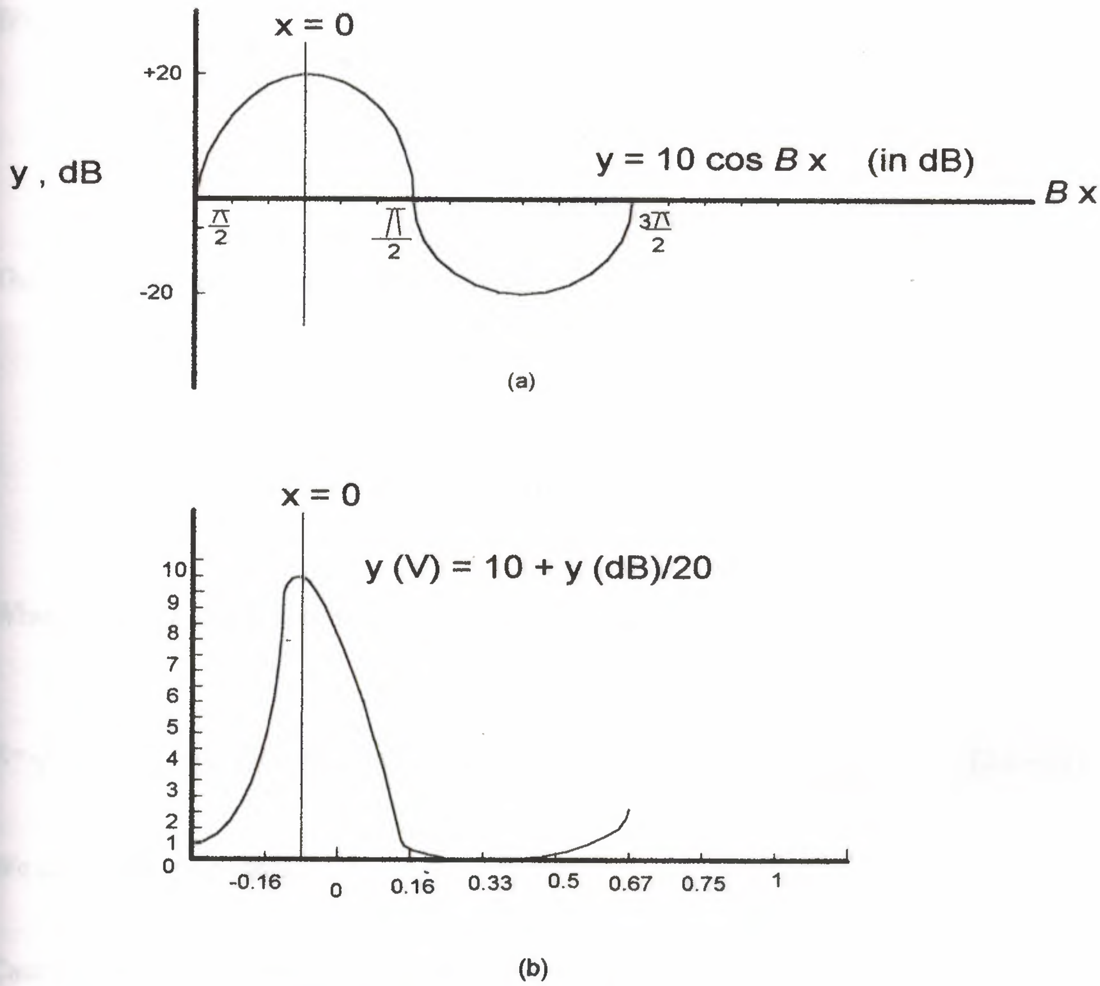

Figure 2.7 The linear plot and the log plot of a sine wave. (a) In linear scale;(b) in Log scale.

In a log plot becomes an unsymmetrical waveform when plotted on a linear scale. It shows that the sine wave waveform in a log scale becomes a completely different waveform when expressed on a linear scale and vice versa. Two sine waves, the incident wave ravelling along the x-axis (travelling to the left) and the reflected wave ravelling in the opposite direction, can be expressed a

$$e_0 = E_0 \, e^{j(\omega t + \beta x)} \qquad (2.6\text{-}10)$$

$$e_1 = E_1 \, e^{j(\omega t - \beta x + \delta)} \qquad (2.6\text{-}11)$$

Where

ω = Angular frequency

β =Wave number = $(2\pi/\lambda)$

δ = Time-phase lead e_1 with respect to e_0 at x= 0

The two waves from standing —wave pattern

$$e = e_0 + e_1 = R\cos(\omega t - \delta) \tag{2.6-12}$$

$$\text{Standing wave ratio (SWR)}=\frac{E_0 + E_1}{E_0 + E_1} = \infty$$

Where the amplitude R becomes

$$R=\sqrt{(E_0 + E_1)^2 \cos^2 \beta X + (E_0 - E_1)^2 su\ ^2 \beta X} \tag{2.6-13}$$

We are plotting two cases.

Case I. Eo = 1, E_1 = 1, that is, reflecting coefficient =1,

And

$$R= 2\cos \beta x \tag{2.6-14}$$

Case 2. Eo = l, E_1 = 0.5; that is the reflection coefficient = 0.5. SWR = 3, and

$$R = \sqrt{\ } (1.5)^2 \cos^2 \beta X + (0.5)^2 \sin^2 \beta X \tag{2.6-15}$$

-Delay spread and coherence bandwidth

Delay spread. In the mobile radio environment, as a result of the multi path reflection phenomenon, the signal transmitted from a cell site and arriving at a mobile unit will be from different paths, and since each path has a different path length, he time of arrival for each path is different. For an impulse transmitted at the cell site by the time this impulse is received at the mobile unit it is no longer an impulse but rather a pulse with a spread width that we call the delay spread. The measured data indicate that the mean delay spreads are different in different kinds of environment.

Table 2.1: Mean delay spread

Type of environment	Delay spreads
Open area	<0.2
Suburban area	0.5
Urbane area	3

Coherent bandwidth. The coherence bandwidth is the defined bandwidth in which either the amplitudes or the phases of two received signals have a high degree of similarity. The delay spread is a natural phenomenon, and the coherence bandwidth is a defined creation related to the delay spread.

A coherence bandwidth for two fading amplitudes of two received signals is A coherence bandwidth for two random phases of two received signals is

$$B_C = \frac{1}{4\Delta\pi}$$

A coherence bandwidth for two random phases of two received signals is

$$B'_C = \frac{1}{4\Delta\pi}$$

2.6.4 Direct wave path, line-of-sight path, and obstructive path

A direct wave path is a path clear from the terrain contour. The line-of-sight path is a path clear from buildings. In the mobile radio environment, we do not always have a line-of-sight condition.

When a line-of-sight condition occurs, the average received signal at the mobile unit at a 1-mi intercept is higher, although the 40-dB/ Dec. path-loss slopes remain the same. In this case the short-term fading is observed to be a richen fading. II results from a strong

Line-of-sight path and a ground-reflected wave combined, plus many weak building-reflected waves.

When an out-of-sight condition is reached, the 40-dIE/dec path-loss slope still remains. However, all reflected waves, including ground-reflected waves and building-reflected waves, become dominant. The short-term received signal at the mobile unit observes a Raleigh fading. The Raleigh fading is the most severe fading. When the teOrrain contour blocks the direct wave path, we call it the obstructive path.

2.6.5 Noise level in cellular frequency Band

The thermal noise kTB at a temperature T of 290 K (17C) and a bandwidths B of 30 kHz is —129 dBm Assume that the received front-end noise is 9dB, and then the noise level is — 120 dBm. Now there are two kinds of man-made noise, the ignition noise generated by the vehicles and the noise generated by 800-MHz emissions.

-The ignition noise. In the past, 800 MHz was not widely used. Therefore, the manmade noise at 800 MHz is merely generated by the vehicle ignition noise. The automotive noise introduced at 800 MHz with a bandwidth of 30 kHz can be deduced.

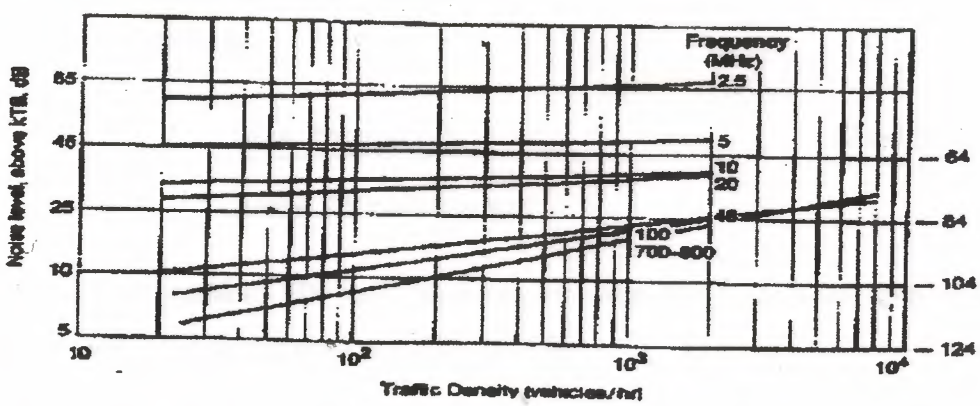

Figure 2.8 average automotive-traffic-noise powers for various traffic densities and frequencies. Detector noise bandwidth 30 kHz at room temperature (17C)

-The – 800- MHz emission noise. As a result of the cellular mobile systems operating in all the major cities in the United States and The spurious energy generated outside each channel bandwidth, the early noise data measurements are no longer valid. The 800-MHz-emission noise can be measured at au idle channel (a forward voice channel) in the 870- to

890-MHz region while the mobile receiver is operating on a car battery in a no-traffic spot in a city. In this case, no automotive ignition noise is involved, and no cochineal operation is in the proximity of the idle-channel receiver. We found that in some areas the noise level is 2 to 3 dB higher than- 120 dB m at the cell sites and 3 to 4 dB higher than -120dBm at the mobile stations.

2.6.6 Amplifier noise

An amplifier will amplify a mobile radio signal received by a receiving antenna, Either at the cell site or at the mobile unit. We would like to understand how the signal is affected by the amplifier noise. Assume that the amplifier has an available power gain g and the available noise power at the output is N_0. The input signal-to-noise (S/N) ratio is P, /N4 the output signal-to-noise ratio is Ps/Ni. and the internal amplifier noise is Ni.

Then the output Ps/Ni becomes.

$$\frac{P_O}{N_O} = \frac{gP_S}{g(N_I) + N_a} = \frac{P_{SO}}{N_i + \left(N\alpha / g\right)} \qquad (2.6\text{-}16)$$

The noise figure F is defined as

$$F = \frac{\text{Max. Possible } S/N \text{ ratio}}{\text{Actual } S/N \text{ ratio at output}} \qquad (2.6\text{-}17)$$

Where the maximum possible SIN ratio is measured when the load is an open circuit. Equation can be used for obtaining the noise of the amplifier.

$$F = \frac{P_S / KTB}{P_O / N_O} = \frac{N_O}{\left(P_O / P_S\right) KTB} = \frac{N_O}{g(kTB)} \qquad (2.6\text{-}18)$$

Substituting in Eq. (2.6-16) In Eq. (1.6-18) yields

$$F=\frac{P_S/KTB}{P_S/[N_S+(N_\alpha/g)]}=\frac{N_I+(N\alpha/g)}{kTB} \qquad (2.6\text{-}19)$$

The term kTB is the thermal noise as described in Sec. 2.65. The noise figure is a reference measurement between a minimum noise level due to thermal noise and the noise level generated by both the external and internal noise of an amplifier.

2.7 Operation of Cellular Systems

This section briefly describes the operation of the cellular mobile system from a customer's perception without touching out the design parameters .The operation Can be divided into four parts and a handoff procedure.

-Mobile unit initialisation. When a user sitting in a car activates the receiver of the mobile unit, the receiver scans 21 set-up channels, which are designated among the 333 channels. It then selects the strongest and locks on for a certain time. Since each site is assigned a different set-up channel, locking onto the strongest set-up channel usually means selecting the nearest cell site. This self-location scheme is used in the idle stage and is user-independent. It has it great advantage because it eliminates the load on the transmission at the cell site for locating the mobile unit. The disadvantage of the self-location scheme is that no location information of idle mobile units appears at each cell site. Therefore, when the call initiates from the landline to a mobile unit, the paging process is longer. Since a large percentage of calls originate at the mobile unit the use of self-location schemes is justified. After 60 s, the self-location procedure is repeated. In the future, when landline originated calls increase, a feature called "registration" can be used.

-Mobile originated call. The user places the called number into an originating register in the mobile unit, checks to see that the number is correct, and pushes the "send" button. A request for service is sent on a selected set-up channel obtained from a self-location scheme. The cell site receives it, and in directional cell sites selects the best erective antenna for the voice channel to use. At the same time the cell site sends a request to the mobile telephone switching office (MTSO) via a high-speed data link.

The MTSO selects an appropriate Voice channel for the call, and the cell site acts on it through the best directive antenna to link the mobile unit, The MTSO also connects the wire-line patty through the telephone company zone office.

