Altahadi University
Faculty of Engineering
Department of Electrical &Electronics engineering

Electromagnetic Radiation from mobile phone base stations. Libyana company base stations as a case study

As partial fulfillment of the requirements for the degree of Master of Science in communication engineering

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Spring 2007
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الإهـــــــداء

إلى رمز الحب والعطاء والدتي الحبيبة

إلى رمز الصدق والخير والدي العزيز

الباحثة

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M.Sc Thesis Title:

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Libyana company base stations as a case study

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List of Abbreviations

2G	2nd Generation
3G	3rd Generation
ADC	American Digital cellular
AMPS	Advanced Mobile Phone Service
ANSI	American National Standards Institute
AUC	Authentication Center
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CEPT	Conference of European Posts and Telegraphs
D-AMPS	Digital Advanced Mobile Phone Service
DCS	Digital Cellular System
DNA	Deoxyribe Nucleic Acid
EIR	Equipment Identity Register
ELF	Extremely Low Frequency
ETSI	European Telecommunications Standards Institute
FPLMTS	Future public Land Mobile Telecommunication system
G	Gauss
GSM	Global System of Mobile
HLR	Home Location Register
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
ITU	International Telecommunication Union
MS	Mobile Station
MSC	Mobile Service Switching Center
NCRP	National Council on Radiation Protection
NMT	Nordic Mobile Telephone
NRPB	National Radiological Protection Board
PDC	Personal Digital Cellular
RFR	Radio Frequency Radiation
SAR	Specific Absorption Rate
SIM	Subscriber Identity Module
SS	Switching System
TDMA	Time Division Multiple Access
UWPC	Universal Wireless Personal Communications
VLR	Visitor location Register
W-CDMA	Wideband Code division Multiple Access
WHO	World Health Organization

Abstract

There is a substantial advancement in the world's wireless communications, and communication antennas were installed in places where people live or work. in addition. because of pervading the mobile phone networks the numerous base station antennas installed on homes and schools. As other countries, Libya has been substantial growth in use of mobile communication services; therefore. it is very important to conduct a study to measure the radiation levels from the base stations. The measurements give information on radio wave exposure levels from base stations in the mobile communication networks, and compare the radiation levels with limit values prescribed in International Commission on Non-Ionizing Radiation Protection for exposure levels.

Governmental organizations, nongovernmental organizations. and numerous people live or work near base station antennas are concerned about the health effects of radiation. Nevertheless. the scientists not emphasized if this radiation are caused adverse health effects or not.

There is no study to affirm that the electromagnetic radiations emitted by mobile base station antennas caused adverse health effects specially when emitted within limited levels that issued by international guidelines.

The aim from this research is to measure power density of selected base station on schools of local communication networks and compare the measured data with adopted guidelines for exposure levels.

The measurement of radiated power density from mobile phone base station antennas conducted for seven schools in Tripoli city, on which installed mobile phone base stations; and comparison the measured data with ICNIRP guidelines, to ensure power radiation level radiated by base

station antennas over these schools is within the level of radiation permitted by ICNIRP guidelines.

The measurements conducted using two types of measurement devices, and can be noted from conducted measurements and from all obtained results that all values of power densities was less than the international guidelines. In addition, the measurement conducted for some home appliances and mobile handsets for comparison between these measurements and that is for base stations and can be noted from measuring that some mobile handset radiated power density higher than power density, which measured under the mobile base stations.

الملخص

شهد العالم تقدما كبيرا في عالم الاتصالات اللاسلكية، فقد انتشرت هوائيات الاتصالات في العديد من الأماكن الاهلة بالسكان ، وقد ازداد الأمر بدرجة أكبر بعد ظهور شبكات اتصالات الهواتف النقالة مما أدى إلى انتشار محطات الهاتف النقال على أسطح المنازل والمدارس ، وتعددت شركات الهواتف النقالة.

لقد شهدت ليبيا كغيرها من بلدان العالم توسعا كبيرا في مجال الاتصالات اللاسلكية والهواتف النقالة مما أدى إلى تركيب العديد من هوائيات الموجات الميكروية والهواتف النقالة في الأماكن الأهلة بالسكان وعلى أسطح المدارس، ويتساءل العديد من الأباء عن ما أذا كان للإشعاعات المنبعثة من الهوائيات المركبة على أسطح المدارس أي ضرر على أبنائهم، وهذا السؤال يتداول أيضا بين الجيران القاطنين بجانب الهوائيات المركبة على منزل جارهم.لذلك من المهم جدا القيام بدراسات لقياس مستويات الإشعاعات المنبعثة من هذه المحطات. حيث أن إجراء مثل هذه القياسات يعطي مؤشر عن مستوى هذه الإشعاعات بالنسبة إلى المدى المسموح به عالميا.

لقد اهتمت العديد من البلدان وعدد من المنظمات الحكومية والجمعيات الأهلية بموضوع الطاقة الإشعاعية المنبعثة من هوائيات الهواتف النقالة وفيما كانت هذه الإشعاعات الصادرة من تلك المحطات تسبب أضرار صحية للناس الذين يعيشون أو يعملون بالقرب من محطات الهاتف النقال. لم يجزم العلماء إلى هذا اليوم ما إذا كانت هذه الموجات مضرة للإنسان أم لا ، وإذا كانت كذلك فما هي كثافة الطاقة الإشعاعية المؤثرة على الإنسان والمدى الترددي المؤثر وكذلك الجرعة المؤثرة .

هناك بعض المعايير الدولية لمستويات التعرض للموجات الكهرومغناطيسية الصادرة من محطات الهاتف النقال ، أما بالنسبة إلى ليبيا لا توجد حتى اليوم أي مواصفات قياسية في هذا المجال.

في هذا البحث سنقوم بإجراء القياسات لمستويات كثافة القدرة الإشعاعية لهوائيات الهاتف النقال لعدد سبعة مدارس في مدينة طرابلس ،للتأكد من أنها تشع ضمن المواصفات القياسية العالمية في هذا المجال، حيث تم اختيار المعيار العالمي "ICNIR STANDARAD" كمرجع لمقارنة القيم التي تم قياسها مع القيم الحدودية لهذا المعيار.

لقد تم إجراء القياسات باستخدام نوعين من الأجهزة وقد تبين من القياسات التي أجريت على عينة المدارس أن مستويات كثافة القدرة الإشعاعية أقل من المستويات القياسية العالمية .

كما قمنا بإجراء بعض القياسات على بعض الأجهزة المنزلية، وبعض أجهزة الهواتف النقالة وذلك للمقارنة بين هذه القياسات مع القياسات التي أجريت على محطات الهاتف النقال، وقد تبين من هذه القياسات إن بعض أجهزة الهاتف النقال تشع قدرة أعلى من تلك التي قيست عند محطات الهاتف النقال.

Chapter one

Radiation and Health Concerns

1-1 Introduction

The radiation, specially the electromagnetic radiation, and its importance in science and technology, and its effects on health and environment, are one of important subjects that had been studied by specialized persons, and many other people are concerned about the health effects of electromagnetic radiation. The main objective was the useful use of electromagnetic radiations, as well as, minimizing the possible effects which following the exposing to these radiations. Therefore, there is great attention to study these possible effects, to know what is the best using of the electromagnetic radiation without any health concerns. Many studies concerned about the possibility of adverse health effects arising from exposure to radiation from mobile base stations.

As an introduction to this work, will be review the electromagnetic radiation concepts, types of these radiations, and its possible effects on health and environment, will be given in this chapter, possible effects of the radiation that is radiated by mobile base stations on the health and environment will be given special attention.

1-2 Electromagnetic spectrum

The electromagnetic (EM) spectrum is a name that scientists gave to a bunch of types of radiations so that they to talk about them as a group. Radiation is an energy that travels and spreads out as it goes visible light that comes from a lamp or radio waves that come from a radio station are two types of electromagnetic radiation. Other examples of EM radiation are infrared and ultraviolet light, X-rays and gamma rays. Hot objects and events create higher energy radiation than cool objects. Only extremely hot objects or particles moving at very high velocities can create high-energy radiation like X-rays and gamma rays. A graphical representation of the electromagnetic spectrum is shown in Figure (1-1)

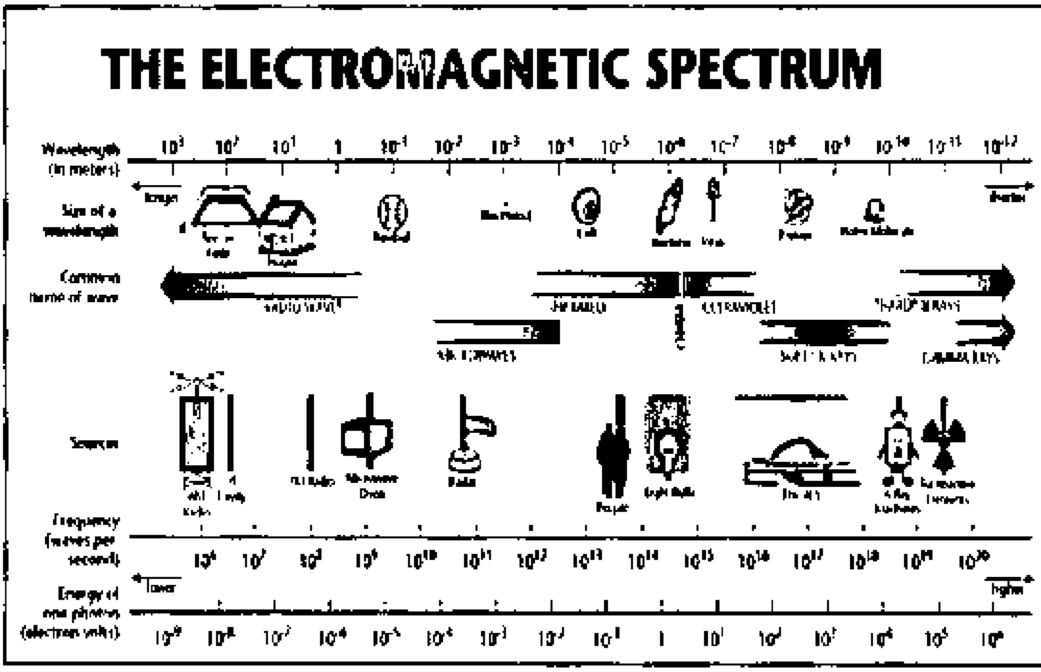


Fig (1-1) Electromagnetic spectrum [1]

1-2-1 Radio frequency

Radio frequencies are a range of frequencies, which are used for radio broadcasting stations, amateur radio, television, and mobile phones. Different parts of the radio spectrum have been allocated to the various services see Figure (1-1). Radio waves have a much longer wavelength than light waves.

1-2-2 Microwaves

The microwave spectrum is defined as electromagnetic energy ranging from approximately 1 GHz to 1000 GHz in frequency. Most common applications are within the 1 to 40 GHz range. Microwave radio is used in broadcasting and telecommunication transmissions because, due to their short wavelength. Typically, microwaves are used in television news to transmit a signal from a remote location to a television station from a specially equipped van. [2]

1-2-3 Infrared radiation

These radio/light waves have a very short wavelength; their wavelength is longer than visible light. Infrared can be detected by special infrared film. It covers the range from roughly 300 GHz (1 mm) to 400 THz (750 nm). It can be divided into three parts:

- Far infrared, from 300 GHz (1 mm) to 30 THz (10 μm). The lower part of this range may also be called microwaves. This radiation is typically absorbed by so-called rotational modes in gas-phase molecules, by molecular motions in liquids, and by phonons in solids. The water vapor in the earth's atmosphere absorbs so strongly in this range that it renders the atmosphere effectively opaque. However, there are certain wavelength ranges within the opaque range, which allow partial transmission, and can be used for astronomy. The wavelength range from approximately 200 μm up to a few mm is often referred to as "sub-millimeter". in astronomy, reserving far infrared for wavelengths below 200 μm.

- Mid-infrared, from 30 to 120 THz (10 to 2.5 μm). Hot objects (blackbody radiators) can radiate strongly in this range.

- Near infrared, from 120 to 400 THz (2,500 to 750 nm). Physical processes that are relevant for this range are similar to those for visible light [3].