-Network originated call. A landline party dials a mobile unit number. The telephone company zone office recognizes that the number is mobile and forwards the call to the MTSO. The MTSO sends a paging message to certain cell sires based on the mobile unit number and the search algorithm. Each cell site transmits the page on its own set up channel. The mobile unit recognizes its own identification on a strong set-up channel, locks onto it, and responds to the cell site. The mobile unit also follows the instruction to tune to an assigned voice channel and initiate user alert.

-Call termination. When the mobile user tins off the transmitter a particular signal (signalling tone) transmits to the cell site, and both sides free the voice channel. The mobile unit resumes monitoring pages through the strongest set-up channel.

-Handoff procedure. During the call, two parties are on a voice channel. When the mobile unit moves out of the coverage area of a particular cell site, the reception becomes weak. The present cell site requests a handoff the system switches the call to a new frequency channel in a new cell site without either interrupting the call or alerting the user. The call continues as long as the user is talking. The user does not notice the handoff occurrences.

2.8 Marketing Image of Hexagonal-Shaped Cells

We have to realize that hexagonal-shaped communication cells are artificial and that such a shape cannot be generated in the real world. Engineers draw hexagonal-shaped cells on a layout to simplify the planning and design of a cellular system because it approaches a circular shape that is the ideal power coverage area. The circular shapes have overlapped areas, which make the drawing unclear. The hexagonal-shaped cells fit the planned area nicely, as shown in fig 2.8 with no gap and no overlap between the hexagonal cells.

A simple mechanism, which makes the cellular system implement-able, based on hexagonal cells, will be illustrated in later chapters. Otherwise, a statistical approach will be used in dealing with a real-world situation. Fortunately, the outcomes resulting from these two approaches are very close, yet the latter doesn't provide a clear physical picture, as shown later. Beside today these hexagonal-shaped cells has already become a widely promoted symbol for cellular mobile systems. The reader can, easily adapt an analysis using hexagonal cells if it is desired.

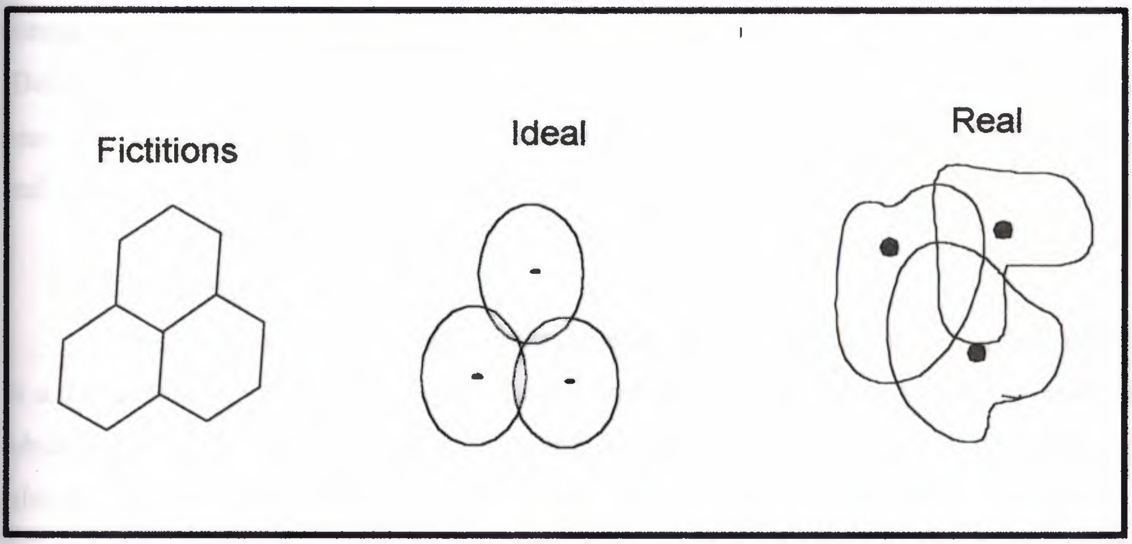

Figure 2.9 hexagonal cells and real shapes of their coverage's.

2.9 Planning a Cellular System

2.9.1 How to start planning?

Assume tat the construction permit for a cellular system in a particular market area is granted. The planning stage becomes critical. A great deal of money can be spent and yet poor service may be provided if we do not know how to create a good plan. First, we have to determine two elements: regulations and the market situation.

-Regulations. The federal regulations administered by the FCC are the same throughout the United States. The state regulations may be different from state to state, and each city and town may have its own building codes and zoning laws. Become familiar with the rules and regulations. Sometimes waives need to be applied for ahead of time. Be sure that the plan is workable.

-Market situation. There are three tasks to be handled by the marketing department.

-Prediction of gross income. We have to determine the population, average income, business types, and business zones so that the gross income can be predicted.

-Understanding competitors. We also need to know the competitor's situation overage, system performance, and number of customers. Any system should provide a unique and outstanding service to overcome the competition.

-Decision of geographic coverage. What general area should ultimately be covered? What near-term service can be provided in a limited area? These questions should be answered and the decisions passed on to the engineering department.

2.9.2 The engineer's role

1. The engineers follow the market decisions by initiating a cellular mobile service in a given area by creating a plan that uses a minimum number of cells sites to cover the whole area. It is easy for marketing to request but hard for the engineers to fulfil. We will address this topic later.

2. Checking the areas that marketing indicated were important revenue areas. The number of radios (number of voice channels) required to handle the traffic load at the busy hours should be determined.

3. Studying the interference problems, such as co channel and adjacent channel interference, and the inter modulation products generated at the cell sites, and finding ways to reduce them.

4. Studying the blocking probability of each call at each cell site, and trying to minimize it.

5. Planning to absorb more new customers. The rate at which new customers subscribe to a system can vary depending on the service charges, system performance. and seasons of the year. Engineering has to try to develop new technologies to utilize fully the limited spectrum assigned to the cellular system. The analysis of spectrum efficiency due to the natural limitations may lead to a request for a larger spectrum.

2.9.3 Finding solutions

Many practical designs tools, methods of reducing interference and ways of solving the blocking probability of call initiation will be introduced in this book.

2.10 Cellular Systems

2.10.1 Cellular systems in the United States

There are 150 major market areas in the United States where the FCC can grant licenses for cellular systems. Their populations into five groups have classified them. Each group has 30 cities.

1. Top 30 markets—very large cities

2. Top 31 to 60 markets—large-sized cities

3. Top 61 to so markets—medium-sized cities

4. Top 91 to 120 markets—below medium-sized cities

5. Top 121 to ISO markets—small-sized cities

2.10.2 Cellular systems outside the United States

Japan. Nippon Telegraph and Telephone Corporation (NTT) developed an 800-MHz land mobile telephone system and put it into service in the Tokyo area m 1979. The general system operation is similar to the AMPS system. It accesses approximately 40,000 subscribers in 500 cities. It covers 75 percent of all Japanese cities, 25 percent of inhabitable areas, and 60 percent of the population. In Japan, 9 automobile switching centres (ASC5), 51 mobile control stations (MCS5). 465 mobile base stations (MBS5), and 39,000 mobile subscriber stations (MSS5) were in operation as of February 1985.

The Japanese mobile telephone service network configuration is. In the metropolitan Tokyo area, about 30,000 subscribers are being served.

The 1985 system operated over a spectrum of 30 MHz. The total number of channels was 600, and the channel bandwidth was 25 kHz. This system comprised an automobile switching centre (ASC), a mobile control station (MCS), a mobile base station (MBS). And a mobile subscriber station (MSS). M present there is no competitive situation set up by the government. However, the Japanese Ministry of Post and Telecommunication (MPT) is considering providing a dual competitive situation similar to that in the United States.

United Kingdom. In June 1982 the government of the United Kingdom announced two were competing national cellular radio networks. The UK system is called TACS (Total Access Communications System). The total number of channels was 1000, with a channel bandwidth of 25 kHz per channel. Among them, 600 channels are assigned and 400 are reserved. Two competing cellular network operators, Cell net and Voda phone are operating in the United Kingdom. Each network system has only 300 spectral channels. The Cell net system started operating in January 1985. Cell net has over 200 cell sites, covering 82 percent of the United Kingdom. Videophone, though, which started operations late, has sensed the same areas as Cell net.

Canadian system. In 1978, a system called AURORA was designed for the Alberta government telephone (AGT). The system provides province wide mobile telephone service at 400 MHz. Ongoing developmental works on the AURORA is underway at 800 MHz.

Nordic system. This system was built mostly by Scandinavian coin-tries (Denmark, Norway, Sweden, and Finland) in cooperation with Saudi Arabia and Spain and is called the NMT network. It is currently a 450-MHz system, but an 800-MHz system will be implemented soon since the frequency-transparent concept as the AURORA 800 system is used to convert the 450-MHz system to the 800-MHz system. The total bandwidth is 10 MHz, which has 200 channels pith a bandwidth of 25 kHz per channel. This system does have handoff and roaming capabilities. It also uses repeaters the

European cellular systems. All the present generation of European cellular networks is totally lacking in cross-border compatibility. Besides the United Kingdom *and NMT* networks, the others include the following.

Benelux-country network. The Netherlands served on their ATF2 network (the same as the NMT 450 network) at the beginning of 1985. It has a nationwide coverage using 50 cell sites with two different cell sizes, 20- and 5-km radii. The capacity of the present systems 15,000 to 20,000 subscribers. Dutch PT&T is using a single Ericsson AXE 10 switch Lunenburg came on air in August 1985. In 1986, Belgium joined the network. It operates at 450 MHz The network is compatible among the three countries.

France. A direct-dial car telephone operating at 160 MHz can access the system in 10 regional areas. The network serves 10000 subscribers. By the end of 1984, 450 MHz was in operation. In the meantime Radium 2000 (digital signalling) was introduced, operating at 200 MHz but with no handoff feature.

Spain. It uses an NMT 450-MHz cellular network introduced in 1982. It was the first cellular system in Europe. The number of cells in service is 13. There are three separate networks operating 104 channels. Each channel bandwidth is 25 kHz.

Austria. A new NMT cellular network called Autotelefonnetz C has two mobile switching exchanges and has enough capacity 'or 30,000 subscribers.

The Austrian PT&T have allocated 222 duplex channels in ranges 451.8 to 455.7 MHz and 461.8 to 465.7 Mm, with a channel bandwidth of 20 kW. Although both Austria and Spain are using NMT 450 systems, their systems are not compatible because of different frequency allocations, channel spacing (bandwidth), and protocols by different PT&T

Germany. A full national coverage,, including West Berlin, using a C-450 cellular system was installed in 1985 with 100 cell Sites. Another 75 C and France are working on cross-border compatibility in cellular radio systems and have proposed a CD-900 digital system.

Switzerland Swiss PP&T decided to install an NMT 900-MHz cellular network that had a capacity of 12,000 subscribers. A pilot scheme pith 20 transmitters (cell sites) was installed in the Zurich area in late 1986.

Cellular systems in the rest of the world. Australia is installing a system

Using Ericsson's AXE-10 switching networks and will operate at 800 MHz with 12 sites

CHAPTER 3

RADIO FREQUENCY FIELDS FROM MOBILE PHONE SYSTEM

3.1 Radio frequency Radiation Usage

Mobile phones and their base stations transmit and receive signals using electromagnetic waves (also referred to as electromagnetic radiation or fields, or radio waves). Electromagnetic radiation is emitted by many natural and man-made sources and plays a very important part in our lives. We are warmed by the radiation from the Sun or from an electric fire and we see using that part of the electromagnetic spectrum that our eyes can detect. All electromagnetic radiation consist of oscillating electric and magnetic fields and the frequency. For (nu), which is the number of times per second at which the waves oscillate, determines their properties and the use that can be made of them. Frequencies are measured in hertz or Hz. where 1 Hz is one oscillation per second. 1kHz or kilohertz is a thousand Hz, 1 MHz or megahertz is a million Hz, and 1 GHz or a thousand million Hz or 10 9 Hz. Frequencies between about 30 kHz and 300 GHz are widely used for telecommunication, including broadcast radio and television and comprise the Radio frequency (RE) band.