1-2-4 Visible radiation (light)

The light that our eyes can see is actually part of the electromagnetic spectrum. This visible part of the electromagnetic spectrum consists of the colors that we see in a rainbow - from red, orange, through blue, and purple. Each of these colors actually corresponds to a different wavelength of light. The sun and other stars emit most of their radiation in this range.

1-2-5 Ultraviolet light (UV)

This is a radiation whose wavelength is shorter than the violet end of the visible spectrum. These waves have very high energy and very short wave lengths, UV can break chemical bonds, making molecules unusually reactive or ionizing them, in general changing their mutual behavior. Some animals as honeybees can see ultra-violet light[4] .Some plants have white flowers, at least you think that they are all white, but they may appear to be different colors to a honeybee because of the amounts of ultra-violet light that they reflect. Sunburn, for example, is caused by the disruptive effects of UV radiation on skin cells, which can even cause skin cancer, if the radiation damages the complex DNA (Deoxyribe Nucleic Acid) molecules in the cells. The sun emits a large amount of UV radiation, which could quickly turn earth into a barren desert, but most of it is absorbed by the atmosphere's ozone layer before reaching the earth surface.

1-2-6 X-rays

X-Rays have so much energy and such a short wavelength that they can go right through, they cannot get through bone as easily as they can get through muscle [4]. X-rays are used for seeing through some objects and not through others, as well as for high-energy physics and astronomy.

1-2-7 Gamma rays

The gamma rays have very high energy and will even go through metals. So they can be used for finding tiny cracks in metals. They are useful to astronomers in the study of high-energy objects or regions and find a use with physicists thanks to their penetrative ability and their production from radioisotopes. Gamma rays and X-Rays can cause cancer, but gamma rays can also be used to destroy cancer cells this is radiotherapy [4].

1-3 Types of radiation

The main two types of radiation are ionizing radiation and non-ionizing radiation.

1-3-1 Ionizing radiation

Ionizing radiation is either particle radiation or electromagnetic radiation in which an individual particle/photon carries enough energy to ionize an atom or molecule by completely removing an electron from its orbit, if the individual particles do not carry this amount of energy, it is essentially impossible for even a large flood of particles to cause ionization. If these ionizations enough occur, can be very destructive to living tissue, and can cause DNA damage and mutations, examples of particle radiation that are ionizing may be energetic electrons, neutrons, atomic ions or photons. Electromagnetic radiation can cause ionization if the energy per photon, or frequency, is high enough, and thus the wavelength is short enough. The amount of energy required varies between molecules being ionized. X-rays, and gamma rays will ionize almost any molecule or atom; Far ultraviolet, near ultraviolet and visible light are ionizing to some molecules; microwaves and radio waves are non-ionizing radiations.

Visible light ionization is so common that molecules that are ionized by it will often react nearly spontaneously unless protected by materials that block the visible spectrum [4].

Ionizing radiation sources can be found in a wide range of occupational settings, including health care facilities, research institutions, nuclear reactors and their support facilities, nuclear weapon production facilities, and other various manufacturing settings. Ionizing radiation has many uses. An X-ray is ionizing radiation, and ionizing radiation can be used in medicine to kill cancerous cells. However, although ionizing radiation has many uses the overuse of it can be hazardous to human health [5]. There are three main kinds of ionizing radiation: [6]

- Alpha particles, which include two proton and two neutrons.
- Beta particles, which are essentially electrons.
- Gamma rays and x-rays, which are pure energy (photons).

1-3-2 Non-ionizing radiation

Non-ionizing radiation has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to remove electrons. Non-ionizing radiation ranges from extremely low frequency radiation, microwave, and visible portions of the spectrum into the ultraviolet range.

ELF (Extremely low frequency) has very long wavelength and frequencies in the range of 100Hz or less. Radio frequency have frequencies in the range of 1 to 100 MHz. Microwaves have frequencies of about 3×10^9 - 3×10^{12}Hz [5].

1-4 Effects of radiation

The World Health Organization (WHO) profess that there is an international concerns about exposure to electromagnetic radiation, and some diseases; the level of these concerns varying from country to another. Attention still has been focused on the health effects of base stations radiation; this attention was from government and nongovernmental organizations. Effects of these radiations depend on three factors, are the frequency, the power, and exposure time, effect produced by exposure to little power in long time, equal to effect produced by exposure of high level to power in minor with same frequency.

1-4-1 Thermal effects

Thermal effects from radio frequency radiation (RFR) exposure are defined as biological effects that result from absorbed electromagnetic energy that elicits a biological response from the heat 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 because of the interaction with water [7].

The main objectively measurable hazard of microwave radiation is injury to the eyes, especially damaging at frequencies above 800 MHz. Since the lens of the eye does not have an adequate vascular system for the exchange of heat, even a slight rise in temperature can cause protein coagulation, and opacities in the lens may form. This may already be defined as a cataract, however in clinical practice the term cataract is normally not used unless the opacity has progressed so much as to interfere with visual acuity. Experimentally cataracts in animals develop after exposure to power densities above 100 mW/cm^2. Missing was exact information on duration. It is safe to assume a short pulse was sufficient, since most researchers feel strongly that repeated exposure of the lens to lower doses of radiation can result in accumulation of injury. [8]

1-4-2 Non-thermal effects

On balance, current research does not indicate the likelihood of any long-term health effects associated with the use of mobile phones, or through exposure to microwave radiation emitted from base stations.

Non-thermal effects are manifested as changes in cellular metabolism caused by both resonance absorption and induced EMFs and, when neural structures are involved, are often accompanied by a specific behavioral response. There has been no conclusive evidence to date that these non-thermal effects result in injury to tissue. Furthermore, these effects take place at exposure levels at or near the limits set in the Standard and not at the much lower exposure levels surrounding base stations. [9]

Important non-thermal biological effects have been demonstrated which could account for the development of cancer, asthma and the lowering of male fertility. Cell membranes carry charge and surface receptors (usually proteins) are highly charged. Signals are transuded into the cell interior where growth, development and cell division are regulated by processes, which involve ions. These features have been shown to alter their behavior in the presence of imposed external electromagnetic fields. [10]

1-4-3 Athermal effects

There is a considerable amount of scientific literature that 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 low-level effects, often referred to as athermal, are controversial and have not been shown to cause adverse health effects [7].

1-5 Electromagnetic radiation from home appliances

Electrical home equipments like hair dryers, microwave ovens, mixers, coffee makers, fridges, washing machines, conditioners, answer machines, TV, videos, mobile phones produce high electromagnetic fields near them, and diminishes quickly with distance; therefore, the person must be far enough from them when turning on these devices. This means, the level of electromagnetic pollution increases closer to the source, values of RFR for some sources are given in the Table (1-1). Of the most important electromagnetic field sources are power lines, mobile base stations, paging and other communications antennae such as those used by fire police, and emergency services, operate at similar power levels as cellular base stations, and often at a similar frequency. In many urban areas television and radio, broadcast antennae commonly transmit higher RF levels than do mobile base stations.

Table (1-1) Electromagnetic fields for some sources [11]

sources	Distance from appliance		
	10cm	30cm	50cm
Hair dryer	185mG (Gauss)	10 mG	4.6 mG
dishwasher	24 mG	4.8 mG	1.8 mG
Vacuum cleaner	45 mG	9 mG	2.6 mG
Photocopier	27 mG	6 mG	2.1 mG
Color TV	20 mG	6.2 mG	2.2 mG
Computer monitor	4.9 mG	2.1 mG	0.6 mG
Microwave oven	140 mG	4.6 mG	1.4 mG
Bedside clock radio	700 mG	2.3 mG	0.9 mG
Juicer	11.5 mG	2.2 mG	0.7 mG
Washing machine	12.3 mG	8.2 mG	5.4 mG
Sewing machine	23 mG	3.5 mG	1.2 mG
Juicing machine	20 mG	12.8 mG	6.6 mG

In some work places, there could be high level of RF pollution produced by electromagnetic waves according to type of work and its place, the places near the power lines and power distribution or near electric power networks, there is high level of electromagnetic pollution. And the people who work by Sewing machines, computers, electric devices, fax, printers, scanners, and electric motor; are exposured to high level of electromagnetic fields.

1-6 Mobile phone base stations

There has been a substantial growth use of mobile communication services over the last few years, with this growth comes the inevitable increase in the number of base station sites, base stations transmit power levels from a few watts to 100 watts or more, depending on the size of the region or "cell" that they are designed to service. Base station antennas are typically about 20-30 cm in width and a meter in length, mounted on buildings or towers at a height of from 15 to 50 meters above ground [12]. These antennas emit RF beams that are typically very narrow in the vertical direction but quite broad in the horizontal direction. Because of the narrow vertical spread of the beam, the RF field intensity at the ground directly below the antenna is low. The RF field intensity increases slightly as one move away from the base station and then decreases at greater distances from the antenna. Base stations typically transmit using beam widths roughly seven degrees in the vertical plane in elevation, and about 120 degrees or one third of a circle, in the horizontal plane. Outside this small beam, the radiation is typically 100 to 1000 times less. Usually towers have several antennas transmitting signals in different directions.

In summary, factors that influence how much RFR an individual may be exposed to include: [13]

- The power output, frequency and type of transmitter;
- The distance the person is from the transmitter;
- The location of the person with respect to the transmitted beam;
- The type of antenna and the direction of the transmitted beam;
- The presence of other structures near the person that may shield or reflect the RF signals towards him;
- The time spent in a particular area of the RF field.

Many measurements in many developed countries have been conducted to verify that the power radiated by base station antennas complies with international guidelines. Some studies that have done are:

1- In Canada a survey of five Vancouver schools, conducted in response to parental concerns about safety, showed levels of radiofrequency radiation many times below established safety limits. The maximum level at one school with PCS (Personal Digital Cellular) antenna across the street was $1620\,\mu W/m^2$, whereas the Canadian safety limit is $10\,W/m^2$. At second school with an analogue base station on roof. the maximum level was $25600\,\mu W/m^2$. At a third, also with an analogue station nearby, the maximum level was $2250\,\mu W/m^2$. The safety limit for these two situations is $5.9\,W/m^2$. Other studies in Ontario, Canada, in response to concerns about analogue base stations had even lower measurements $10\,\mu W/m^2$ at one site, and $0.2\,\mu W/m^2$ at another [14].

2- In the UK, the NRPB (National Radiological Protection Board) took measurements at 118 locations of public access near base stations and found that the maximum exposure was 0.023% of their guidelines. Another report by the NRPB in September 2004 examined exposure to the public at 610 locations in the area of 10 microcell and picocell base stations. Exposure quotients were generally in the range 0.002-2% of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) public reference level. The maximum level found was 8.6% of the reference level [15].

3- In 2001, the Radio communications Agency of the UK Department of Trade and Industry measured RF energy levels at 100 schools that had mobile phone base stations on (or near) them. The maximum RF level measured at any school was less than 1% of the ICNIRP standard [16].

4- A 2000 survey of GSM (Global System of Mobile) base stations by the Australian Radiation Protection and Nuclear Safety Agency found that public exposures to RF energy were less than 0.1% of their standard [16].

1-7 Exposure to RFR Emitted by a Base Station Antenna

The strength of RF fields is greatest at its source, and diminishes quickly with distance. Access near base station antennas is restricted where RF signals may exceed international exposure limits. Recent surveys have indicated that RF exposures from base stations and wireless technologies in publicly accessible areas (including schools and hospitals) are normally thousands of times below international standards.

1-8 Specific absorption rate

A widely adopted measurement of radiation absorption is the SAR (Specific Absorption Rate). This is defined as the derivative of energy divided by mass i.e.: dW/dm. It is measured in Watts per kilogram (W/kg). Specific absorption rate (SAR) is a measure of the rate at which radio frequency (RF) energy is absorbed by the body when exposed to radio-frequency electromagnetic field. The IEEE (Institute of Electrical and Electronics Engineers) has defined the specific absorption rate:

- "The time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density"[17].

In conclusion there is no affirmed study that the electromagnetic radiations emitted by mobile base stations cause adverse health effects specially when emitted within the limited levels issued by international guidelines these effects usually are accumulate, it may have an effect by passing time. However, it is very important to determine the levels of electromagnetic radiation emitted by base stations and to know if the radiation level radiated by base station antennas is within the level of radiation permitted by the international health organization or not.

In Libya mobile phone services has been started in 1996 by AL-Madar Company; and in 2004 Libyana started its mobile phone services. Users of mobile phone were few thousands in the ninety, and reached more than three million in 2006.