In the UK, AM radio uses frequencies between about ISO kHz and 1.6 MHz, EM radio ranges from 88 to l08 MHz, and TV ranges from 470 to 854 MHz. Cellular mobile phone services operate within the frequency ranges 872—960 MHz and 1710— 1875 MHz. Waves at higher frequencies but within the RF region, up to around 60 MHz, are referred to as microwaves and have a wide variety of uses. These include radar, telecommunications Links, and satellite Communications weather observations and medical diathermy; intense sources of 2.45 MHz microwaves confined within ovens am used for cooking. At even higher frequencies, radiation takes the form of infrared, then visible, ultraviolet, X-rays and eventually the x-rays (gamma rays) emitted by radioactive material. Electromagnetic radiation is also characterized by its wavelength (lambda), light) divided, by its frequency. Which equals the velocity or speed of the wave (the speed of light) divided, by its

2. Radio communication

A RF wave used for Radio communication is referred to as a carrier wave. The information it carries — speech, computer data, etc — has to be added to the carrier wave in some way, a process known as modulation. The information can be transmitted in either analogue or digital form. For example, the electrical signal from a microphone produced by speech or music is an analogue signal at frequencies up to about 15 kHz. So the signal varies significantly with time on a scale of a few microseconds or s (1 s is a millionth of a second). At a particular time it might have any value within quite a large range. So if this signal is sent by analogue transmission, the size or amplitude of the RE carrier wave at any instant is made proportional to the size of the electrical modulating signal at that instant (this is called amplitude modulation and other forms modulation can also be used)

The carrier wave varies very much faster than the signal so that the modulation produces a relatively slow oscillation in the amplitude of the carrier wave. Information can also be transmitted in digital form. In this case only a small number of symbols are used. Printed language is an example of digital information since it only uses the symbols of the alphabet. Morse code is another and only uses two symbols, dots and dashes, so is called a binary system. A number, which in general is not an integer (whole number) describes analogue signals, arid the first step in digitising it is to round this to the nearest integer. For example, if the strength of an electrical signal from a microphone at a particular instant is 12793.56 microvolts or V (1 V is a millionth of a volt) the number 12793.56 is rounded to 12794. This can then be expressed in binary form in which it is represented by a series of zeros and ones, and these can be transmitted digitally to a receiver that converts them back to a signal of strength 12794 V. Digital transmission, usually binary, offers many technical advantages over analogue transmission systems. It is, for example, less susceptible to distortion by interference and electrical noise, and it is replacing or has replaced analogue transmission radio, TV, mobile phones, etc.

3.3 Electromagnetic Compatibility

The ability of electrical and electronic systems to operate in an electromagnetic Environment without adverse effects is known as electromagnetic compatibility (EMC). The reality is that all electrical systems can be disturbed if subjected to sufficiently Powerful emissions. For this reason, limiting or controlling achieves EMC electromagnetic emissions in addition to ensuring that electrical systems are sufficiently immune to electromagnetic interactions.

Mobile phones are intended to be electromagnetic emitters and as such their Radiation characteristics (frequency, power etc) are tightly regulated by standards set by organizations such as the European Telecommunications Standards Institute (ETSI). However, the distance between a mobile phone and an electrical system can vary Considerably. A substantial research project recently concluded (DTI, 1999) that future mobile phone systems would have less adverse EMC effects than present systems, and suggested some techniques for reducing the effects still further.

EMC is of particular concern in hospitals because of the diversity of electronic equipment in use and safety-critical circumstances involved. The Medical Devices Agency issued a warning in 994 and recommendations in 1997 (MDA, 1997) and many hospitals have imposed restrictions of varying degrees on the use of mobile phones in hospitals. Similarly, the use of mobile phones in aircraft is not permitted for EMC reasons.

3.4 Technology of Cellular Mobile Phones

Cellular Radio frequency networks

A mobile phone sends and receives information (voice messages, computer data, etc) by Radiocommunicatiom Radio frequency signals are transmitted from the phone to The nearest base station and incoming signals are sent from the base station to the phone at a slightly different frequency. Once the signal reaches a base station it can be transmitted to the main telephone network, either by telephone cables or by higher frequency (such as 13,23 or 38GHz) radio links between an antenna (e.g. dish) at the base station and another at a terminal connected to the main telephone network. These microwave radio links operate at rather low power and with narrow beams in a direct line of sight between the antennas, so that any stray radiation from them is of much lower intensity than the lower frequency radiation transmitted to the phones (FEI, 2000) Signals to and from mobile phones are usually confined to distances somewhat beyond the line of sight.

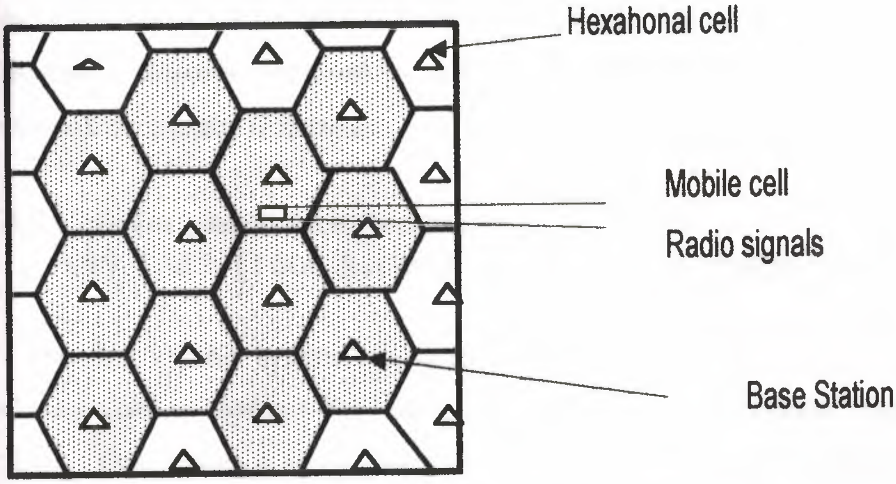

Figure 3.1 networks of base stations at the centre of hexagonal cells

They can reach into buildings and around corners due to various processes including kin (22 miles). For such reasons an extensive network of base stations is needed to ensure coverage throughout the UK. An ideal network may be envisaged as consisting of a mesh of hexagonal cells, each with a base station at its center (Figure 3.1), but in practice the coverage of each cell will usually depart appreciably from this because of the topography of the ground and the availability of sites for the base stations.

The sizes of the cells are usually less than the *35* km maximum because obstruction by hills, buildings and Frequencies are reused several cells away and the capacity of a network (the number of simultaneous phone calls which may be made) depends on the extent of the frequency spectrum available, the cell diameter and the ability of the system to work against a background of interference from other cells. Other ground features reduces the effective range. To accommodate the steadily increasing volume of users. Cell sizes have to be progressively reduced (for example, by using base station antennas of lower height and reduced power) so that the frequencies may be reused more often. Indeed in large cities, base stations may only be a few hundred meters apart. The 20,000 or so base stations in the UK.

Mentioned in last chapter each serve a "macro cell". Additional, smaller base stations operating over even shorter distances are being installed in places such as railway stations where the density of users is particularly large (micro cells" arid also within buildings such as office blocks ('Pico cells). Cellular systems also include technology that ensures that the frequency channels employed by a user in a vehicle change automatically as the vehicle moves from one cell to the next.

3.5 Cellular phone technologies

3.5.1 TACS (Total Access Communication System) (analogue)

The first cellular system employed in the UK was the analogue TACS (Total Access Communication System) for which the phones have a nominal output of 0.63W(FET, 2000). This system is being phased out so that the frequency channels it uses around 900 MHz may be allocated to more recent systems. It uses frequency modulation that results in only very small and essentially random changes in the amplitude of the carrier wave.

3.5.2 UMTS/IMT-2000 (Universal Mobile Telecommunication System), (digital)

A third generation of mobile telecommunications technology has now been agreed and will be introduced in the next few years In Europe this is called UMTS (Universal Mobile Telecommunication System) and worldwide it is known as IMT-2000 (International Mobile Telecommunications - 2000). The frequency bands identified for this system are 1885—2010 MHz and 2110—2200 MHz and the need for additional frequency spectrum to meet the future expected demand for capacity has also been recognized and will be debated at the World Radio communication Conference in May 2000. The specifications allow some choice in the modulation to be used but it is expected that the main choice will be CDMA (Code Division Multiple Access). The frequency channels will have 5MHz bandwidths and, as in GSM, each can be used by a number of users at the same time. However. In CDMA, a transmission is "labelled" by a coding scheme that is different for each user. Since all the transmissions occur at the same time, the changes in amplitude of the canter wave are essentially random (noise-like).

Two types of CDMA are likely to be implemented: FDD (Frequency Division Duplex) where separate 5MHz channels are used for the two directions (to and from the mobile phone), and TDD (Time Division Duplex) where the saint channel is caused but in different time slots. Both types lead to pulse modulation because of the need to send regular commands from the base station to change the power level. In FDD the pulse frequency is 1600 Hz, while for TDD it can vary between 100 Hz and 800 Hz (Peterson and Anderson, 1999).

The expected demand for the use of UMTS both for speech and for data and Internet services is such that systems may be expected to employ macro cells and micro cells, and also short-range pica cells, to meet the various requirements for mobility and wide bandwidth services — for example, in the office environment

3.5.3 DECT (Digital Enhanced Cordless Telecommunications), (digital)

Cordless phones are used at very short ranges between a base station located at the telephone socket outlet within the house or office and the cordless phone handset. Earlier cordless phones used analogue technology and are now being replaced by a digital system, DECT (Digital Enhanced Cordless Telecommunications) that has performance advantages in terms of privacy and protection against interference. DECT is now in widespread and increasing use and operates at similar frequencies, around 1850 MHz, to cellular mobile phones. There are ten channels with â spacing of 1728 MHz. In each channel there are 24 time slots within a 10 ms frame and the transmission within a slot uses a form of frequency modulation. So a particular phone emits a pulse every 10 ms (100 Hz) during one of he time slots. Since the maximum power emitted is 250 mw the average power emitted is about 10 mw. Possibly. DECT technology may form part of an overall UMTS system

3.5.4 TETRA (Terrestrial Enhanced trunk Radio System), (digital)

The new TETRA (Terrestrial Enhanced Trunk Radio System) technology is not intended for public systems connected to the telephone network. It is designed for closed groups (e.g. for communication within an organization or company) and is coming into use for the emergency services and some commercial applications. Frequency bands are available at about 400 MHz and 900 MHz. The modulation method is complex The main features, however, are a 25 kHz band divided into four frequency channels, each of which is divided into 56.7 ms frames containing 4 time slots. So the transmission is pulsed at 17.6 Hz (l/56.7 ms)

Other radio systems

A modem environment contains many types of radio transmitter. Broadcast radio and television transmitters usually have substantially higher powers than those of mobile phone base stations do because they are designed to serve large areas of the countryside. For the same reason, their antennas are usually placed on taller masts located on higher ground at some distance from centres of population Other high power transmitters are used for air traffic control and surveillance radar, which usually employ pulse modulation. Transmitters of much lower power, roughly comparable to those of the macro cell base station transmitters used in mobile telecommunications, are used for other communications purposes such as radio paging and communications by the police, emergency services, local government utility services, security personnel, amateur radio operators, and taxi services. They vary widely in the type of coverage needed but a large number of transmitters are needed for many of the services because of their relatively low power outputs. So it is important to recognize that the exposure from mobile phone base stations is just one component of the total RE exposures that people receive. Indeed, the exposure received by people living near to broadcast transmitters of high power output is likely to be appreciably greater than that received by people living near to mobile phone base stations, although less than that from a mobile phone near to the body.

Individuals may also be exposed to radiation from nearby low power transmitting devices such as wireless burglar alarms, toys, baby alarms, microphones, theft protection devices and car door openers. All of these types of equipment are of such low power that they do not need individual spectrum licenses.

There are also RF amplifiers, which are use in such away that they are not intended to radiate. These include RF beating — for example, in, the plastics industry —microwave diathermy in physiotherapy and microwave ovens. Some of these sources, such as industrial heat sealers and medical diathermy equipment, give rise to exposures to patients, workers and physicians that are far higher than those to the public from mobile phone base stations, although, the exposures are for far less time.

3.6 Electric and Magnetic Fields, intensities

An electromagnetic wave consists of electric and magnetic fields that oscillate between their peak (largest) values (positive arid negative) and zero. The size of a field can be indicated either by the magnitude of the peak value or by an average value. Since the field is positive for half the time and negative for the other halt; its mean value is zero. So the average used is the tins. Or root mean square value (the square root of the average of the square of the field), which is equal to the peak value, divided by 1.4 (2). All fields in this report are quoted in rms, values unless otherwise indicated. The electric (E) fields are measured in volts per meter or V/m and the magnetic (B) fields (or magnetic flux densities) in tesla or T or, more usually, in ml (a thousandth of a tesla) or T (a millionth of a tesla). (The magnetic H-field, measured in amperes per metre or A/m, is sometimes stated rather than the B-field. In the materials of interest here an H field of 1 *A/m* corresponds to a B-field of 1.3 micro tesla) If an electrically charged object such as an ion (an atom or group of atoms which has lost or gained one or more electrons) or a cell is exposed to an electric field, it feels a force of magnitude proportional to the field. If, however, it is exposed to a magnetic field it only feels a force if it is moving at an angle to the field. The size of the force is proportional to the magnetic field and to the speed at which the object is moving across die field Magnetic fields can also interact strongly with magnetic material such as iron. The intensity I, or power density, of an electromagnetic wave is the power passing through 1 m 2, The power is usually measured in watts (W), mill watts (Mw) or microwatts (W) where 1 W =1,000 mW = 1,000,000 micro W, and the intensity is measured in watts per square meter or W/m 2 (or in mW/m 2 or W/m 2). Since the area of a sphere surrounding a source increases as the square of its radius, then in an ideal case (in the absence of any nearby objects including the ground) the intensity falls off as l/(distance)

3.6.1 properties of an electromagnetic field

The change with the distance from the source. They are simplest at distances of more than a few wavelengths around a meter or more at the frequencies of interest here, which are referred to as the far-field region. In this region, the electromagnetic wave consists of an electric field E and a magneto field B oscillating at right angles both to each other and to the direction in which the power of the wave is travelling (the direction of the intensity). The fields are in phase, so that the point at which E is greatest coincides with the point at which B is greatest, and their magnitudes are related to the intensity I (in W/m 2) by the expressions:

$$E = 19\sqrt{1}\ \text{V/m} \qquad (3.6\text{-}1)$$

$$B = 0.06\sqrt{1}\ \alpha T \qquad (3.6\text{-}2)$$

In the near-field region, however the situation is more complicated. The amount of power being radiated outwards is the same as that in the far-field region, but near to the antenna a considerable amount of electromagnetic energy is also being stored. So as well as the net radiated energy flowing outwards, there is additional energy that oscillates to and from. These oscillating flows occur perpendicularly to the outward direction *from* the antenna as we[11] as along it so the net energy flow is tilted with respect to the outward direction. The E-field and B-field are still at right angles to each other and to the direction, in which the energy is being carried, but they are longer in phase and their values can differ appreciably from the simple expressions that apply in the far-field region.

The difference in these properties near arid far from an electric dipole antenna is illustrated in the magnetic field directions are perpendicular to the paper.) Far from the antenna, the energy flows outwards. However, near to the antenna, most of the energy is stored around the antenna and only a small proportion is radiated outwards.

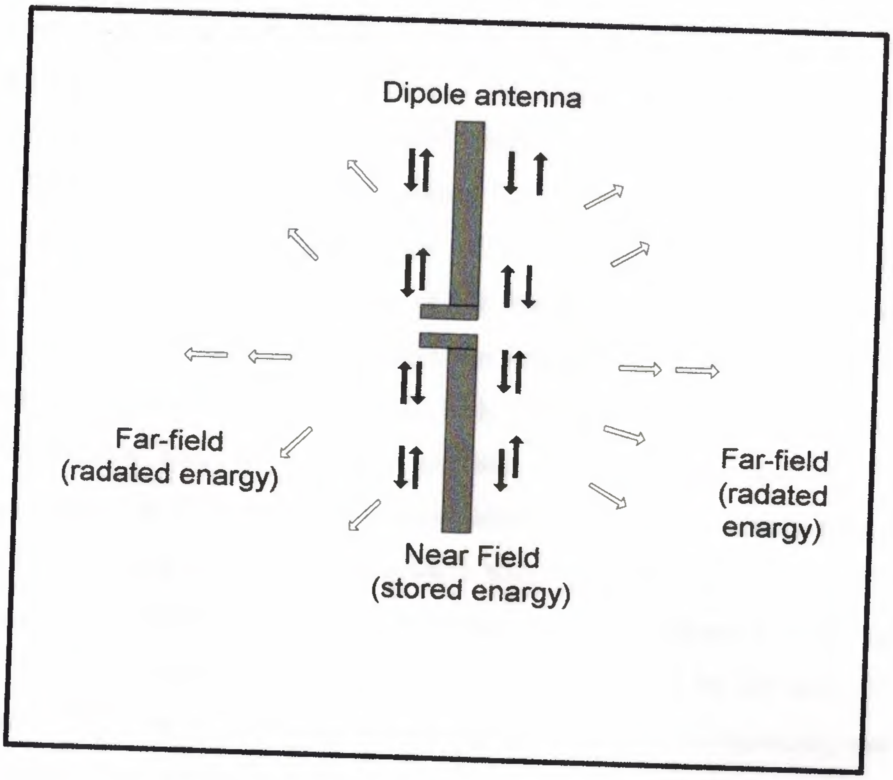

Figure 3.2 electric dipole antennas showing the directions in which most of the electromagnetic energy flows

3.7 Fields from Mobile Phone Systems

The considerations in this section are restricted to the fields produced by GSM mobile phones and base station antennas since these form the large majority of those presently in use in the UK and Europe.

3.7.1 Output from mobile phones

The antenna together with circuit elements inside the handset mainly transmits the KF power from a phone. The antenna is usually a metal helix or a metal rod a few centimetres long extending from the top of the phone. Neither type is strongly directional, although more power is radiated in some directions than others. At points 2.2 cm from an antenna (the distance at which calculations were made), The maximum values of the electric field are calculated to be about 400 V/m for a 2 W, 900 MHz phone and about 200 V/m for an 1 W, 1800MHz phone and the maximum magnetic fields calculated to be about 1 T for both phones. For both 2 W, 900 MHz phones and 1 W, 1800 MHz phones the maximum intensity 2.2 cm from the antenna Is very roughly about 200 *W/m* 2 *(this* is about one-quarter of the intensity of the Sun's radiation on a clear summer day, although the frequency of the emission from a phone is a million or so times smaller). These are the fields and intensities when the antenna is a long way from the head or body. When the antenna is near the body, the radiation penetrates it but the fields inside are significantly less, for the same antenna, than the values outside. For example, the largest maximum fields inside the head when its surface is 1.4cm from the antenna are calculated to be about three times smaller than the values given above. (The average field values are all appreciably less than these maximum values for the reasons explained earlier.) As well as these RF fields, that are pulsed at 8.34 Hz and 217 Hz, there are magnetic fields near to the phone that oscillate at these same frequencies, and are a few T in magnitude. These are generated by currents flowing from the battery which are switched on and off at these frequencies as a result of TDMA

An indication of the size of these fields may be obtained by noting that the maximum values of these low and high frequency oscillating magnetic fields are about one-tenth the size or less of the Earth's static magnetic field, 50 T, while the maximum values of the oscillating electric fields outside the body are a few times greater than the electric field at the surface of the Earth due to its static charge. This is directed towards the ground and on a fine day has a constant value of about 100 V/m.

3.7.2 Output from base stations

The base station antennas serving macro cells are either mounted on freestanding towers, typically 10—30 m high on short towers on top of buildings, or attached to the side of buildings in a typical arrangement, each tower supports three antennas, each transmitting into an 120sector. A large proportion of the power is focussed into an approximately horizontal beam typically about 6 wide in the vertical direction and the rest goes into a series of weak beams (called side lobes) either side of the main beam. The main beam is tilted slightly downwards but does not reach ground level until the distance from the tower is at least 50 m (usually 50—200 m)

The base station antennas transmit appreciably greater power than the phones. The limit to the power is formally set by the need to avoid 1W interference and defined by a license issued by the Radio communication Agency. This does not directly limit the total power emitted but does so indirectly by fixing the maximum intensity that an antenna can transmit into the main beam. This is done by defining the maximum "equivalent isotropic ally radiated power" (EIRP) that can be transmitted. The EIRP is the power that would have to be emitted equally in all directions to produce a particular intensity. In fact, as already noted, the antennas used are very far from isotropic, with most of tile power being emitted into the main beam, and the ratio of the EIRP to the total power output is called the gain of the antenna. For a 120 sector antenna the gain is usually between about 40 and 60.

The license sets the maximum EIRP at 1500 W per frequency channel corresponding to a maximum total radiated power of about 30 W per channel (=EIRO/gain). It also limits the number of channels per antenna to 16 (for 1800 MHz) and 10 (for 900 MHz). However, we have been told hat in practice the number of channels is typically less than 4 for 1800 MHz and 2 to 4 at 900 MHz (FF1, 2000), which would correspond to maximum radiated powers of less than 120 W and 60-420 W, respectively. Similarly, the total radiated power emitted from an antenna is generally limited by the characteristics of the equipment to somewhat fewer than 70 W, and a figure of 60 W will be assumed. It needs to be stressed that the number of channels used, and hence technical rater than legal requirements, which would in fact permit significantly larger powers to be radiated, limits the total radiated power. As with a phone, and for largely the same reasons, the average power transmitted by a base station is normally less than the maximum power, although in this case it could rise to the maximum at times (rather than to one-eighth of the peak power in the case of a phone). By the inverse square law, the maximum intensity in the main beam at a point on the ground 50 m from a 10 m tower carrying an antenna transmitting 60W into an 1200sector is about 100 mw/m2. This corresponds to oscillating electric and magnetic fields of about 5 V/m and 0.02 T, respectively, very roughly about 50 to 100 times smaller than those 2.2 cm from the antenna of a phone The heating effects that these fields would produce will vary with the intensity and are about 5000 times smaller than the maximum value 2.2 cm from the antenna of a mobile phone.

The RE intensity on the ground is not zero outsides the mains beam, because of the power emitted into the side lobes. Its value will depend on the design of the antenna but it seems unlikely that it could ever be significantly more than that within the beam. So the values given above should be reasonable indications of the maximum intensity and fields that would be present on the ground around base station .The intensity will however, become appreciably larger as the antenna is approached, as it might be by maintenance workers.

In the last year or so NRPB has made spot checks on tire average intensities around base stations. Eight of these stations were mounted on the roofs of schools; four were on tower blocks and five on other buildings. Measurements were made at various points within the buildings, at ground level or at other locations of public access (Mannetal in press). The measured intensities were typically between 0.01 and 1 mw/m^2 and the maximum was never more than $10mw/m^2$. These values are then very much less than the calculated values in the beam given above, although the sample is small, It is also of note that one operator for towers used the calculations and most of the measurements only. The average intensities would be expected to be larger near to a tower used by more than one operator.

We note that these measurements by NRPB were spot checks made under contract at the request of a client such as a local authority. Neither NRPB nor any other independent agency has made any systematic experimental study in the UK of, for example, how the intensity changes with distance from a base station, although such studies have been reported in the USA The NRPB report also includes the measurements made during these spot checks of the intensities due to radio and TV transmissions but again there have been no systematic studies which would have allowed us to make a useful comparison of the intensity of typical exposure levels received by individuals from mobile phone transmitters compared with those from other RI' sources. Surveys of this sort have been conducted in the USA but they are several years old and have been made obsolete by the rapid development of wireless technologies. This is, indeed, a very complex problem given the great diversity of RF sources that are presently in operation.

If the electromagnetic waves emitted by both mobile phones and base stations that might be of significance in their interaction with biological tissue are their frequency spectrum and coherence time. The emission from a mobile phone is essentially at one frequency and that from a base station is at several specific frequencies and, in both cases, the waves have the relatively long coherence time of around 4 s (the coherence time is the average time between random phase changes, which in this case are the result of phase modulation. Both these properties are very different from those of, say, the radiation from the Sun, which consists of a broad spectrum of frequencies and electromagnetic waves with coherence, times which are shorter by a factor of around a hundred-thousand.

3.7.3 Base stations near schools

A common concern among members of the public who attended our open meetings was the sitting of macro cell base stations on or near school premises. The placement of a base station on a school building may indirectly benefit its pupils through the income generated in rent. The balance of evidence indicates that there is no general risk to the health of people living near to base stations where the exposures are only small fractions of guidelines. However, it was suggested to us that children might be especially vulnerable to any adverse effects of RF radiation. There is evidence that at the frequencies used in mobile phone technologv, children Viii absorb more energy per kilogram of body weight from err external electromagnetic field than adults. A one year old could absorb around double, and a five year old around 60%, more than an adult. Additionally, since children arc being exposed to RE radiation from base stations (and from mobile phones) from a younger age than adults, they will have a longer time in which to accumulate exposure over the course of their lives, and a longer time for any delayed effects of exposure to develop.

In recognition of this, some countries have prohibited the placement of macro cell base stations on sensitive sites such as schools. Such policies have the merit of being easy to administer, but they may not always produce the desired effect. For example, because of the way in which emissions are beamed, a macro cell base station located near to a school may cause higher exposure to pupils than if it were placed on the roof of the school building.

The better approach would be to require that the beam of greatest RE intensity from a macro cell base station sited within the grounds of a school should not be permitted to fall on airy part of the school grounds or buildings without agreement from the school and parents. Furthermore, when consent is sought from a school and parents about this question, they should be provided with adequate information to make an informed decision, including an explanation of the way in which the intensity of radiation falls off with distance from the antenna. This may be particularly relevant for schools with large grounds. If, for an existing base station, agreement could not be obtained, its antennas might need to be readjusted.

The similar considerations should apply hi relation to a macro cell base station outside the grounds of a school but at a distance from the edge of the grounds comparable to that of a macro cell base station were it to be placed within the school grounds. In this case, if requested by die school or parents, the network operator should be required to inform the school whether the beam of greatest intensity falls on the school grounds or buildings. If it does, the operator should tell them where it falls and the nearest distance from the antenna to these points. It should also provide them with adequate information to make an informed consideration of the level of the intensity of RE radiation. This information should include an explanation of the way in with the intensity of radiation falls off with distance from the antenna. If there is major concern about the situation from the school and parents, it may be necessary for the network operator to make adjustments to the antennas.

In relation to macro cell base stations sited within school grounds, that the beam of greatest RE intensity should not fall on any part of the school grounds or buildings without agreement from the school and parents. Similar considerations should apply to macro cell base stations sited near to school grounds. Developments in rural areas

In urban environments and adjacent to major roads and railways, the need for new base stations will arise principally from growth in the number of phone calls that must be handled at anyone time. In rural areas, however, the main drive to expansion of networks at present is the need for wider geographical coverage. In this circumstance, there may be scope to limit the number of masts that are required though agreements between operators on mast sharing and roaming.