Many mobile base station antennas has been constructed over public schools, this raised a question for the public will these stations have an effect on the students or not; and here comes the question whether the radiation levels are in the range of the world standard for exposure levels or not.

In Chapter two, the mobile phone system is will be presented with some details. The information on international guidelines for exposure level of electromagnetic radiation is present in Chapter three. In this work we will measuring the RF power radiated by base station antennas and compare the results to the international guidelines limits; chapter four shows and discusses results of these measurements. Chapter five gives conclusions and recommendations.

Chapter two

Mobile System Fundamentals

2-1 Introduction

There has been substantial growth in the use of mobile communication services over the last few years, with this comes the inevitable increase in number of base station sites; that has raised questions about possible health effects of radio waves emitted by base stations. In this chapter, we will introduce some facts about mobile phone system and history of mobile communication with details about the base station and its characteristics. We will also introduce global system of mobile (GSM). Specifications of GSM, development stages of GSM, and ingredients of GSM network.

2-2 History of Mobile Communications

Cellular phone system is one of the fastest growing and most demanding telecommunications applications. Today, it represents a continuously increasing percentage of all new telephone subscribers around the world. It is forecasted that cellular systems using a digital technology will become the universal method of telecommunications.

The idea of cell-based mobile radio service was formulated in the United States at Bell Labs in the early 1970. 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 system began in the United States with the release of the advanced mobile phone service (AMPS) system in 1983. The AMPS standard was adopted by Asia, Latin America, and Oceanic countries, creating the largest potential market in the world for cellular.

In the early 1980, most mobile telephone systems were analog rather than digital, like today's newer systems. One challenge facing analog systems was the inability to handle the growing capacity needs in a cost-efficient manner. As a result, digital technology was welcomed. The advantages of digital systems over analog systems include ease of signaling, lower levels of interference, integration of transmission and switching, and increased ability to meet capacity demands, Table (2-1) shows the development of mobile telephone systems [18].

Table (2-1) Development of mobile telephone systems[18]

year	Mobile system
1981	Nordic Mobile Telephone(NMT)450
1983	American Mobile phone System (AMPS)
1985	Total Access Communication System(TACS)
1986	Nordic Mobile Telephone(NMT)900
1991	American Digital Cellular (ADC)
1991	Global System for Mobile communication(GSM)
1992	Digital Cellular System (DCS)1800
1994	Personal Digital cellular (PDC)
1995	PCS1900-Canada
1996	PCS-United States

In the past, the main applications of mobile radio communication were in the army, aviation companies, the police, the civilian advocateship, and the different commercial projects; such as ships and aircrafts navigation. In that early period, the transmitters and receivers were large and expensive.

Shortcoming of traditional radio system can be summarized in the following:

- Only car telephone service.
- Heavy, bulky and expensive equipment.
- No handover capability.
- Poor grade of service.

- Low speech quality.
- Low capacity.
- High market saturation.
- No frequency reuse.
- Power level is not safe (very high).
- Power hungry transceivers.

The rapid development of mobile telecommunications was one of the most notable success stories of the 1990s. The 2nd Generation (2G) networks began their operation at the beginning of the decade (the first GSM network was opened in 1991 in Finland), and since then they have been expanding and evolving continuously [19].

2-2-1 First Generation of Mobile Systems

The first generation of mobile cellular telecommunications systems appeared in the 1980s. The first generation was not the beginning of mobile communications, as there were several mobile radio networks in existence before then, but they were not cellular systems either. The capacity of these early networks was much lower than that of cellular networks, and the support for mobility was weaker [19].

The technologies that adopted by this system are frequency reuse, adaptive power control, cell sectorization, cell splitting, and handover.

The Shortcoming of this technology can be summarized in the following [20]:

- Depending on analog technology
- Different operating frequency ranges
- Suffer from capacity saturation
- Limited voice service
- Insufficient transmission quality
- No encryption.

2-2-2 Second Generation of Mobile Systems

The second generation (2G) of mobile cellular telecommunications appeared in the end of 1980s. There are four main standards for 2G systems; Global System for Mobile (GSM) communications and its derivatives; digital AMPS (D-AMPS); code division multiple access (CDMA) IS-95; and personal digital cellular (PDC). GSM is by far the most successful and widely used 2G system. Objectives of this generation Can be summarized in the following[20]:

- Common standard
- International roaming
- Huge capacity
- Digital encryption techniques
- Noise and interference robust
- Enhanced range of services
- Low cost equipment
- Low power consumption
- Lightweight, compact, pocket size terminals
- TDMA (Time Division Multiple Access) digital transmission
- Integrated services digital network compatibility

2-2-3 Third Generation of Mobile Systems

The third generation systems are being employed via universal wireless personal communications (UWPC) systems, which provide universal speech services and local multimedia services. The third generation personal communication systems are in the process of implementation worldwide by the International Telecommunications Union (ITU) within the framework of the future public land mobile telecommunications systems (FPLMTS)/international mobile telecommunications-2000 (IMT-2000) [21].

2-3 Principle of cellular system

The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. Instead of using one powerful transmitter, many low-power transmitters were placed throughout a coverage area to create cells variable power levels allow cells to be sized according to the subscriber density and demand within a particular region, see Figure (2-1). As mobile users travel from cell to another, their conversations are "handed off" between cells to maintain seamless services channels frequencies used in one cell can be reused in another cell some distance away [22].

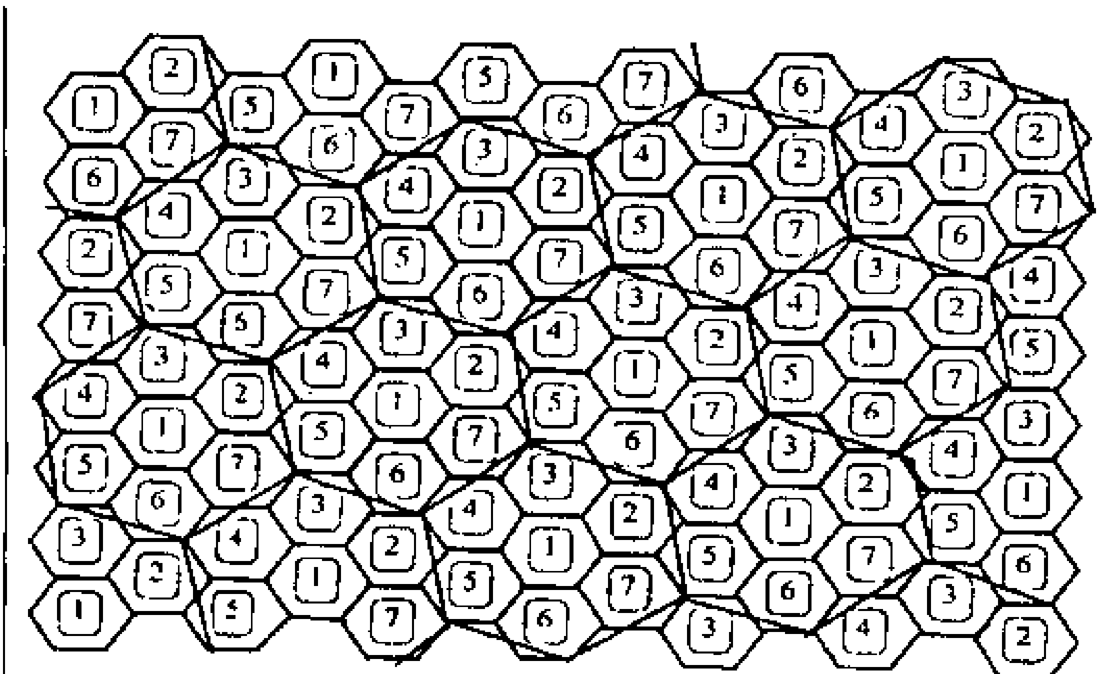


Figure (2-1) Cellular concept

2-4 Cellular system architecture

In modern cellular telephony, rural urban regions are divided into areas according to specific provisioning guidelines. Provisioning for each

region is planned according to an engineering plan that includes cells, clusters, frequency reuse and handovers.
Mobile communication network are divided into geographic areas called cells, each served by a base station.

2-4-1 Frequency reuse

Because only a small number of radio channels frequencies were available for mobile systems so the same group of channels may be used to cover different cells that are separated from one to another by distances large enough to keep interference level within tolerable limits. Interference due to common use of the same channel is called cochannel interference and is a major concern in the concept of frequency reuse [23]. The frequency reuse factor is the rate at which the same frequency can be used in the network. It is 1/n where n is the number of cells which cannot use the same frequency for transmission [24].

2-4-2 Handoff

When mobile subscriber moves into different cells, while a conversation is in progress the MSC (Mobile service Switching Center) automatically transfers the call to the new base station. Processing handoff is an important task in any cellular system; see Figure (2-2). The exact detail of the mobile system's move from one base station to the other varies considerably from system to system. For example, in all GSM handovers and W-CDMA inter-frequency handovers the mobile station will measure the channel it is meant to start using before moving over. Once the channel is confirmed okay, the network will command the mobile station to move to the new channel and at the same time start bidirectional communication there, meaning there is no break in communication. In CDMA2000 and W-CDMA (Wideband Code Time Division Multiple

Access) same –frequency handovers, both channels will actually be in use the same time this is called a soft handover or soft handoff. In IS-95, inter-frequency handovers and older analog systems such as NMT it will typically be impossible to measure the target channel directly while it is communicating. In this case other techniques have to be used such as pilot beacons IS-95. This means that there is usually a brief break in communication while it is searching for the new channel followed by the risk of an unexpected return to the old channel [24].

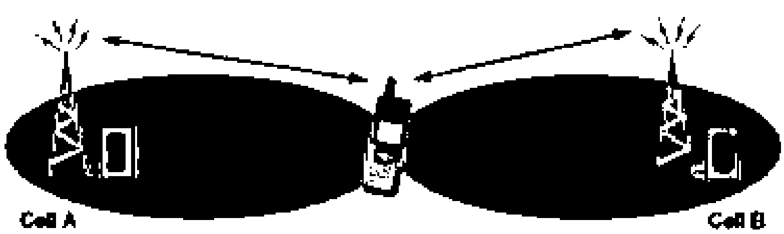


Figure (2-2) Handoff process [25]

2-4-3 Improving Coverage and capacity in cellular system

Transmitted power signal falls off rapidly with distance from base stations and mobile phones, but certain minimum signal strength is required for adequate reception. Cellular design techniques that needed to provide more channels per cell such as cell splitting, sectoring, and zone microcell concept are used to expand the capacity of cellular system.

- **Cell splitting**

When the traffic density starts building up then the frequency channel in each cell cannot provide enough mobile calls, hence the original cell can be split into smaller cells [23], each with its own base station and a corresponding reduction in antenna height and transmitter power. Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused. By defining new cell which have smaller radius than the original cells and by installing these smaller cells between the existing cells, capacity increases due the additional number of channel per unit area.

In order to cover the entire service area with smaller cells, approximately four times as many cells would be required. This can be easily shown by considering a circle with radius R; the area covered by such circle is four times as large as the area covered by a circle with radius R/2. The increased number of cells would increase the number of clusters over the coverage region, which in turn would increase the number of channels, and thus capacity, in the coverage area.

For the new cells to be smaller, the transmit power of these cells must be reduced. In practice, not all cells are split at the same time. It is often difficult for service providers to find real estate that is perfectly situated for cell splitting. Therefore, different cell size will exist simultaneously. In such situations, special care needs to be taken to keep the distance between co-channel cells at the required minimum, and hence channel assignment become more complicated. In addition, handoff issues must be addressed so that high speed and low speed traffic can be simultaneously accommodated. If the smaller transmit power is used for all the cells, there would be parts of the larger cells left unserved. For this reason, channels in the old cell must be broken down into two channel groups, one that corresponds to the smaller cell reuse requirements and the other that corresponds to the larger cell requirements. The larger cells are usually dedicated to high-speed traffic so that handoffs occur frequently.

The two channel group sizes depend on the stage of splitting process. At the beginning of the cell splitting process, there will be fewer channels in the small power groups. However, as demand grows, more channels will be required, and thus the smaller groups will require more channels. This splitting process continues until all the channels in an area are used in the lower power group, at which point cell splitting is complete within region, and the entire system is rescaled to have a smaller radius per cell [22].