Operators should actively pursue a policy of mast sharing and roaming where practical, and that they should be considered by planning authorities as an alternative option when new masts are proposed.

3.8 Field penetration into the body: dosimetry

Radio frequency fields penetrate the body to an extent that decreases with increasing frequency. To understand the effects this might have on biological tissue, the magnitude of the fields needs to be determined within the various parts of the body that are exposed. This requires knowledge of the electrical properties of the different types of tissue and, once this has been determined, it is possible to calculate E and B at every part of the body caused by a particular source of radiation such as a mobile phone. The rate at which the energy is absorbed by a particular mass of tissue m, s-m E2/, and are, respectively, the conductivity and density of the tissue and F is the rms. Value of the electric field. The quantity E 2 / is called the specific energy absorption rote or SAR and is measured in watts per kilogram (W/kg). It varies from point to point in the body both because the electric field changes with position and because the conductivity is different for different types of tissue. (The density is much the same for all tissues apart from bone.) Since the average values of the conductivity at 900 MHz and the density of body tissue are 1 S/m and 0.001 kg/m3, respectively, tire typical value of electric field needed to produce an SAR of 1 W/kg is about 30 *V/m*. (The average value of conductivity is somewhat higher at 1800 MHz so lower electric fields, about 25 *V/m*, are needed.) The SAR produced by a particular value of electric field is somewhat larger in children than in adults because their tissue normally contains a larger number of ions card so has a higher conductivity (Gabriel, 2000). We understand that an internationally agreed standard testing procedure that will allow the SAR from mobile phones to be compared is being developed and will be finalized this year (2000).

It is important to stress that these are the electric fields inside the body The fields outside the body that correspond to these internal fields are typically around three times larger; this was discussed in paragraph 3.7.2.

It is very well established, that electromagnetic radiation can only be absorbed in quanta of energy h where h s Planck's constant. Now the energy needed to remove an electron from (ionise) an atom or molecule is a few electron volts (eV) (an eV is the energy needed to move an electron of charge e from an earthed plate to one at a negative voltage of one volt). So if the quantum of energy is less than about 1 eV, it is essentially impossible for ionisation to occur 1. The quantum of energy of RF radiation is in fact many thousand times less than eV and so RE radiation cannot ionise atoms or molecules and is described as non-ionising radiation (NIR). However, higher frequency radiation, such as far-ultraviolet radiation and X-rays, has energy quanta bigger than 1 eV and so can readily ionise atoms and molecules, and produce some damage to biological tissue even at very low intensities. This is referred to as ionising radiation. The intensity determines the number of quanta striking the body per second and, even though this is small at low intensities, each quantum still has a certain probability of ionising and so damaging biological molecules such as DNA. Non-ionising electromagnetic radiation, however, is believed to be harmless at very low intensities, although, it can be damaging at high intensities. For example, light at modest intensities produces useful biological effects, which allow us to see illuminated objects. However, if the intensity of the light becomes too large, the eye can be seriously damaged. Very high intensity RE radiations can also he damaging as is clear from the strong heating effects produced in a microwave oven. So we need to know at what intensity the radiation starts to produce damage; this might usually be expected to be higher than the lowest intensity at which biological effects can be detected. The current guidelines that are in force to protect people from harmful exposures are discussed.

CHAPTER 4

EFFECT OF ELECTROMAGNETIC RADIATION ON HUMAN HEALTH

4.1 Electromagnetic Radiation:

The word radiation is often thought of as referring to the emanations from radioactive material and x-rays. However when scientists use the word radiation they are usually referring to electromagnetic radiation (EMR), which can be emitted from such sources as radio or television transmissions, the humble light globe as well as x-ray machines.

It is the energy transfer in the form of waves, thus the (EM) or the electromagnetic radiation is the transfer of energy though out the electromagnetic waves. In Communications the (TEM) wave is used in unlimited fields, it is represented in the F.M coordination in a normal form. This arrangement shows E and H inter changing and being normal to each of the transfer of energy has the form of transfer of waves or the transfer of particles. This explains the electromagnetic waves as (wave-particle) transfer of energy. Radiation is measured by toules equation:

$$W=h*f \qquad (4.1.1)$$

Where

h: Planck constant

$h=6.626*10^{-14}$ t.s

f: in hertz

More over the electron volt (eV) radiation is given by

$$W = 4.14125*10^{-15} f (eV)$$

And $1\ eV= 1.6*10^{19}$

The electromagnetic radiation's spreading from a lot of equipment's that human beings use in their daily life has great effects on human health and environment. IRPA and ICNIRP have developed standards to reduce the effect of electromagnetic radiation's on human health. GSM equipment's are another source of electromagnetic radiation pollution.

IRPA and ICNIRP also has developed and stated limits for the radiation of EM fields to reduce their effects on human health. More over, to reduce their effects the base stations of GSM and other EM fields have to be constructed for away from schools; hospitals, park and other public are as The public should be informed of the bad effects of GSM and EM fields with their electromagnetic radiation's.

The electromagnetic fields (EM) with its radiation have side effects on, Human bodies absorbs the energy of EM fields which warms up the body and thus causes changes of the electrical current that exit in some part of the human body.

In addition, EM radiation has chemical effects on the human bodies cells and their molecular structure. Also the EM radiation causes Changes in the electrical signal of the mind (BEG) ionic changes of bodies' cells headaches dizziness.

Electromagnetic radiation has electric and magnetic field components and passes through space at the speed of light - about 300,000,000 meters per second (186,000 miles per second). It is the interaction of these fields with matter that determines the effects of EMR. The study of this interaction is an important branch of physics and the knowledge gained enables us to control radiation for the benefit of mankind. The properties of EMR vary with wavelength or frequency (wavelength is inversely related to frequency) and thus we have radio communications, television, radar, microwave ovens, magnetic resonance imaging, toasters, cameras, lasers and X-ray machines, etc.

4.1.1 The Electromagnetic Spectrum

The scale at the bottom of the diagram below measures the wavelength of the electromagnetic radiation (EMR) from long wavelength (low energy) on the left, to short wavelength (high energy) at the right. The human eye is able to discriminate wavelength in the visible part of the spectrum and this region has been expanded in the diagram.

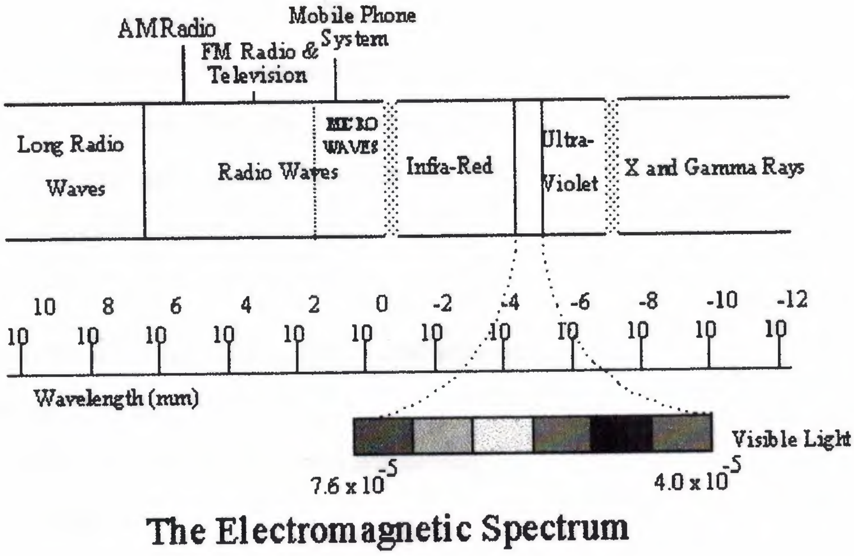

Figure 4.1 The Electromagnetic Spectrum

The variation in wavelength is sensed as a change in co lour. Immediately to the left of the visible spectrum is infrared radiation which can be detected as heat although not very efficiently when compared with the ability to detect visible light. Further to the left are radio waves (including microwaves) and long radio waves, which complete the low energy end of the spectrum. These radiations are unable to be perceived at normal levels. The mobile phone system operating at about 900 MHz (megahertz) is located in a region of the spectrum that is referred to as both microwave radiation and radio frequency radiation (RFR). For the purposes of this discussion both terms will be used interchangeably.

4.1.2 Ionization: -

Is releasing some electrons from around the nucleus free electrons. The most constant atom is (He) arid its energy of ionisation is measured as (13.6 eV).

Ionisation results in changes of the molecular structure of the elements, in biological it has effect on the DNA structure of the living cells the high energetic particles makes ionisation in the molecular structure of the cells.

The (EM) fields' radiation can be called the non-ionise radiation, since its energy is less then that energy required for ionisation. This kind of non-ionise is termed in (IRPA I ICNIRP) as the radiation that has less than 12[eV] of a photon, The waves which axe longer than l00nm and has frequency less than 300 TH2.

This category includes X and (Gamma rays too/

4.1.3 Sources of electromagnetic radiation: -

Those sources can be stated as:

a. Electrical and electronic equipment's and devices
b. Electrical trains
c. TV and computers
d. Welding machines and induction ovens.
e. Radar system
f. Florasan lambs
g. Radio and TV stations and airless communication devices
h. Satellites used for communication
i. Microwaves ovens
j. GSM equipment's and mobiles

Devices, which are used in our houses, can transfer and make large magnetic fields. Some medical equipment can cause radiation and EM fields.

As an example of the pollution of EM radiation, the microwave source station in trabzoor botanic has a 300KW of power and a frequency of F = 954 kh2 and this effect the inhabitant of the near by areas. Some medical devices in a hospital near that station like EKG, EEG are being effected by this radiation more over the phone arise rear by are mined with the radio signal that has a frequency of 953 kh2 this kind of radiation effects some steel-made rods too resulting in contraction of their length.

The human cells on organisms are producing different electrical signals. This electrical signal controls the function of the mind and the other functions of the human organs. Thos. Human electrical signals are measured in Iv. Except the signals that functions our hearts its measured in mV.

sends and reduced the wave signals, in the EM field the radiation power Is 54 EM waves radiation of the antenna

4.2 EM waves radiation of the antenna:

EM waves radiation of the (antenna) basically is a device that sends and reduced the wave signals, in the EM field the radiation power is defined as

4.2.1 (Antes) without direction:-

Is the antenna, which produces waves in all directions equally. it is used as reference antennas.

4.2.2 Directional (antenna): -

It sends the different EM waves to the different directions. Some of the waves are stronger than the others

4.2.3 Partial directional (antenna): -

It sends the EM waves In a circular from such that it has no horizontal specified direction.

4.2.4 (antenna)'s field: -

a. Reactive near-field area it is the area nearest to the (antenna)

$$R < Ra \qquad (4.2\text{-}1)$$

Where

$$Ra = 0.62\sqrt{\frac{3D}{\lambda}} \qquad (4.2\text{-}2)$$

b. Radiation near-field area

c. For-field area: -

d. Is the angular field where the field is independent of the (antenna) radiation

That is ;If

$$D > \lambda \qquad (4.2\text{-}3)$$

$$R_h = \frac{2D^2}{\lambda} \qquad (4.2\text{-}4)$$

If

$$D<\lambda \tag{4.2.5}$$

$$R_h = \frac{\lambda}{2\pi} \tag{4.2-6}$$

Where R_b is the far-area's borders and D is the antenna dimension

If $D<\lambda$ in small antennas

Then

$$R >> R_b = \frac{\lambda}{2\pi} \text{ and } R \cong 3\pi \tag{4.2-7}$$

In GSM system f=900 MHz and λ=0.3 and R=1m the near field changes with the Changing distance from the antenna,

$$\frac{1}{r}, \frac{1}{r^2}, \ldots\ldots \frac{1}{r^n} \tag{4.2-8}$$

And the areas far a way from the antennas $1/r^2$,$1/r^3$ are getting weaker .thus hr and its changing terms is dominant.

$$E = \eta_O .H \tag{4.2-9}$$

$$H = \frac{E}{\eta_O} \tag{4.2-10}$$

In the far field area E and H are dependent on each other such that,

Where lie is the vacuums characteristic constant.

$$\eta_O = 120\pi = 377\,\Omega$$

The density of the powers can be written as

$$S = E{*}H = \frac{|E|^2}{\eta_0} = |H|^2 .\eta_0 \tag{4.2-11}$$

4.3 Radiation effect

4.3.1 The effect of the low-frequency radiation

Low-frequency (0Hz-10 kHz) radiation and its effect on the human health

To be protected from the EM radiation effects it is important to consider and to use less radiation-producing device or to limit this kind of radiation.

Table 4.1*:* The effect of current density

The density of current	**Effect of this density**
>=1000	Effect on health such as the beat of the human heart and contraction of it
1000-100	Central nerve system is effected possibility of health problems
100-10	Changes in DNA natural nervure system is effected
10-1	Not so much important in human health
<1	Effect on human health has no effects

Table 4.2: *The density of induced current.*

0.1	40	16
1-4	40/f	16/f
4-1000	10	4
1000-10000	F/100	F/250

Table 4.3: Current in contact its limits (rms.)[ma]

Frequency area H2	**Limit**	**Public health limits**
0.1-7500	3.5	1.5
7500-10000	3.5	$2.10^{-4}f$

If the current resulting from the changing electric and magnetic fields it high it can cause damages and effects on the public health. Some standards are set for the limits of EM to protect the public from those effects.