- **Sectoring**

Sectoring consists of dividing an omnidirectional view from the cell site into non-overlapping slices called sectors which when combined provide the same coverage but are considered to be separate cells, as in Figure (2-3). In this approach, first, the SIR (Signal to Interference Ratio) is improved using directional antennas, and then capacity improvement is achieved by reducing the number of cell in a cluster, thus increasing the frequency reuse. In order to do this successfully, it is necessary to reduce the relative interference without decreasing the transmit power.

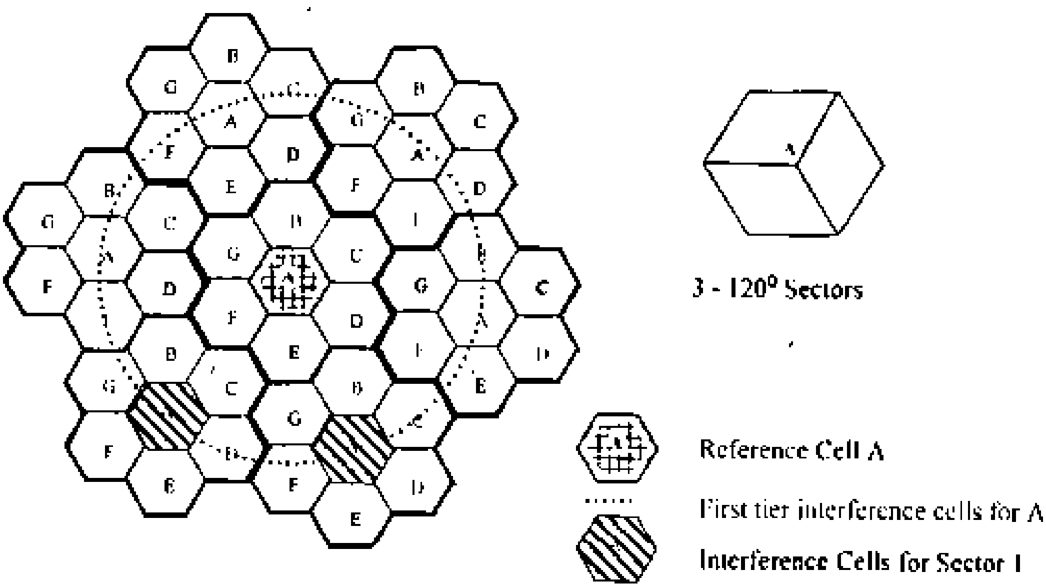


Figure (2-3) Sectoring

The factor by which the co-channel interference is reduced depends on amount of sectoring used. A cell is normally partitioned into three 120° sectors or six 60° sectors. When sectoring is employed, the channels used in a particular cell are broken down into sectored groups and are used only within a particular sector [22].

- **Microcell zone concept**

Microcell zone concept consists of a single base station with distributed system. Because the system is distributed, less power is needed per antenna.

In this approach, each of the three or possibly more zone sites is connected to single base station and share the same radio equipment. The zones are connected by coaxial cable, fiber optic cable, or microwave link to the base station. Multiple zones and single base station make up a cell. As mobile travels within the cell, it is served by the zone with strongest signal. This approach is superior to sectoring since antennas are placed at outer edge of the cell, and any base station channel may be assigned to any zone by the base station.

As mobile travels from one zone to another within the cell, it retains the same channel. Thus, unlike in sectoring, a handoff is not required at MSC (Mobile Switching Center) when the mobile travels between zones within the cell. The base station simply switches the channel to a different zone sites.

The advantages of the zone cell technique is that while the cell maintains a particular coverage radius, the co-channel interference in the cellular system is reduced since a large central base station is replaced by several lower powered transmitters on the edges of the cell. Decreased co-cannel interference improves the signal quality and leads to an increase in capacity without degradation in trucking efficiency caused by sectoring [22].

2-5 Base Station characteristics

Base stations are medium to high-power multichannnel two-away radio, which are in a fixed location. They have antennas, mounted either on freestanding masts or on exiting structures and buildings, which use radio signals similar to those used in TV and radio broadcasting. Calls pass through these antennas as people use mobile phones within their areas of coverage.

Cells usually have a radius of several kilometers. However, more base stations are needed where mobile phone usage is high. Therefore, in rural areas cells can have a radius of 10km, while in towns and cities their radius can be less than a few hundred meters. They overlap at the edges to ensure that mobile phone users remain within range of a base station.

Without sufficient base station in the right locations, mobile phones will not work. However, people who live or work close to the place where the base stations are sited sometimes-express concerns about their health [26].

2-5-1 Types of base station

Different types of relay antennas or base stations are in use, depending on the area covered and the number of calls made:

- Macrocell installations: provides the largest area of coverage within a mobile network. The most common of this type can emit a maximum power of 20 to 30 watts per frequency band. In rural settings, the power will be elevated to cover extended areas (10 - 30 km) with a limited number of user frequency bands, whereas in urban areas the power will be distributed among several user bands within a smaller area (500 m). The antennas for macrocells can be mounted on ground-based masts, rooftops at a height that is not obstructed by terrain or buildings. Macrocells provide radio coverage over varying distances depending on the frequency used, the number of calls made and the physical terrain.
- Microcells provide additional coverage and capacity where there are high numbers of users within urban and suburban macrocells. The antennas for microcells are mounted at street level,

typically on the external walls of existing structures, lampposts and other street furniture. Microcell antennas are smaller than macrocell antennas and when mounted on existing structures can often be disguised as building features. Microcells provide radio coverage over distances, typically between 300m and 1000m and have lower output powers compared to macrocells, usually a few watts.

- Picocells provide more localized coverage than microcells. These are normally found inside buildings where coverage is poor or where there are a high number of users such as airport terminals, train stations or shopping centers [27].

The characteristics of each type of base station are summarized in table (2-2).

Table (2-2) Characteristics of types of base station

Type of cell	Macro	Micro	Pico
Beam	<20 km	< 1000m	<100 m
Antenna	Rooftops	Sides of Buildings	Ceilings, Walls
Applications	Countryside Urban areas Cities	High call density	Buildings, City centers
Data rate	<144 kb/s	<384 kb/s	<2 Mb/s

2-5-2 Antenna beam shapes

There are many different types of base station antennas, and the RF energy patterns from them can be quite different. The most basic difference is between high-gain antennas and low-gain antennas. Unfortunately, the development of newer antenna designs and the variety of different ways to stealth (hide) antennas now often makes it impossible to determine what kind of antenna has been installed just by looking. The RF patterns for different types of antennas are very different. For a low-gain antenna with a 1000 W of the type formerly used by many mobile phone base stations, [16] the pattern shown in the Figure (2-4).

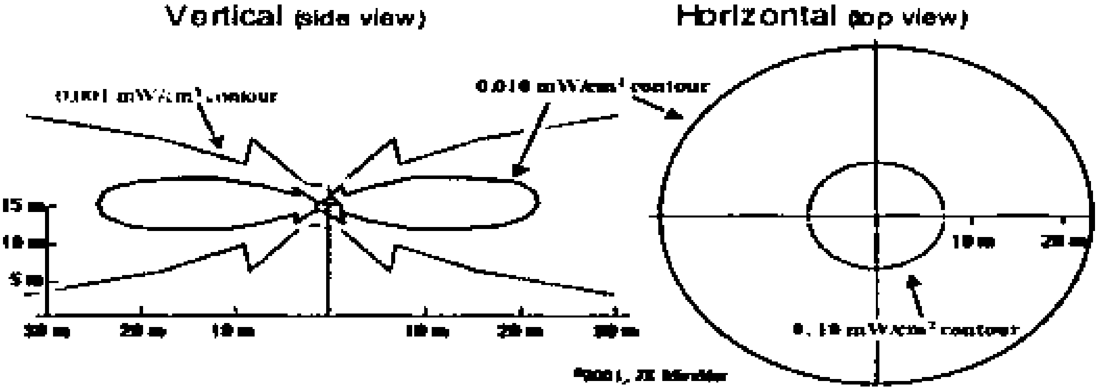


Figure (2-4) Pattern for low gain antenna [16]

For a high-gain (sector) antenna of the type used in many of the newer base stations, the pattern shown in the Figure (2-4).

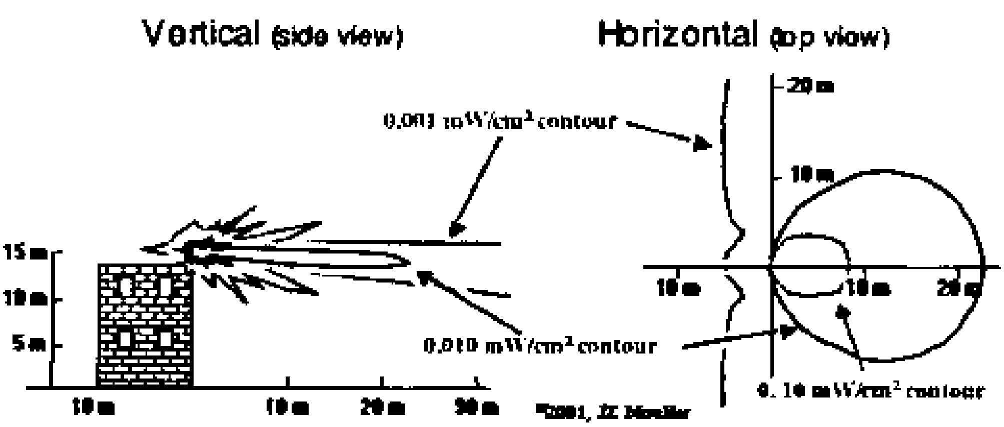


Figure (2-5) Pattern for high gain antenna [16]

The power from antennas used with macrocellular base stations is radiated in conical fan-shaped beams, which are essentially directed towards the horizon with a slight downward tilt. This is illustrated in Figure (2-6) and it causes the radio wave strengths below the antennas and at the base of masts to be very much lower than directly in front of the antennas at a similar distance. The beams from the antennas spread out with distance and tend to reach ground level at distances in the range of 50-300 m from the antennas. The radio wave levels at these distances are much less than those directly in front of the antennas and can easily be calculated. At distances closer to the mast than where the main beam reaches ground level, exposure occurs due to weaker beams known as sidelobes whose power density is not so easy to calculate unless one has detailed technical information about the beam pattern from the antennas [27].

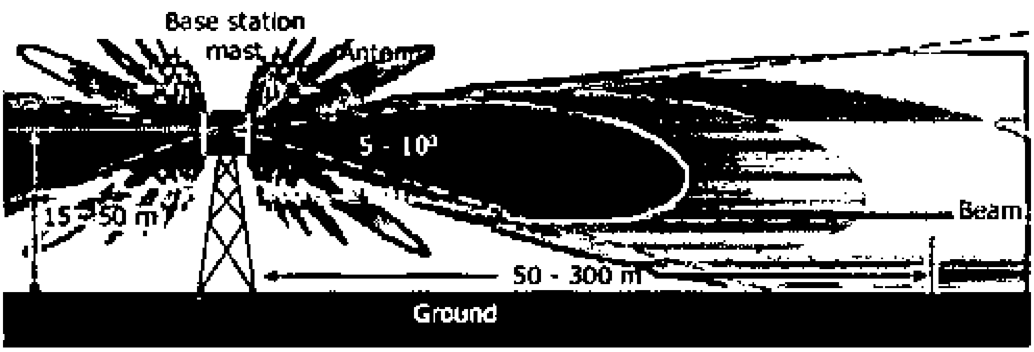


Figure (2-6) Macrocellular base station's beam [27]

2-6 Frequency allocations

The frequency bands used by mobile phone network are as shown in Table (2-3). Each frequency band contains a large number of channels. The GSM900 systems operate close to 900MHz and the GSM1800 system operate close to 1800MHz.

Table (2-3) Frequency bands for mobile phone network

Frequency band (MHz)			Channel spacing (KHz)	Number of channels
system	uplink	Downlink		
GSM900	890-915	935-960	200	174
GSM1800	1710-1785	1805-1880	200	374

Each GSM radio channel consists of paired uplink and downlink frequencies that are exactly 45MHz apart for GSM900 and 95MHz apart for GSM1800.

2-7 Output power from base station

Varieties of different power classes are defined in the GSM standard and these are as shown in Table (2-4).

Table (2-4) Output power from GSM900 and GSM1800 base station transmitters

GSM900			**GSM1800**		
Cell type	Power class	Power(W)	Cell type	Power class	Power(W)
Macro	1	320-(<640)	Macro	1	20-(<40)
Macro	2	160-(<320)	Macro	2	10-(<20)
Macro	3	80-(<160)	Macro	3	5-(<10)
Macro	4	40-(<80)	Macro	4	2.5(<5)
Macro	5	20-(<40)			
Macro	6	10-(<20)			
Macro	7	5-(<10)			
Macro	8	2.5(<5)			
Micro Micro	M1 M2	(>.08)-.25) (>.025-.08)	Micro Micro	M1 M2	(>.05)-1.6 (>0.16)-0.5
Micro	M3	(>.008)-.025	Micro	M3	(>0.05)-.16
Pico	P1	(>.02)-0.1	Pico	P1	(>0.04)-0.2

Where the shadow part show the sort and power used in Libya.

Base stations often contain more than one transmitter and the outputs of each transmitter are combined before being fed via cables to the radiating antennas. When the signal are combined, the radiated power would ideally be equal to sum of the output powers from the transmitters, but some loss occurs in combiner and connecting cables. This loss is generally between 4 and 6 dB so the power radiated by the antennas will be less than half of that produced by the transmitters.

2-8 Global System for Mobile

Global system for mobile communication (GSM) is globally accepted standard for digital cellular communication. The development of GSM started in 1982, when the Conference of European Posts and Telegraphs (CEPT) formed a study group called Group Special Mobile (the initial meaning of GSM). The group was to study and develop a pan-European public cellular system in the 900MHz range. In 1989, the responsibility for GSM was transferred to the European Telecommunication Standards Institute (ETSI). Commercial operation of GSM network started in mid-1991 in European countries. By the beginning of 1995, there were 60 countries with operational or planned GSM networks in Europe, the Middle East, the Far East, Australia, Africa, and South America, with over 5.4 million subscribers [22].

2-8-1 Architecture of the GSM network

The functional architecture of a GSM system can be divided into the mobile station is carried by the subscriber, the base station controls the radio link with the Mobile Station, and the network subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.

1-Mobile station (MS)

The mobile station consists of the mobile equipments and 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 International Mobile Equipment Identity (IMEI) uniquely identifies the mobile equipment. The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information. The IMEI and the IMSI are independent, thereby allowing personal mobility. The SIM card may be protected against unauthorized use by a password or personal identity number.

2-Base Station Subsystem

The base station subsystem is composed of two parts, the base transceiver station (BTS) and the base station controller (BSC), Figure (2-7) shows base station subsystem. The BTS is radio equipment needed to serve each cell in the network. It handles the radio link with to mobile station. In large urban area, there will be a large urban area. there will be a large number of BTSs deployed, and thus the requirements for BTS are raggedness, reliability, portability and minimum cost.

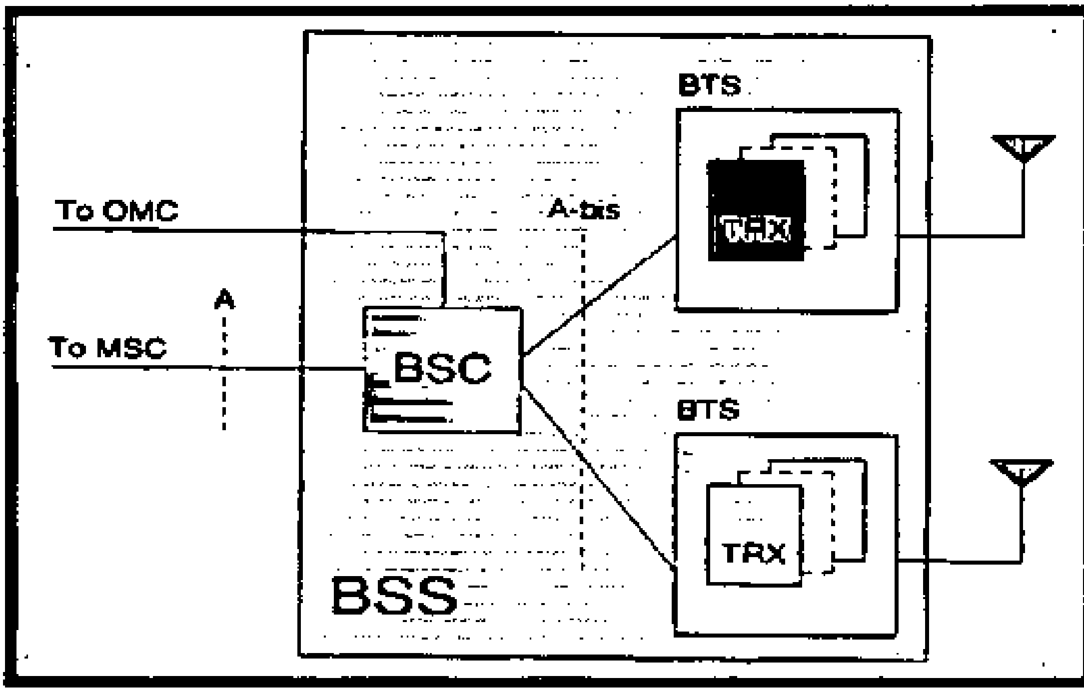


Figure (2-7) Base station subsystem

The BSC provide all the control functions and physical links between the MSC and BTS. It handles radio channel setup, frequency hopping and handovers. The BSC is the connection between the mobile station and the mobile service-switching center (MSC).

3-The Switching System

The switching system (SS) is responsible for performing call processing and subscriber- related function. The switching system includes the following functional units:

- **Home location register (HLR):** The HLR is database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status [18], it is illustrated in Figure (2-8).

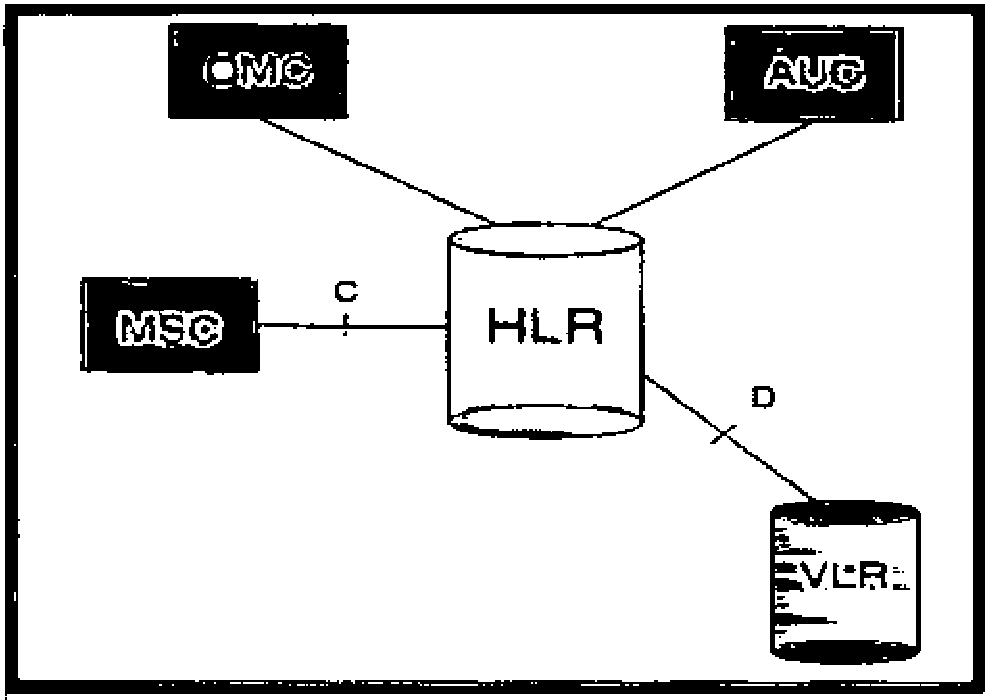


Figure (2-8) Home location register [20]

- **Mobile services switching center (MSC):** the MSC performs the telephony switching functions of the system, it is illustrated in Figure (2-9). It control calls to and from other telephone and data system. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others [18].

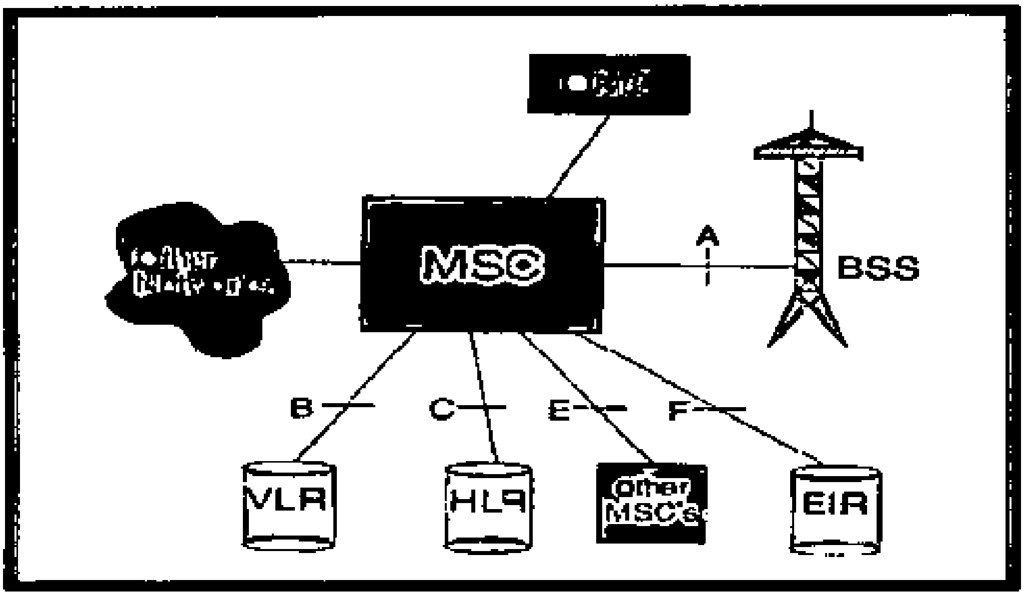


Figure (2-9) Mobile service switching center [20]

- **Visitor location register (VLR):** The VLR is database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. When mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. If the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time [18]; it is illustrated in Figure (2-10).

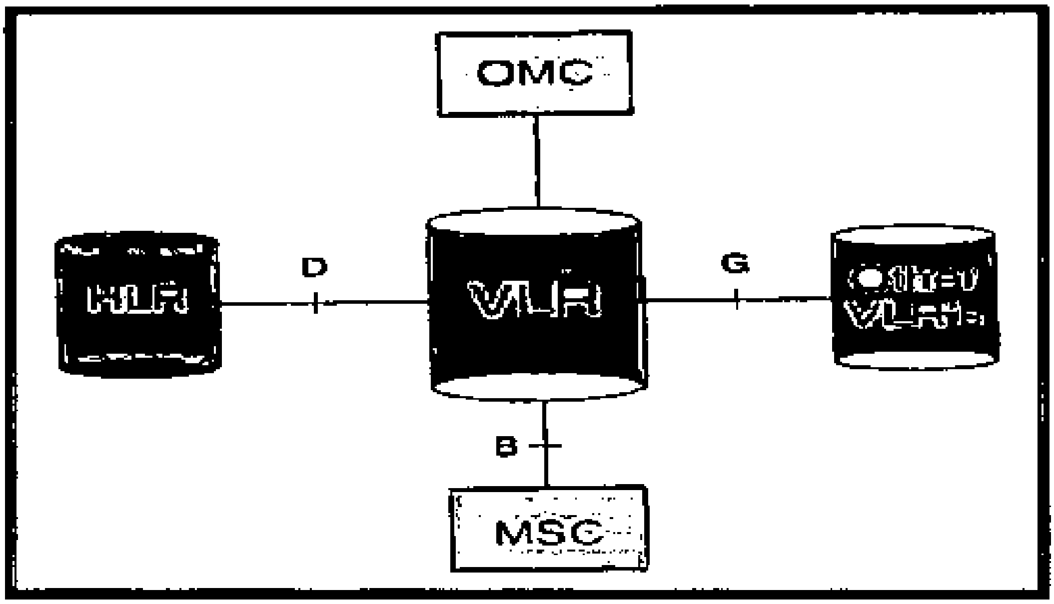


Figure (2-10) Visitor location register[20]

- **Authentication center (AUC):** A unit called the AUC provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects network operators from different types of fraud found in today's cellular world [18]; it is illustrated in Figure (2-11).