Limit *of* the current density:

Induced current's effects are stated below.

Induced current can effect the nerves and muscles.

A human being walking in a high static magnetic field can feed headaches and dizziness, if human beings in a magnetic field touch a metallic subject the electrostatic discharge that result may in hence the body cells and nerves.

The strength of the magnetic is measure by H and it has A/m unit and induced current is B the unit of it tesla

$$\mathrm{T} = \frac{V_S}{m^2} = \frac{wb}{m^2} \tag{4.3-1}$$

Practically

$$\mathrm{m\,T} = 10^{-3}\ \mathrm{T} \tag{4.3-2}$$

$$\mu T = 10^{-6}\ \mathrm{T} \tag{4.3-3}$$

are used in magnetic currents density has a ratio with H such that B/Fm

The magnetic devices p has a changeable value but from biological point of new it has constant value that is

$$\mu_o = 4.\pi.10^{-7}[H/m] \tag{4.3-4}$$

4.3.2 High frequency EM radiation with its effects limits and standards:

The human body is sensitive for the high frequency radiation the body absorbs the energy of radiation, which is converted into heats that warms up the body. The high frequency field warms up the body the heat controlling systems of our body is located in the senses of the skin the high frequency waves passes through skin without alarming the heat controlling systems that is why the radiation shock is unexpected event.

Due to the technical development the device that radiate EM energy is getting more and more, this what causes the damage threatening the human health getting more and more. As a result standards for EM strength and energy ever set to limit those effect on health. The human body acts as an antenna that receives waves from space around it but absorbs more energy.

SA. **(Specific absorption)**

If a biological mass of (dm) is absorbing an amount of energy (dw) then absorption is the t

$$SA = \frac{d\omega}{dm}$$

specific absorption is (dm = pdv) is the mass density expression

$$SA = \frac{dw}{dm} = \frac{dw}{\rho dm}[J/KG], \rho[kg/m^3]$$

SAR (specific absorption rate): -

Is the speed of which the body absorbing energy

Taking the integral

E: Electrical field in the body [V/m]

δ : Conduction of the body [S/m]

$$\text{SAR} = c_1 \frac{dT}{dt} \tag{4.3-5}$$

$$\text{SA} = \int_0^1 (SAR)dt \tag{4.3-6}$$

$$\text{SAR} = \frac{(j)^2}{\rho + \sigma} \tag{4.3-7}$$

$$\text{SAR} = \sigma \frac{[E]^2}{\rho} \tag{4.3-8}$$

C_1: The specific heat of the body [J/kg.k]

IRPA (The international radiation protection association)

ANSI (American National Standard Institution)

The harmful range of radiation is SAR= 4[W/kg]

Thus (1/10) of this value is a limit RE radiation limit is called (Occupational exposure limits).

For the public health the radiation limit is named as (Exposure limits for the general population) and it is S times less than the exposure limit that is to say for health the average effective SAR limit is 0.08 [W/kg].

If the body absorbs less than the standard SAR it is not certain that will not be harmful for its health due to the presence of local warning up. So it is right to take the basic limit as S W/100g. This value was derived for 10 micro μHz -300GHz

SAR 0.4[W/kg] limit.

For the general public health, if the Pr radiation is bigger than 10 μ Hz and if the body is exposed to the radiation for 6 minute the average SAR should not exceed 0.08 W/kg.

Table 4. 4: The GSM hands for the public health

			Waves power density	
Frequency	**RmsV/m**	**Rms A/m**	**(W/m)**	**(MW/cm)**
900	41.25	0.111	4.5	0.45
1800	58.34	0.157	9	0.9
900	59.93	0.161	9.5	0.95

4.3.3 Thermal Effect

Thermal effects from RFR exposure are defined as biological effects, which result from absorbed electromagnetic energy, which elicits a biological response from theheat it produces. Radio frequency radiation interacts with matter by causing molecules to oscillate with the electric field. This interaction is most effective for molecules that are polar (have their own internal electric field) such as water. The water molecule loses this rotational energy via friction with other molecules and causes an increase in temperature. This effect is the basis for microwave cooking. RFR absorbed by the body occurs primarily as a result of the interaction with water

4.3.4 A thermal Effects

There is a considerable body of scientific literature, which describes effects of RFR in biological systems that cannot be directly attributed to heating. Low levels of RFR have been demonstrated to cause alteration in animal behavior, or changes in the functioning of cell membranes. These effects, referred to as a thermal, are controversial and have not been shown to cause adverse health effects.

4.4 The Interaction of Radio Frequency Radiation (RFR) with Matter

4.4.1 Introduction

Although ionizing radiation, such as X rays and RF radiation are both part of the electromagnetic spectrum their interaction with matter is not related. Radiation such as X rays and gamma rays are able to ionize matter and this in turn causes chemical reactions. Ionizing radiation is known to be carcinogenic (cancer causing agent). Electromagnetic radiation at longer wavelengths than X rays does not have sufficient energy to cause ionization and this region of the spectrum is collectively known as non-ionizing radiation. RFR forms a part of this region of the spectrum at wavelengths longer than infrared radiation and has not been proven to be a carcinogen. When matter absorbs RF radiation it causes molecules to vibrate which in turn causes heating. This thermal effect is the basis for determining the health hazard from RF exposure.

4.4.2 Absorption of RFR from a Mobile Phone

At distances within a wavelength from a RF transmitter is a region known as the near field. Since mobile phone radiation has a wavelength of 30 cm at 900 MHz the users head will be within this near field region. The head disturbs the field and alters the manner in which RFR interacts with tissue. This interaction complicates the absorption of RF energy within the head and makes calculations difficult. Absorptions within the head are therefore determined experimentally or by simulation on a computer. The diagram below shows a computer generated simulation of the distribution of RF absorption in the head from a mobile phone held next to the left ear. The shaded region represents maximum absorption and corresponds to a peak Specific Absorption Rate (SAR) of 2-3 W/kg (Watts per kilogram). Radiated power was simulated at 1 Watt (four times the output of a GSM phone). A SAR of 4W/kg is associated with a 1-degree temperature rise in humans. In practice a digital phone will only cause a temperature rise of a fraction of a degree, which is unlikely to be noticed, compared with the normal daily variations in body temperature.

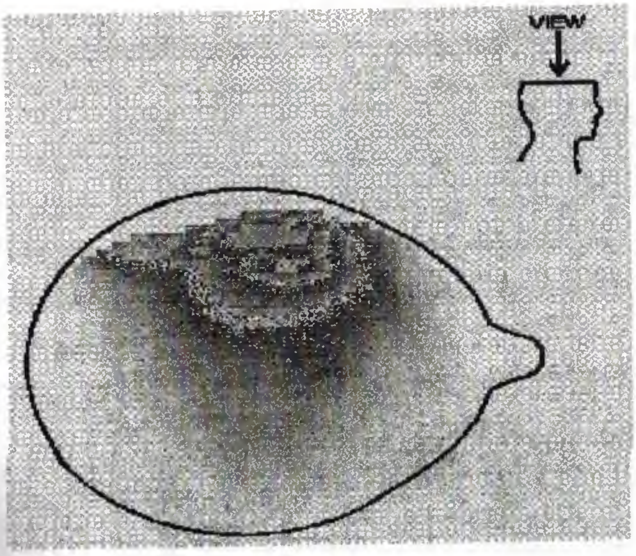

Figure 4.2 Computer generated simulation of the distribution of RF absorption in the head from mobile phone held next to the left ear.

4.4.3 Exposure to RFR Emitted by a Base Station Antenna

As described above the RFR power emitted from a base station varies from one site to another. The graph below shows the variation of power density levels with distance averaged for four typical base station antennas.

The peak value of 0.1 microwatts per square centimeter compares with the Australian Standard maximum exposure level of 200 microwatts per square centimeter.

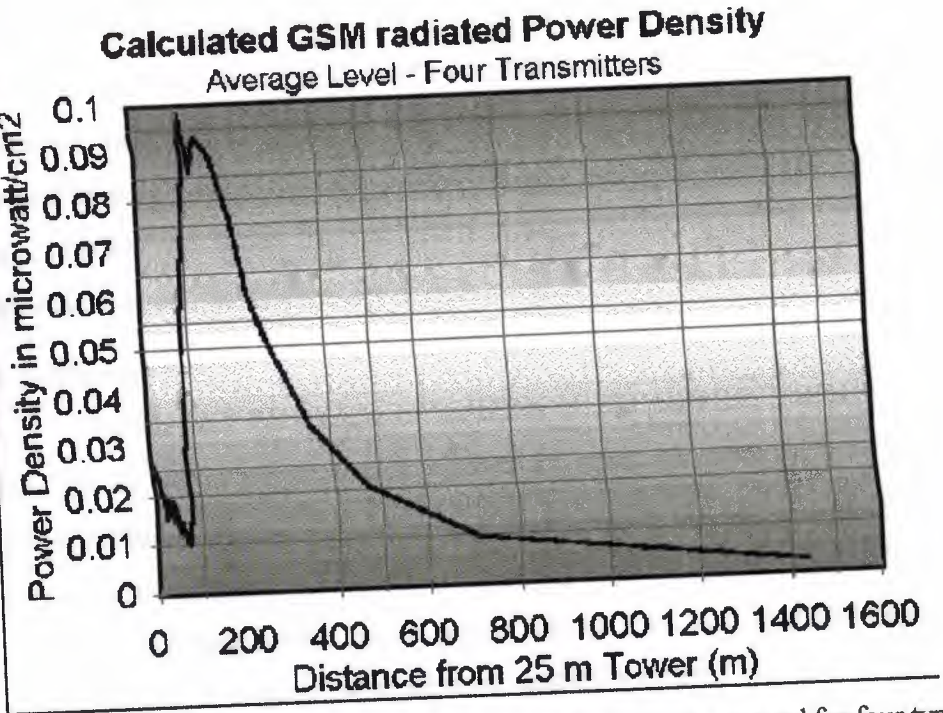

Figure 4.3 variation of power density levels with distance averaged for four typical base Station antennas.

4.4.4 Comparison with Heating by Conduction

In conventional cooking a gas flame or electric radiator will transfer heat into a metal pot and then into food via conduction. In this process molecules rotate and vibrate rapidly with increased temperature and pass the energy onto neighboring molecules through collisions. This is a relatively slow process relying on the thermal conductivity of the food to transfer heat into the center. In the case of heating with RFR the energy is absorbed deeper in the object allowing rapid heating to occur. The depth of penetration of RFR in matter varies depending on the nature of the absorbing material. For example, at 1 MHz the depth of penetration (the depth at which the EMR is reduced by about a third) varies from 0.25 meters in seawater to 7.1 meters in fresh water. Thermal conduction still plays a roll in this type of heating but it is less important.

4.4.5 Comparison with Heating by Infra Red Radiation

The effect of heating by infrared radiation is commonly experienced when exposed to direct sunlight. In fact all heat received from the sun comes to us via infrared. Infrared radiation interacts with matter by causing molecules to vibrate when the radiation is absorbed. This vibration energy is then transferred to adjacent molecules by conduction as described above. Since infra-red radiation is readily absorbed by the skin it does not cause internal heating (other than by conduction) as does RF radiation. The radiated power at approximately one meter from a typical electric bar heater (albeit infra red rather than RF radiation) is about 100,000 microwatts/cm^2.

4. 5 Measurement

To measure the amount of exposure to EM radiation , basically the strength of the field should be measured first In most of the cases of exposure to radiation there is not a simple relation between the magnetic and the electric fields, if there two fields can not be converted to each other, then every field's strength can be measured separately.

The fields' strength or the power density can be measured by some measuring devices that can he divided into three parts; sensors, connection cables and measuring units. The electric sensor of Dipolar can be used to measure magnetic fields as well. The signal, which is received from the sensor, is passed through the cables and delivered to the evaluation and measuring unit. Here the measurement is shown on a small screen of the device. Usually the 1 MHz devices can measure the electric field's strength and the magnetic current, If the device can measures. Frequencies more than 1 MHz can measure the average field's value as squared value E, E. The measuring device must have at least one of the following parameters.

a. The average power density (W/M2,MW/CM2).
b. The average (E) field (V/m) or the squared value of E.
c. The average (H) field (A/m) or H squared value.

The power's density of the near field is difficult.

In EM field the wave radiation can be reduced if there exists a reflection, absorption or preventing obstacles, If no such events take please for the radiation wave. Still the waves can disappear and vanish and this is called the space vanishing of wave .The free space vanishing (Lf) can be expressed as

$$Lf=32.4+20 \log f+ 20 \log d \text{ [dB]} \qquad (4.5\text{-}1)$$

Here f =[MHz] and d, in km].