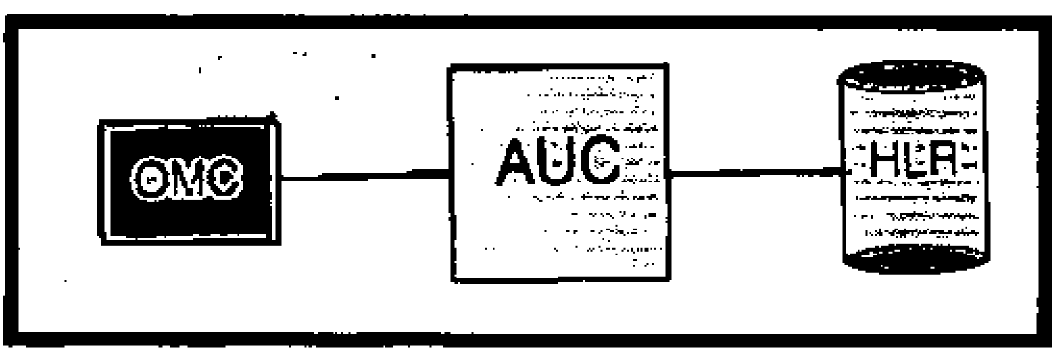


Figure (2-11) Authentication center [20]

- **Equipment identity register (EIR):** The EIR is a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations [18]; it is illustrated in Figure (2-12).

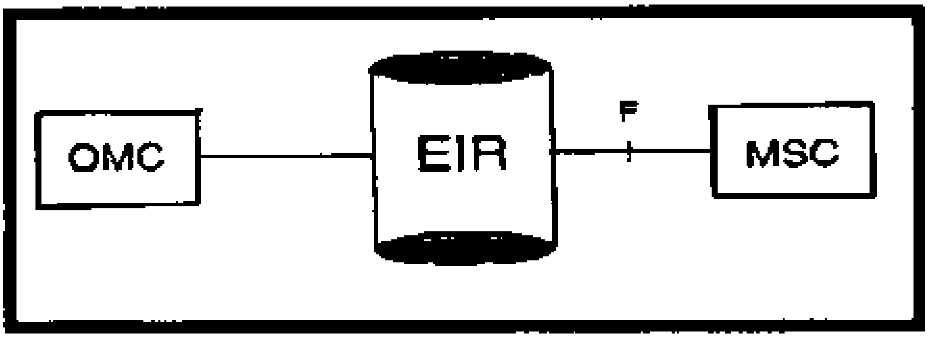


Figure (2-12) Equipment identity registers [20]

Chapter three

EM radio Exposure Guidelines

3-1 Introduction

During the second half of the twentieth century, there has been concentrated effort to establish and refine the radiation exposure standards and guidelines for ionizing radiation. Emphasis on the non-ionizing portion of the electromagnetic spectrum over the past twenty years has resulted in exposure limit values for the optical region of the spectrum, as well as the radio frequency and ELF regions.

There are national and international safety guidelines for exposure of the public to the RF energy produced by mobile phone base station antennas. The most widely accepted standards are those developed by the Institute of Electrical and Electronics Engineers and American National Standards Institute (ANSI/IEEE), the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the National Council on Radiation Protection and Measurements (NCRP) [16].

When scientists have examined all the published literature on the biological effects of RF energy, they found that the literature agreed on a number of key points:

1. Exposure to RF energy can be hazardous if the exposure is sufficiently intense. Possible injuries include cataracts, skin burns, deep burns, heat exhaustion and heat stroke.
2. Biological effects of RF energy depend on the rate of energy absorption: and within a broad range of frequencies (1 to 10,000 MHz), the frequency matters very little.
3. Biological effects of RF energy are proportional to the rate of energy absorption; and the duration of exposure.

4. No biological effects have been consistently shown below a certain rate of whole body energy absorption (SAR).

Based on this scientific consensus, different agencies and countries took different approaches to setting safety guidelines. A typical approach was that used by ANSI/IEEE and ICNIRP [16]:

1. They reviewed the scientific literature to find the lowest energy absorption rate (SAR) that consistently showed potentially harmful biological effects.
2. To establish occupational exposure guidelines, they applied a 10-fold safety margin to that SAR.
3. They then applied an additional 5-fold safety margin to establish guidelines for continuous exposure of the general public.
4. Finally, detailed engineering and physics studies were done to establish the relationship of power density, which can be routinely measured, to the energy absorption rate (SAR), which really matters.
5. The result was a highly conservative public exposure guideline that was set at a level that is only 2% of the level where potentially harmful biological effects have actually been demonstrated.

There are differences between the standards. ANSI/IEEE, ICNIRP and FCC all use the same general approach to setting safety guidelines. However, there are differences in the physics models used by the different groups, and hence there are slight differences in the final numbers. A number of countries have their own regulations for public exposure to RF energy from mobile phone base station antennas. While most of these regulations follow the same patterns and rationales used by ANSI/IEEE and ICNIRP, they do differ.

Some countries (e.g., Switzerland and Italy) have adopted regulations for public exposure to RF energy that are dramatically lower than the ANSI/IEEE and ICNIRP guidelines. In general, these lower numbers are based on political considerations rather than on different interpretations of the science [16].

This part of research reviews the most sets of guidelines.

3-2 ICNIRP guidelines

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 develops international guidelines on limits of exposure to non-ionizing radiations and the guidelines on limiting exposure to electromagnetic fields were published in April 1998 [15].

3-2-1 Basic restrictions

The ICNIRP guidelines specify basic restrictions on SAR and state "protection against adverse health effects requires that these basic restrictions are not exceeded". The basic restrictions on SAR that apply to frequency within range 10MHz to 10GHz for occupational and public exposure are given in Table (3-1). Restrictions are to be time-averaging over a six-minute period. The restrictions on localized SAR permit averaged over a 10 g mass of contiguous tissue.

For exposure to radio waves with frequencies between 10 and 300 GHz, the ICNIRP guidelines stipulate basic restrictions on power density alone. The basic restrictions are 50 W/m^2 for occupational exposure and 10 W/m^2 for exposure of the general public. Provision is also made by averaging power density over specified areas of the body surface in this frequency range so the ICNIRP guidelines are complied with if the following two conditions are satisfied:

1- The power density averaged over 20 cm^2 is less than the basic restrictions.

2- The power density averaged over 1 cm^2 is less than the 20 times the basic restriction [15].

Table (3-1) ICNIRP basic restrictions on exposure to electric and magnetic fields in frequency range 10MHz to 10 GHz for occupational and general public exposure[15]

Exposure quantity	occupational	General public
SAR averaged over the body and over any 6 minute period	0.4W /kg	0.08W/ kg
SAR averaged over any 10 g in the head and trunk and over any 6 minute period	10 W /kg	2W/ kg
SAR averaged over any 10 g in the limbs and over any 6 minute period	20W/ kg	4W/ kg

3-2-2 Reference levels

A system of reference levels is given by ICNIRP and the levels reflect the factor of five differences between the public and occupational basic restrictions. Compliance with the reference levels ensures compliance with the ICNIRP basic restrictions. The reference levels for occupational exposure to electromagnetic fields in the frequency range 10MHz to 300GHz are given in Table (3-2).Reference levels for exposure of the public are given in Table (3-3).

Table (3-2) ICNIRP reference levels for occupational exposure to electromagnetic fields in the frequency range 10MHz to 300GHz[15]

Frequency range	Electric field strength (v/m)	Magnetic field strength (A/m)	Power density (w/m^2)
10-400MHz	61	0.16	10
400-2000MHz	$3f^{\frac{1}{2}}$	$0.008f^{\frac{1}{2}}$	f/40
2-300GHz	137	0.36	50

Table (3-3) ICNIRP reference levels for general public exposure to electromagnetic fields in the frequency range 10MHz to 300GHz[15]

Frequency range	Electric field strength (v/m)	Magnetic field strength (A/m)	Power density (w/m^2)
10-400MHz	28	0.073	2
400-2000MHz	$1.375f^{\frac{1}{2}}$	$0.0037f^{\frac{1}{2}}$	f/200
2-300GHz	61	0.16	10

Where f is the frequency in MHz.

The lowest values of the reference levels over bands at which mobile phone base stations are summarized in Table (3-4).

Table (3-4) ICNIRP reference levels for public and occupational exposure at transmit frequency of base stations.[15]

guidelines	power density (w/m^2)		
	TACS/GSM900	GSM1800	2100MHz
ICNIRP worker	23	45	-
ICNIRP public	4.6	9	10
Electric field strength(v/m)	41	58	61

The ICNIRP guidelines are applied in some of countries in the world; these countries are France, Germany, Brazil, Norway, Malta, Ireland, Netherlands, Austria, New Zealand, Spain, Australia, Belgium, and Czech Republic. In addition, there are another countries issued own guidelines, we will show some of these guidelines for this countries.

3-3-1 United Kingdom guideline

The advice relevant to radiofrequency radiation provided is contained in published guidelines on restricting human exposure to time-varying electromagnetic fields and radiation with frequencies up to 300GHz [28].

The four basic restrictions on SAR that apply for exposure to electromagnetic fields with frequencies between 10MHz and 10 GHz are listed in Table (3-5). The investigation levels are frequency dependent and are shown in Table (3-6)

Table (3-5) NRPB basic restrictions on exposure to electric and magnetic fields in the frequency range 10MHz to 10GHz.[28]

Exposure quantity	occupational
SAR averaged over the body and over any 15 minute period	0.4W /kg
SAR averaged over any 10 g in the head or fetus and over any 15 minute period	10 W /kg
SAR averaged over any 100 g in the neck and trunk and over any 6 minute period	10 W/ kg
SAR averaged over any 100 g in the limbs and over any 6 minute period	20W/ kg

Table (3-6) NRPB investigation levels for exposure to electric and magnetic fields in the frequency range 12MHz to 300GHz[28]

Frequency range	Electric field strength(V/m)	Magnetic field strength(A/m)	Power density (w/m^2)
12-200MHz	50	0.13	6.6
200-400MHz	250f	0.66f	165f^2
400-800MHz	100	0.26	26
0.8-1.55GHz	125f	0.33f	41f^2
1.55-300GHz	194	0.52	100

3-3-2 United States of America guideline

The U.S. Federal Communications Commission issued Radiofrequency Radiation Exposure Limits that published in 1996 [29]. The basic restrictions and reference levels given in Tables (3-7) and (3-8). Where f is frequency in MHz

Table (3-7) Basic restrictions for time varying electric and magnetic fields up to 300GHz[29]

Exposure category	Frequency range	Whole-body average SAR (W/kg)	Spatial peak SAR in the head & trunk (W/kg)	Spatial peak SAR in limbs (W/kg)
Occupational	0.3MHz-6GHz	0.4	8	20
General public	0.3MHz-6GHz	0.08	1.6	4

Table (3-8) Reference levels for time varying electric and magnetic fields up to 300GHz[29]

Exposure category	Frequency range	E-field strength (kV/m)	H-field strength (A/m)	Equivalent plane wave power density (W/m^2)	AVG time (min)
Occupational	0.3-3.0 MHz	0.614	1.63	1000	6
	3.0-30 MHz	1.842/f	4.89/f	9000/f*2	6
	30-300 MHz	0.0614	0.163	10	6
	300-1500 MHz	-	-	f/30	6
	1.5-100 GHz	-	-	50	6
General public	0.3-3.0 MHz	0.614	1.63	1000	30
	3.0-30 MHz	0.824/f	2.19/f	1800/f*2	30
	30-300 MHz	0.0275	0.073	2	30
	300-1500 MHz	-	-	f/150	30
	1.5-100 GHz	-	-	10	30

3-3-3 Canada guideline

The Health ministry of Canada issued Guidelines document in 1999 [30]. The restrictions and reference levels given in Tables (3-9) and (3-10). Where f is frequency in MHz

Table (3-9) Basic restrictions for time varying electric and magnetic fields up to 300 GHz [30]