For example f=900[MHz] and d = 20[cm] then

Lf= 17.5 [dB] =0.01778

In the GSM systems the basic station radiation can give damage to the human health as well as the mobile equipment itself. The if power of the mobile equipment is about 2W. The mobile equipment is put near the head to talk or it can be carried near the human body so the if energy is absorbed by the body. Almost 48%-68% of the radiation that sent by a mobile that is 7 and 2cm away from the head, is absorbed by the head and the body of the human, and 0,12-0,2 *mw/g as* an average is absorbed by the head itself. (as maximum SAR 0,18-7,6 mw/g)GSM system's radiation has damaging effects not only on the human health but also on the environment as well. GSM has effect on airplane electrical equipment's and the ABS systems of the cars and also on the medical equipment's too.

4.6 Reducing the effects of EM radiation's on human health and on the environment.

4.6.1 Legal rules.

a. (Protection from EM department) should environment and the ministry of health. Constructing new FM stations as advised their limits.

Frequently measuring the EM radiation of the previously constructed stations and control the limits not to be exceeded.

b. The basic stations of GSM systems and other EM radiating unit must be kept far from schools, public areas, hospitals and parks.

c. The FM radiating systems and devices should be kept under the (IRPA/ICNIRP) Limits and standards.

d. Informing the public about the effect of EM radiation

4.6.2 FDA's role concerning the safety of mobile phones

Under the law, FDA does not review the safety of radiation-emitting consumer products such as mobile phones before marketing, as it does with new drugs or medical devices. However, the agency has authority to take action if mobile phones are shown to emit radiation at a level that is hazardous to the user. In such a case, FDA could require the manufacturers of mobile phones to notify users of the health hazard and to repair, replace or recall the phones so that the hazard no longer exists.

Although the existing scientific data do not justify FDA regulatory actions at this time, FDA has urged the mobile phone industry to take a number of steps to assure public safety. The agency has recommended that the industry:

- support needed research into possible biological effects of RF of the type emitted by mobile phones;
- design mobile phones in a way that minimizes any RF exposure to the user that is not necessary for device function ; and
- cooperate in providing mobile phone users with the best possible information on what is known about possible effects of mobile phone use on human health.

At the same time, FDA belongs to an interagency working group of the federal agencies that have responsibility for different aspects of mobile phone safety to ensure a coordinated effort at the federal level. These agencies are:

- National Telecommunications and Information Administration
- The National Institute for Occupational Safety and Health
- Environmental Protection Agency
- Federal Communications Commission
- Occupational Health and Safety Administration

For the new constructed GSM stations

To construct a Base station for GSM systems the following procedure is considered

a. The strength of the electric field and the magnetic fields should be measured in the area where the station is to be built.
b. The, base stations technical units, should be controlled and considered working frequencies the antenna's radiation power. Etc/
c. The electrical power that is needed to run the base station should be located.

d. The geographic location of the area.

e. Calculation for the amount of radiation and the EM, electric field, magnetic fields power That going to be received from the base station

To reduce EM radiation's effect on human beings and environment some advises;

a. Measuring and mapping the ball area's EM radiation.

b. Identifying the SAR that the mobile equipment, present in the market car affects on human being's.

c. Informing the public about the pollution that is caused by EM radiation.

d. National department of protection from the radiation must be constructed.

4.6.3 Personal protection of radiation.

a. Use your mobile as less as you can and hold it as far as you can from your body.

b. Children should be prevented from using the mobile!

c. Do not use your mobile in airplanes, petrol stations, ABS car.

d. Use the low radiation computer's screens and be as far as you can from the screen.

f. Watch your TV while you are at least 2m away from it.

g. Use the flouresan lambs as less as you can and stay at least 50 cm away from the photocopy machine and at least 1m away from the microwave oven.

4.6.4 Shields

Shields seek to reduce the RE radiation to which users of mobile phones are exposed, and various types of device have been produced for this purpose. For most of them, e.g. ceramic-absorbing devices, there is no apparent physical basis for their alleged effect, and there are no convincing tests results to verify that they reduce exposure.

One particular type does have a physical basis. This type consists of a case that fits over the handset and has a metallic or metallic-mesh screen within the case arid a "guard" for the antenna. Together these partially screen the radiation emitted by the phone.

Tests by various laboratories including some that formed the basis of a which? It have measured the effect of this type of shield on the radiation from a mobile phone when it was set to produce constant power. The shield substantially reduced the radiation by a factor that could be adjusted by the user.

In most normal use, however, the shield would not reduce the exposure of the user to this extent, since the reduction in radiation produced by the shield would automatically be compensated for by adaptive power control. (This increases or reduces emissions to give an optimal signal at the base station.) An exception would occur where the mobile phone was already operating at or close to its maximum power, e.g. because it was a long way from the base station or in a building, but in this situation, the signal at the base station would be weakened by the shield and communication might not be possible.

Some of the test results have shown that the radiation is reduced more in the direction of the head than in the direction away from it. If so, users could reduce their exposure somewhat by turning the appropriate side of their head towards the base station. However, this could only be done if they could see the base station, which is not the usual situation. For other orientations of the head the tests imply that the reduction in exposure would be very small.

We conclude that, in practice, there would be very little reduction in the exposure received by most users through use of a shield of this type, and that their reception could be impaired when hey were a long way from a base station or in buildings, cars, etc. If the use of shields became widespread there could also be adverse effects on the environment, since more base stations would likely be needed to maintain the quality of communication.

4.6.5 Hands-free kits

Increasing the distance of the phone from the body can reduce exposure to RE radiation from a mobile phone. This could be achieved by using an appropriately designed hands-free kit. Little or no advantage will be gained, however, if the phone is merely moved Bom the head to, say, the waist since in that case other organs nay receive comparable exposure.

Even if the mobile phone is some distance from the body, reduction in exposure may not be achieved if the wires from the handset to the earpiece can carry radio signals to the ear or they radiate significantly. Since the original purpose of hands-free kits was to permit the use of both hands while phoning, they may not all have been designed with exposure in mind. The report published in April 2000 showed that the hands-free kits tested could increase the exposure to the user. On the other hand, we are aware of other tests, which claim a very substantial reduction. In both cases there is insufficient published information about the measurement methods to form a clear view. We believe, however, that it should be possible to design hands-free kits, which would significantly reduce exposure to the user if used correctly (i.e. with the phone some distance from the body).

The regulatory position on the use of hands-free kits and shields is unclear and the only Information available to the public appears to be that supplied by their manufacturers. We recommend that the Government sets in place a national system, which enables independent testing of shielding devices and hands-free kits to be carried out, and which enables clear information to be given about the effectiveness of such devices. A kite mark or equivalent should be introduced to demonstrate conformity with the testing standard

4.7 Information about uses of Mobile Phone by consumers (protection rules)

Purchasers of mobile phones should have information to allow them to make informed choices about personal exposures resulting from their use. Based on current evidence, the main points to convey would be as follows.

- At present scientific evidence suggests that he RE radiation produced by mobile phones is highly unlikely to be a cause of direct adverse health effects on the general population of the UK.
- There is, however, still some uncertainty about this, and individuals may therefore wish to minimized their exposure to such radiation.
- This can be achieved in several ways including, for example, by making fewer and shorter calls.
- Specific absorption rate (SAR) values are a relevant measure of exposure in this situation and should allow people to make an informed choice.
- Another way of reducing exposure would be by use of an approved, hands-free set.

An internationally agreed standard testing protocol for the assessment of SAR values from mobile phones will soon be available. We welcome this development.

We recommend that an international standard for the assessment of SAR values from mobile phones should be adopted for use in the UK once it has been demonstrated to be scientifically sound.

The information on SAP, values for mobile phones must be readily accessible to consumers:

- At the point of safe with information on the box,
- On leaflets available in stores giving comparative information on different phones and with explanatory information,
- *As* a menu option on the screen of the phone, and as a label on the phone.
- On a national web site, which lists the SAR values of different phone types.

In order that consumers can interpret *SAP,* values it will also be necessary to provide them with an explanation of the measure and its application.

Such information could be given by mobile phone manufacturers or retailers in addition to that already provided. However, we believe that it would carry more weight fit came from Government and were clearly seen to be independent.

4.7.1 Use by children

We have already discussed the arguments for minimizing the exposure of children in school to RF radiation from base stations. These apply even more to the higher exposures that occur from use of mobile phones. There may be circumstances where the use of a mobile phone by a child can promote safety (e.g. to ask a parent for a lift rather than walk home alone). This effect translates into a substantially increased risk of an accident. Perhaps surprisingly, current evidence suggests that the negative effects of phone use while driving are similar whether the phone is hand-held or hands-flee. Overall we conclude that the detrimental effects of hands-flee operation are sufficiently large that drivers should be dissuaded from using either hand-held or hands-Bee phones whilst on the move.

If there are currently unrecognized adverse health effects from the use of mobile phones, children may be more vulnerable because of their developing nervous system, the greater absorption of energy in the tissues of the head and a longer lifetime of exposure. In line with our precautionary approach, we believe that the widespread use of mobile phones by children for non-essential calls should be discouraged. We also recommend that the mobile phone industry should refrain from promoting the use of mobile phones by children.

4.7.2 Use near hospitals

There is a potential hazard Thorn the indiscriminate use of mobile phones in hospitals and other sites where RF radiation could interfere with sensitive electronic equipment. We support the steps that are already being taken both by mobile phone manufacturers and hospitals to want people about the dangers of using phones In such sites.

The health authoflties4boards issue guidance on the use of mobile phones. We recommend that they should ensure that all hospitals comply. This guidance should include the placing of visible warning signs at entrances to buildings to indicate that mobile phones should be switched off

4.7.3 Use while driving

There is strong evidence that use of a mobile phone whilst driving significantly increases the risk of accidents, It has been suggested to us that the use of hand-held phones while driving should be banned, and the Department of the Environment, considered this issue sufficiently important to warrant a publicity campaign aimed at dissuading drivers from using a mobile phone, especially one which is hand-held, when in control of a vehicle. But note that, perhaps surprisingly, current evidence indicates that the negative effects of phone use while driving are broadly similar whether the phone is hand-held or hands-free.

We conclude that the detrimental effects of hands-free operation are sufficiently large that drivers should be dissuaded from using either hand-held or hands-free phones whilst on the move

4.8 Definition of Technical Terms

4.8.1 The International Commission on Non Ionizing Radiation Protection (ICNIRP)

Is an independent scientific organization responsible for providing guidance and advice on the health hazards of non-ionizing radiation exposure. ICNIRP was chartered in 1992.

The Organization maintains a close liaison and working relationship with all international bodies engaged in the field of non-ionizing radiation protection and represents radiation protection professionals worldwide through its close collaboration with the International Radiation Protection Association and its national societies.

Activities

Work is conducted in conjunction with international and national health and research organizations as well as universities and other academic institutions. ICNIRP has established four standing Committees covering epidemiology, medicine and biology, physics and engineering, and biophysical aspects of optical radiation. ICNIRP international membership comprises individual experts covering the disciplines of medicine, biology, epidemiology, physics, and engineering.

ICNIRP concluded -

" The results of published epidemiological studies do not form a basis for health hazard assessments to RF fields, neither can they be used for setting quantitative restrictions on human exposure. They do not provide a basis for hazard assessments in relation to the use of hand-held radiotelephones and base-transmitters.

1. from laboratory studies relevant to cancer do not provide a basis for limiting exposure to the fields associated with the use of hand-held radiotelephones and base transmitters.

2. Limits for human exposure to the fields associated with the use of hand-held radiotelephones and base transmitters should be those of the INIRC (IRPA/INIRC 1988) for whole body average SAR and those of ICNIRP for localized SAR set out in this document.

There is no substantive evidence that adverse health effects, including cancer, can occur in people exposed to levels at or below the limits on whole body average SAR recommended by INIRC (IRPA/INIRC 1988), or, at or below the ICNIRP limits for localized SAR set out in this document.

3. At the frequencies and power levels involved in the use of hand-held radiotelephones there will be no concern about shocks and burns.

4. The localized SARs in the head associated with the use of hand-held radiotelephones must be assessed for each frequency and configuration used.

5. For hand-held radiotelephones used in occupational situations, ICNIRP recommends that the localized SAR in the head be limited to 10W/kg` averaged over any 10g mass of tissue in the head (0. 1 W absorbed in any 10g mass of tissue in the head).

6. For hand-held radiotelephones used by the general public, ICNIRP recommends that the localized SAR in the head be limited to $2W/kg^{-1}$ averaged over any 10g mass of tissue in the head (0.02 W absorbed in any 10g mass of tissue in the head).

7. The use of radiotelephones should be restricted to areas where interference effects are unlikely to occur (for example, well away from hospital intensive care departments and similar locations). Manufacturers of electrical equipment are encouraged to design and manufacture equipment that is insensitive to RF interference."

4.8.2 World Health Organization (WHO)

Founded in 1948, the World Health Organization leads the world alliance for Health for All.

A specialized agency of the United Nations with 191 Member States, WHO promotes technical cooperation for health among nations, carries out programmes to control and eradicate disease and strives to improve the quality of human life.

WHO has four main functions:

- to give worldwide guidance in the field of health
- to set global standards for health
- to cooperate with governments in strengthening national health programmes
- to develop and transfer appropriate health technology, information and standards.

Exposure to RF Fields and Cancer:

Current scientific evidence indicates that exposure to low levels of RF fields, including those emitted by mobile phones and their base stations, is unlikely to induce or promote cancers.