Exposure category	Frequency range	Whole-body average SAR (W/kg)	Spatial peak SAR in the head & trunk (W/kg)	Spatial peak SAR in limbs (W/kg)	Power density (W/m^2)
Occupational	100 kHz - 10 GHz	0.4	8	20	
	10 GHz - 150 GHz				50
	150 GHz - 300 GHz				$3.33 \times 10^{-}$[illegible] f
General public	100 kHz - 10 GHz	0.08	1.6	4	
	10 GHz - 150 GHz				10
	150 GHz - 300 GHz				$6.67 \times 10^{-5} f$

Table (3-10) Reference levels for time varying electric and magnetic fields up to 300GHz[30]

Exposure category	Frequency range (MHz)	E-field strength (V/m)	Equivalent plane wave power density (W/m^2)	Averaging time
Occupational	0.003 - 1	600		6
	1.0 - 10.0	$600/f$		6
	10.0 - 30.0	60		6
	30 - 300	60	10*	6
	300 - 1500	$3.54f^{0.5}$	$f/30$	6
	1500 - 15000	137	50	6
	15000 - 150000	137	50	$616000/f^{1.2}$
	150000 - 300000	$0.354f^{0.5}$	$3.33 \times 10^{-4} f$	$616000/f^{1.2}$
General public	0.003 - 1	280		6
	1.0 - 10.0	$280/f$		6
	10.0 - 30.0	28		6
	30 - 300	28	2*	6
	300 - 1500	$1.585f^{0.5}$	$f/150$	6
	1500 - 15000	61.4	10	6
	15000 - 150000	61.4	10	$616000/f^{1.2}$
	150000 - 300000	$0.158f^{0.5}$	$6.67 \times 10^{-5} f$	$616000/f^{1.2}$

*Power density limit is applicable at frequencies greater than 100 MHz

3-3-4 Japan guideline

Ministry of Public Management, Home Affairs, Posts and Telecommunication (MPHPT) issued Radio-Radiation Protection Guidelines for Human Exposure to EMF in 1990 [31]. The basic restrictions and reference levels given in Table (3-11) and (3-12)

Table (3-11) Basic restrictions for time varying electric and magnetic fields up to 300 GHz[31]

Exposure category	Frequency range	Whole-body average SAR (W/kg)	Spatial peak SAR in the head & trunk (W/kg)	Spatial peak SAR in limbs (W/kg)
Occupational	100kHz-3GHz	0.4	10 (10 g ave.)	20(10 g ave.)
General public	100kHz-3GHz	0.08	2 (10 g ave)	4 (10 g ave.)

Table (3-12) Reference levels time varying electric and magnetic fields up to 300GHz.[31]

Exposure category	Frequency range	E-field strength (kV/m)	H-field strength (A/m)	Equivalent plane wave power density (W/m^2)
Occupational	10 kHz - 30 kHz	0.614	163	-
	30 kHz - 3 MHz	0.614	4.9/f	-
	3 MHz - 30 MHz	1.842/f	4.9/f	-
	30 MHz - 300MHz	0.0614	0.163	10
	300 MHz –1.5 GHz	0.00354$f^{1/2}$	$f^{1/2}$/106	f/30
	1.5 GHz –300 GHz	0.137*f [MHz]	0.365*f[MHz]	50*f [MHz]
General public	10 kHz - 30 kHz	0.275	72.8	-
	30 kHz - 3 MHz	0.275	2.18/f	-
	3 MHz - 30 MHz	0.824/f	2.18/f	-
	30 MHz - 300MHz	0.0275	0.0728	2
	300 MHz - 1.5 GHz	0.001585$f^{1/2}$	$f^{1/2}$/237.8	f/150
	1.5GHz-300 GHz	0.0614*f[MHz]	0.163* f [MHz]	10* f [MHz]

3-3-5 China guideline

State Environmental Protection Administration of China issued Regulations for electromagnetic radiation protection in Mar. 11, 1988 [32].

The basic restrictions and reference levels given in Tables (3-13) , (3-14) and (3-15).

Table (3-13) Basic restrictions for time varying electric and magnetic fields up to 300GHz[32]

Exposure category	Frequency range	Whole-body average SAR (W/kg)	Power density (W/m^2)
Occupational	100 kHz - 300 GHz	0.1 W/kg	-
General public	100 kHz - 300 GHz	0.02 W/kg	-

Table (3-14) Reference levels for time varying electric and magnetic fields up to 300GHz[32]

Exposure category	Frequency range	E-field strength (V/m)	H-field strength (A/m)	Equivalent plane wave power density (W/m^2)
Occupational	100 kHz - 3 MHz	87	0.25	
	3 MHz - 30 MHz	$150/f^{0.5}$	$0.4/f^{0.5}$	
	30 MHz -3000MHz	28	0.075	2
	3000 MHz – 15000 MHz	$0.5 f^{0.5}$	$0.0015 f^{0.5}$	f/1500
	15000MHz–30000MHz	61	0.16	10
General public	100 kHz - 3 MHz	40	0.1	
	3 MHz - 30 MHz	$67/f^{0.5}$	$0.17/f^{0.5}$	
	30 MHz -3000 MHz	12	0.032	0.4
	3000 MHz – 15000 MHz	$0.22 f^{0.5}$	$0.001 f^{0.5}$	f/7500
	15000 MHz – 30000 MHz	27	0.073	2

Table (3-15) Exposure limits for microwave in working place[32]

Microwave type	Frequency range	Power density ($\mu W/cm^2$)
Continuous, whole body	300 MHz – 300 GHz	400/t
Pulsed, whole body		200/t
Any type, limb exposure		4000/t

Where (t) is the exposure time in hours (h)

3-3-6 Russian federation guideline

State committee for standardization (GOST) issued standard system in 1984 [33]. The basic restrictions and reference levels given in Tables (3-16) and (3-17).

Table (3-16) Basic restrictions for time varying electric and magnetic fields up 300 GHz[33]

Exposure category	Frequency range	$W_E = E^2 \cdot T$ $[(V/m)^2 \cdot h]$	$W_H = H^2 \cdot T$ $[(A/m)^2 \cdot h]$	$W_s = S.T$
Occupational	0.03-3MHz	20000	200	
	3-30 MHz	7000	-	
	30-50 MHz	800	0.72	
	50-300MHz	800	-	
	0.3-300GHz			200

Table (3-17) Reference levels for time varying electric and magnetic fields up to 300GHz.[33]

Exposure category	Frequency range	E-field strength (V/m)	H-field strength (A/m)	Equivalent plane wave power density (W/m^2)
Occupational	10- 30 kHz	500^{b} ($1,000^{a}$)	50^{b} (100^{a})	
	0.03 -3 MHz	$(20.000/T)^{½}(500^{a})$	$(200/T)^{½}(50^{a})$	
	3- 30 MHz	$(7.000/T)^{½}(296^{a})$		
	30- 50 MHz	$(800/T)^{½}(80^{a})$	$(0.72/T)^{½}(3^{a})$	
	50- 300 MHz	$(800/T)^{½}(80^{a})$		
	0.3- 300GHz			$2 \cdot T^{-1}(10^{a}(50^{d}))$
General public	(0.3)- 300 kHz	25		
	0.3 -3 MHz	15		
	3- 30 MHz	10		
	30- 300 MHz	3g.		
	0.3- 300 GHz			$0.10\ (0.25^{h})$
Mobile terminal users	27– 30 MHz	45^{i}		
	30– 300 MHz	45^{i}		
	300– 2400 MHz			1^{i}

a. The ceiling limit

b. The work day limit (8 hours)

c. Peak values for pulse modulated 50 Hz magnetic field. Mode 1: pulse duration PD ≤ 0.02 s. pause between pulses TP ≤ 2 s / Mode 2: 60 s ≥ PD ≥ 1 s, TP > 2 s / Mode 3: 0.02 s ≤ PD < 1 s, TP > 2 s

d. The ceiling limit for localized exposure (hands and legs)

e. Peak values for pulsed EMF with pulse front duration from 0.1 to 50 ns and pulse duration from 1 to 1000 ns

f. Living areas outside buildings

g. MPL for radio and TV transmitters in frequency ranges 48.5̃ 108 MHz and 174̃ 230 MHz is calculated as $E_{MPL} = 21 \cdot f^{-0.37}$ [V/m], f in MHz; MPL for special purposes long range radars working in 150̃ 300 MHz frequency range is 6 V/m in the near field region and 19 V/m in the far field region

h. For rotating and scanning antennas

i. Near user's head

* Assessment of simultaneous exposure to different sources (more than one in the same place) of EMR or both to electric and magnetic fields is determined by the following relations:

3-3-7 Bulgaria guideline

Agency of standardization and metrology issued standards in 1990 [34] The basic restrictions and reference levels given in Tables (3-18). (3-19) and (3-20).

Table (3-18) Reference levels for static electric and magnetic fields.[34]

Exposure category	E-field strength (kV/m)	B-field (mT)	B-field, ceiling (mT)	B-field, pacemakers (mT)
Occupational	25	60	2000	1.0
General public	-	-	-	-

Table (3-19) Basic restrictions for time varying electric and magnetic fields up to 300 GHz[34]

Exposure category	Frequency range	$W_E = E^2.T$ [$V^2/m^2.h$]	$W_H = H^2.T$ [$A^2/m^2.h$]	$W_S = S.T$ [$\mu W/cm^2.h$]
Occupational	60 kHz-3 MHz	20000	200	
	3 MHz-30 MHz	3200	200	
	30 MHz-300MHz	800		
	300MHz-300GHz			200
General public	-	-	-	-

Table (3-20) Reference levels for time varying electric and magnetic fields up to 300 GHz[34]

Exposure category	Frequency range	E-field strength (V/m)	H-field strength (A/m)	B-field (mT)	Equivalent plane wave power density (W/m2)
Occupational	0 Hz-100 Hz	25,000*		60/f	
	100 Hz-4kHz	2.5x106/f		60/f	
	4 kHz-60 kHz	625		60/f	
	60 kHz-3 MHz	500	50.0		
	3 MHz-10 MHz	200	50.0		
	10 MHz-30 MHz				
	30MHz-300MHz	60	0.16		
	300MHz-300GHz				10.0**
General public	30 - 300 kHz	25			
	0.3 - 3 MHz	15			
	3 - 30 MHz	10			
	30 - 300 MHz	3			
	0.3 - 30 GHz				0.10

* For 50 Hz this is the ceiling limit; the workday limit (8 hours) is 5 kV/m. The time limitations between 5 and 25 kV/m are the following: up to 180 min for 5-10 kV/m; up to 90 min for 10-15 kV/m; up to 10 min for 15-20 kV/m, and up to 5 min for 20-25 kV/m.
** In the presence of ionizing radiation and/or high temperatures (above 28° C) maximal permissible exposure should be not more than 1 W/m2

*** Assessment of simultaneous exposure to different sources (more than one in the same place) of EMR or both to electric and magnetic fields is determined by the following relations

3-3-8 Turkey guideline

Telecommunication commission issued regulation of EMF reference values, at the frequency band 10 KHz – 60GHz in July, 12, 2001 [35] The reference levels given in Table (3-21).

Table (3-21) Reference levels for time varying electric and magnetic fields up to 300GHz [35]

Frequency (MHz)	Total E-Field (V/m)	Total H-Field (A/m)	Total B-Flux density (μT)	Total power density (W/m²)
0.010 - 0.15	87	5	25,06	-
0.15 - 1.0	87	0.73/f	0.92/f	-
1.0 - 10	$87 / f^{1/2}$	0.73/f	0.92/f	-
10 - 400	28	0.073	0.092	2
400 - 2000	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	f/200
2000 - 60000	61	0.16	0.2	10

3-3-9 Taiwan guideline

The Taiwan EPA issued limits for environmental exposure to non- ionizing radiation in January, 12, 2001 [36]. The basic restrictions and reference levels given in Table (3-22).