- Cancer studies using animals have not provided convincing evidence for an effect on tumor incidence. However, a recent study found that RF fields, similar to those used in mobile telecommunications, increased the incidence of cancer among genetically engineered mice that were within (0.65m) of an RF transmitting antenna. Further studies will be carried out to determine the relevance of these results to cancer in human beings.

- To date, epidemiological (population health) studies have not provided adequate information to allow a proper evaluation of human cancer risk from RF exposure because the results of these studies are inconsistent. This can be explained, in part, by differences in the design, execution and interpretation of these studies, including the identification of populations with substantial RF exposure and retrospective assessment of such exposure.

4.8.3 Rate of Electromagnetic flux density

The rate of flow of electromagnetic energy per unit area is used to measure the amount of radiation at a given point from a transmitting antenna. This quantity is expressed in units of watts per square meter (W/m^2) or mill watts per square cm (mW/cm^2). The maximum exposure level for members of the public exposed to RFR at 900MHz is 0.2 mW/cm^2. This figure can be compared with the amount of heat radiated by the human body at room temperature of about $2mW/cm^2$ (x). (Note this energy is radiated primarily in the infra red region not as RFR). Evaluation of mobile phones for compliance with the interim Standard is not required because of their low power output.

4.8.4 Specific Absorption Rate

The absorption of RFR energy is measured by the quantity specific absorption rate (SAR) in units of Watts per Kilogram (W/kg). It is defined as - the rate at which RF energy is absorbed per unit mass of a biological body. An SAR of 0.4 W/kg would take 10 days to melt a kilogram of ice

4.8.5 Dose Response Curve

It is a basic tenet of toxicology (the study of poisonous materials and their effects on living organisms) that 'the dose makes the poison'. At low doses morphine is an analgesic or painkiller. At high doses it is a respiratory depressant which can cause death. As the dose of a potentially noxious agent is increased the number of deleterious effects is expected to increase. This effect is known as a dose response curve and it has not been observed for thermal exposures to RFR.

4.8.6 Biological Mechanism

Cigarette smoking and ionizing radiation (x rays) are both accepted as carcinogens (cancer causing agents). Cigarette smoke is known to contain Benzedrine a chemical that has been demonstrated to induce cancer in animals. Ionizing radiation causes the formation of free radicals that are known to react with DNA (genetic material) hence providing a mechanism for cancer. Since RFR is non ionizing radiation it is not capable of causing chemical change by this method. In fact no method is known by which exposure to a thermal levels of RFR could cause diseases such as cancer.

4.9 The Scientific Literature

4.9.1 Introduction

There have been numerous reviews on the health effects from exposure to RFR and the discussion here will be limited to thermal matters of interest. The thermal biological effects attributed to exposures from low levels of RF radiation are controversial. Basset has described the situation as "Their positions (the non believers in a thermal effects) are fortified with equilibrium thermodynamics and thermal noise, while ignoring non equilibrium phenomena; quantum based, long range effects; and nonlinear electrodynamics."

4.9.2 In Vitro Studies

There is a considerable literature relating to the in vitro thermal effects of exposure to RFR. Much of this material is published in the Journal of the Bioelectromagnetics Society. These studies vary widely in the frequency of radiation used for the exposure, the dosimetry and the outcome.

Lai and Singh performed one of the more significant studies. In their study they exposed rats to 2450 MHz microwaves and demonstrated damage to DNA, which was dose dependent, and at power levels similar to those experienced by mobile phone users. The work thus satisfied the two criteria, which currently deny a health hazard. Work of a similar nature was performed by Malyaba et al, who were unable to detect DNA damage in the mammalian cells they tested. Earlier work by Meltz had demonstrated that exposure to microwave radiation did not interfere with the normal DNA repair mechanisms present in human fibroblasts (found in connective tissue).

4.9.3 Animal Studies

In five animal studies referred to by Elder on the effect of RFR on life span of laboratory animals, four tended to show an increase in life span the fifth study indicating a detrimental effect. An additional study mentioned by Elder suggests RF radiation may act as an accelerator of cancer induction. A recent study in this country also suggested this effect by demonstrating a doubling in cancer rate in mice who were predisposed for contracting cancer. These studies await confirmation before any conclusions can be made.

4.9.4 Epidemiological Studies

The problem with epidemiological studies investigating diseases with low relative risks is that it is difficult to demonstrate a negative result. That is to demonstrate conclusively that, for example RFR exposure is not a health hazard (Ahlbom). Elder has reported three epidemiological studies on human life span, exposure to RFR and cancer incidence. The three groups studied were workers from a Massachusetts Radiation Laboratory, United States Embassy staff in Moscow and U.S. Navy personnel exposed to radar. These studies reported no adverse effect on life span and no statistical increase in cancer incidence.

Two other studies reported a positive association between RF exposure and cancer. One involved amateur radio operators and cancer. The other involved Polish military personnel exposed to radar. Both studies lack dosimetry data. Recent studies on population exposed to Television transmissions have also been equivocal. All these human studies have weaknesses in that the actual exposures are unknown and there are other confounding factors.

4.9.5 Australian Research

A $4.5 million Radio frequency Electromagnetic Energy Program was established by the Federal Government in late 1996 to consult with the public and conduct research into the biological impact of electromagnetic fields. The National Health and Medical Research Council (NHMRC) established an expert committee on electromagnetic energy last year to identify possible areas of research and co-ordinate submissions.

- The NSW Cancer Council will administer a $90,000 contract for a 12-month pilot study of, "A case controlled study of brain and other tumours in adults".

This study will compare the use of mobile phones in people who have developed a tumour of the brain, salivary gland or auditory nerve (all tissues that are very close to the phone when in use) with use by people of the same age and sex who have not developed one of these cancers. This will allow the group to determine whether or not use of mobile phones increases the risk of getting- one of the tumours.

- The Swinburne Institute of Technology, Victoria will receive $50,000 to conduct an 18-month study on human volunteers to determine if exposure to radio frequency electromagnetic energy from mobile phones effects concentration, attention, problem solving and memory.

The proposed study seeks to determine scientifically if mobile phone use affects concentration, attention, problem solving and memory in people, by systematically examining the effects in human volunteers of electromagnetic energy emissions from mobile telephones.

- Flinders University of SA will receive $75,000 to examine the effect of radio frequency electromagnetic energy exposure in mutation and cancer.

There is concern that radio frequency electromagnetic energy causes mutations in DNA and may therefore be a potential carcinogen. Studies to date have not shown any clear evidence of DNA damage. This project will try to establish if there is a direct link between radio frequency exposure in mice, and a biological mechanism known to be involved in carcinogen sis.

- The University of Adelaide will receive $1.064 million for further research into whether the use of mobile phones affects cancer rates. The research will expose genetically modified, cancer-prone mice to the electromagnetic fields emitted by mobile phones. It will build upon a pioneering study conducted at the Institute of Medical and Veterinary Science (IMVS) in Adelaide last year and will improve upon the study design to reflect scientific progress since the earlier work.

It is expected that the research will be completed by 2001, although it may be extended to a second stage depending on its outcomes.

4.9.6 How much evidence is there that hand-held mobile phones might be harmful?

Briefly, there is not enough evidence to know for sure, either way; however, research efforts are on-going.

The existing scientific evidence is conflicting and many of the studies that have been done to date have suffered from flaws in their research methods. Animal experiments investigating the effects of RF exposures characteristic of mobile phones have yielded conflicting results. A few animal studies, however, have suggested that low levels of RF could accelerate the development of cancer in laboratory animals. In one study, mice genetically altered to be predisposed to developing one type of cancer developed more than twice as many such cancers when they were exposed to RF energy compared to controls. There is much uncertainty among scientists about whether results obtained from animal studies apply to the use of mobile phones. First, it is uncertain how to apply the results obtained in rats and mice to humans. Second, many of the studies that showed increased tumor development used animals that had already been treated with cancer-causing chemicals, and other studies exposed the animals to the RF virtually continuously--up to 22 hours per day.

For the past five years in the United States, the mobile phone industry has supported research into the safety of mobile phones. This research has resulted in two findings in particular that merit additional study:

1. In a hospital-based, case-control study, researchers looked for an association between mobile phone use and either glioma (a type of brain cancer) or acoustic neuroma (a benign tumor of the nerve sheath). No statistically significant association was found between mobile phone use and acoustic neuroma. There was also no association between mobile phone use and gliomas when all types of types of gliomas were considered together. It should be noted that the average length of mobile phone exposure in this study was less than three years.

When 20 types of glioma were considered separately, however, an association was found between mobile phone use and one rare type of glioma, neuroepithelliomatous tumors. It is possible with multiple comparisons of the same sample that this association occurred by chance. Moreover, the risk did not increase with how often the mobile phone was used, or the length of the calls. In fact, the risk actually *decreased* with cumulative hours of mobile phone use. Most cancer causing agents increase risk with increased exposure. An ongoing study of brain cancers by the National Cancer Institute is expected to bear on the accuracy and repeatability of these results.

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2- Researchers conducted a large battery of laboratory tests to assess the effects of exposure to mobile phone RF on genetic material. These included tests for several kinds of abnormalities, including mutations, chromosomal aberrations, DNA strand breaks, and structural changes in the genetic material of blood cells called lymphocytes. None of the tests showed any effect of the RF except for the micronucleus assay, which detects structural effects on the genetic material. The cells in this assay showed changes after exposure to simulated cell phone radiation, but only after 24 hours of exposure. It is possible that exposing the test cells to radiation for this long resulted in heating. Since this assay is known to be sensitive to heating, heat alone could have caused the abnormalities to occur. The data already in the literature on the response of the micronucleus assay to RF are conflicting. Thus, follow-up research is necessary.

FDA is currently working with government, industry, and academic groups to ensure the proper follow-up to these industry-funded research findings. Collaboration with the Cellular Telecommunications Industry Association (CTIA) in particular is expected to lead to FDA providing research recommendations and scientific oversight of new CTIA-funded research based on such recommendations.

4.10 Cases of human cancer that have been reported in users of hand-held

Some people who have used mobile phones have been diagnosed with brain cancer. But it is important to understand that this type of cancer also occurs among people who have not used mobile phones. In fact, brain cancer occurs in the U.S. population at a rate of about 6 new cases per 100,000 people each year. At that rate, assuming 80 million users of mobile phones (a number increasing at a rate of about 1 million per month), about 4800 cases of brain cancer would be expected each year among those 80 million people, whether or not they used their phones. Thus it is not possible to tell whether any individual's cancer arose because of the phone, or whether it would have happened anyway. A key question is whether the risk of getting a particular form of cancer is greater among people who use mobile phones than among the rest of the population. One way to answer that question is to compare the usage of mobile phones among people with brain cancer with the use of mobile phones among appropriately matched people without brain cancer. This is called a

rent case-control study of brain cancers by the National Cancer
ollow-up research to be sponsored by industry, will begin to
ation.

CONCLUSION

Despite public concern about the safety of mobile phones and base stations, rather little research specifically relevant to these emissions has been published in the peer-reviewed scientific literature. This presumably reflects the fact that it is only recently that mobile phones have been widely used by the public and as yet there has been little opportunity for any health effects to become manifest. There is, however, some peer-reviewed literature from human and animal studies, and an extensive non-peer-reviewed information base, relating to potential health effects caused by exposure to RF radiation from mobile phone technology. The balance of evidence to date suggests that exposures to RF radiation below NRPB and ICNIRP guidelines do not cause adverse health effects to the general population. There is now scientific evidence, however, which suggests that there may be biological effects occurring at exposures below these guidelines . This does not necessarily mean that these effects lead to disease or injury, but it is potentially important information and we consider the implications below. There are additional factors that need to be taken into account in assessing any possible health effects. Populations as a whole are not genetically homogeneous and people can vary in their susceptibility to environmental hazards. There are well-established examples in the literature of the genetic predisposition of some groups, which could influence sensitivity to disease. There could also be a dependence on age. We conclude therefore that it is not possible at present to say that exposure to RF radiation, even at levels below national guidelines, is totally without potential adverse health effects, and that the gaps in knowledge are sufficient to justify a precautionary approach. In the light of the above considerations we recommend that a precautionary approach to the use of mobile phone technologies be adopted until much more detailed and scientifically robust information on an health effects becomes available. We note that a precautionary approach, in itself, is not without cost but we consider it to be an essential approach at this early stage in our understanding of mobile phone technology and its potential to impact on biological systems and on human health. In addition to these general considerations, there are concerns about the use of mobile phone sin vehicles. Their use may offer significant advantages – for example, following accidents when they allow emergency assistance to be rapidly summoned. Nevertheless, the use of mobile phones whilst driving is a major issue of concern and experimental evidence demonstrates that it has a detrimental effect on drivers' responsiveness. Epidemiological evidence

Indicates that this effect translates into a substantially increased risk of an accident. Perhaps surprisingly, current evidence suggests that the negative effects of phone use while driving are similar whether the phone is hand-held or hands-free. Overall we conclude that the detrimental effects of hands-free operation are sufficiently large that drivers should be dissuaded from using either hand-held or hands-free phone.

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