Table (3-22) Reference levels for time varying electric and magnetic fields up to 300 GHz[36]

Exposure category	Frequency range	E-field strength (kV/m)	H-field strength (A/m)	B-field (mT)	Equivalent plane wave power density (W/m²)
Occupational	-	-	-	-	-
General public	Up to 1 Hz	-	3.2 × 104	4 × 104	-
	1-8 Hz	10,000	$3.2 \times 104/f^2$	$4 \times 104/f^2$	-
	8-25 Hz	10,000	4,000 × 104/f	5,000/f	-
	0.025-0.8 kHz	250/f	4/f	5/f	-
	0.8-3 kHz	250/f	5	6.25	-
	3-150 kHz	87	5	6.25	
	0.15-1 MHz	87	0.73/f	0.92/f	-
	1-10 MHz	$87/f^{1/2}$	0.73/f	0.92/f	-
	10-400 MHz	28	0.073	0.092	2
	400-2000MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	f/200
	2-300 GHz	0.1	0.16	0.2	10

3-3-10 Italy guideline

President of the Council of Ministers Issued exposure limits, attention values, and quality goals to protect the population against electric, magnetic, and electromagnetic fields generated at frequencies between 100 kHz and 300 GHz" in August 28, 2003[37]. It is shown in Table (3-23)

Table (3-23) Reference levels for time varying electric and magnetic fields up to 300 GHz[38]

Exposure limits	Electric field strength (v/m)	Magnetic field strength (A/m)	Power density (w/m^2)
0.1 < f = 3 MHz	60	0.2	-
3 < f = 3000 MHz	20	0.05	1
3 < f = 300 GHz	40	0.1	4
(Attention values) 0.1< f =300GHz	6	0.016	0.1

3-3-11 Switzerland guideline

Swiss federal government issued ordinance relating to protection from non-ionizing radiation (ONIR), in 23 December 1999. [39] Installation Limit Values (ILV) given in Table (3-24).

Table (3-24) Installation Limit Values[39]

Installation	ILV (RMS value)	Reference operational state
Electric power lines; transformer stations; substations	1 μ T	Maximum rated current
Electric railways	1 μ T	24 hour average, at operation according to schedule
Cellular phone base stations 900 MHz ≥ 1800 MHz mixed frequency	 4 V/m 6 V/m 5 V/m	Maximum rated emitted power
Long- and medium-wave broadcasting	8.5 V/m	Maximum rated emitted power
Radar	5.5 V/m	Average over a complete survey scan, at maximum rated power

3-4 Libyan guideline

There is no Libyan standard set for the electromagnetic radiation yet and due to the importance of having a standard to relate any measurement of radiation levels to it; it is proposed to adopt the ICNIRP standard to be the standard to compare the radiation level to its reference level.

Chapter four

The Measurements

4-1 Introduction

Due to the expanding of mobile phone networks in Libya many mobile base station antennas has been installed on roof of many schools where students spend some times and other places where people live for the whole day long. The problem rise out of this is radiation level of the power radiated by base stations over schools; within the level of radiation permitted by the international health organization or not. Therefore, it is necessary to determine the levels of radiation exposure for these stations.

The main objective of this work is to measure RF power density level of selected base station sites of libyana and AL-Madar networks. We have chosen Tripoli city as case study for the measurements of RF power density levels for the base stations. We have selected seven sites in Tripoli where libyana and AL-Madar companies installed many antennas over schools. The study was conducted by measuring the power density on the roof of schools, the second level of school, the first level, and the ground floor where students take their lessons. The measurements were conducted in different time, different directions, and at different distances from the base station antennas. To help understanding the way we conducted the measurements we explain the methodology of measurements and the measurements in the following.

4-2 Methodology of measurements

EM power density levels have been measured in this work using a carefully designed and controlled way of measurements. Elements of this methodology include:

1 - Measurements have been made at a number of different locations around the base stations.

2 - The exact measurement position was recorded using a GPS receiver and metér.

3 - The measurements were repeated at each point three times over three days in each school.

4 - The measurements were repeated at each point three times along one day in different times in each school.

5 – The measurements were repeated in different dates to ensure the readings.

4-2-1 Site selection

Measurements were made at sites where people live., work, or has frequent access. The sites were selected which has the highest number of antennas on rooftop. People are rarely exposed to the main beam, because of close proximity to the mobile phone mast in question, or due to shielding by buildings. Measurements have been taken at seven sites in Tripoli, and these measurements have been made at a number of different locations around base station, inside buildings and rooftops and court-yards. The selected schools are:

1- Ibn Haitham School at Nufliyin in Tripoli.
2- Attasadi School at Gergaresh (Antiquity Avenue) in Tripoli.
3- Atifaq Jerba School at Gurji in Tripoli.
4- Ali Annaffati School at Tajura in Tripoli.
5- AL Entelaka School at Arada in Tripoli.
6- Shohadaabomelyana School at Tariq sur (behind the Islamic museum) in Tripoli.
7- Azzahf Al-Mostamer School at Ghut shaal in Tripoli.

4-2-2 Instrumentation

We have selected two different types of instruments to measure the radiation power density, one of them capable of measuring the total power density in its measuring range. The other is to measure the power density of each signal-radiated frequency. These instruments are as following:

1 - power meter "RF Field Strength Meter ".This meter detects the electric field of radio and microwaves (RF) from 0.5MHz to 3GHz, and expresses the field strength as power density from 0.001 to 200 microwatts/cm2.

2 - power meter"Sagem OT 290"for all cellular frequencies to ensure that the measurements are meaningful and accurate.

The specifications of these two meters are listed in appendix A.

4-3 Technical data of the base stations

The base station antennas that were installed by the operators [AL-Madar and Libyana companies] over the selected sites consist of sector dipoles antennas each cover an angle of 120°. Operators have provided us with the technical data of macrocellular base stations at the seven sites (all sites are shared by the two operators Libyana and AL-Madar except one, Shohadaabomelyana School) is listed in appendix C. The data include the radiated powers, beam characteristics of sector antennas, and powers radiated by dish antennas. Table (4-1) shows the height of the antennas for all the base stations.

Table (4-1) Height of the different floor of schools

school	Height of first floor	Height of second floor	Height of rooftop	Height of antenna
Ibn Haitham	420cm	840cm	1260cm	2410cm
Attasadi	420cm	840cm	1260cm	2050cm
Atifaq Jerba	420cm	-	840cm	1720cm
Ali Annaffati	420cm	840cm	1260cm	2410cm
AL Entelaka	420cm	840cm	1260cm	2410cm
Shohadaabomelyana	420cm	840cm	1260cm	2700cm
AzzahfAl-Mostamer	420cm	840cm	1260cm	2310cm

4-4 Measurements of power density

The measurements of power density is carried out in the period between 8-8-2006 to 19-8-2006 and repeated in the period 1-4-2007 to 5-4-2007 to ensure the measurements.

4-4-1 Measurements using RF Field Strength Meter

The RF field strength meter used in our measurements can measure the power density of all mobile phone base stations and all radio and microwaves (RF) from 0.5MHz to 3GHz at the site. The data are presented as function of the radial distances directly to the base station antennas irrespective of whether the path was obstructed by walls, roofs etc. The measurements were conducted using the RF field strength meter. in different locations in the same elevation and different elevation, and different times.

1- Measurements under antenna tower in different days

The measurements were done for the seven selected schools in the following dates:

- Ibn Haitham School at 8-8-2006 to 17-8-2006.

- Attasadi School at 13-8-2006 to 17-8-2006.
- Atifaq Jerba School at 13-8-2006 to 17-8-2006.
- Ali Annaffati School at 14-8-2006 to 19-8-2006.
- AL Entelaka School at 14-8-2006 to 19-8-2006.
- Shohadaabomelyana School at 14-8-2006 to 19-8-2006.
- Azzahf Al-Mostamer School at 15-8-2006 to 19-8-2006.

The measurements had been made on rooftop and floors under the antennas and repeated along three days; see appendix (B-1). Figure (4-1) shows the power radiation level on rooftop and at different floors below for Ibn Haitham School.

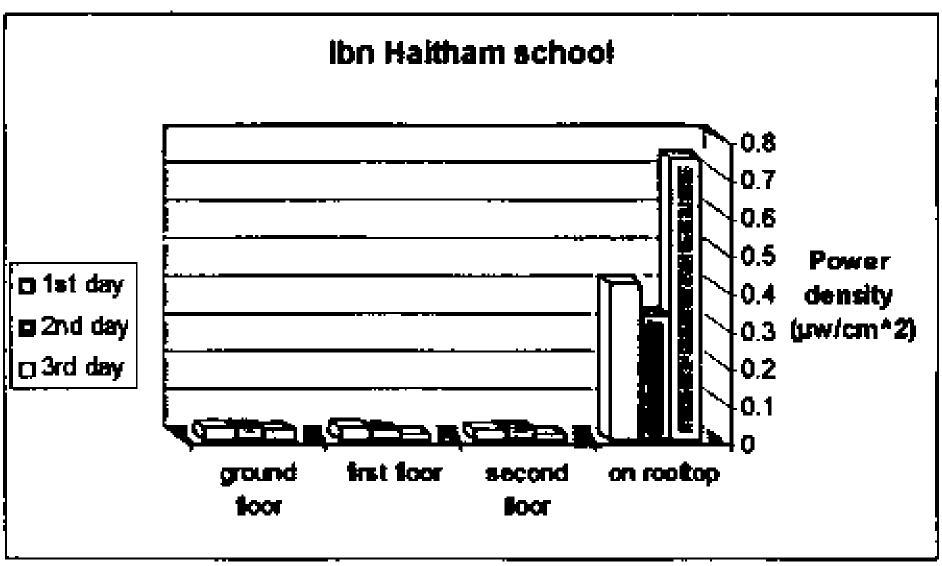


Figure (4-1) Power density level under the tower

From Figure (4-1) it can seen that the power density were maximum on rooftop then decreased progressively in the lower floors; and if we take the power density on rooftop as reference then the power density in second floor decreased to 2.55% of that on rooftop, in the first floor decreased to 2.55% of that on rooftop, and in the open ground floor decreased to 3.75% in first day; and in the second day decreased to 9.64% in the second floor, in the first floor decreased to 8.73%, and in the ground floor decreased to 6.33%; in third day and decreased to 6.97% of that on rooftop in the second floor, in first floor decreased to 7.45% of that on rooftop, and in the ground floor decreased to 8.65% .

Figure (4-2) shows the power radiation level on rooftop and at different floors below for Attasadi School.

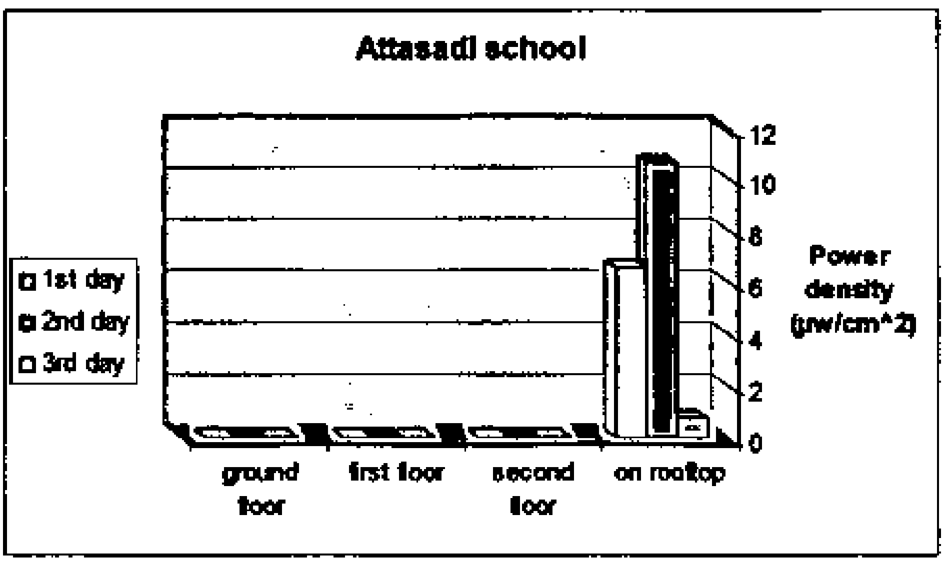


Figure (4-2) Power density level under the tower

From figure (4-2) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 3.77% of that on rooftop, in the first floor decreased to 3.43% of that on rooftop, and in the ground floor decreased to 4.023% in first day. And in second day decreased to 0.66% in the second floor, in first floor decreased to 0.43%, and in the ground floor decreased to 0.37%. And in third day decreased to 0.69% in the second floor, in first floor decreased to 0.6%, and the ground floor decreased to 0.57%.

Figure (4-3) shows the power radiation level on rooftop and at different floors below for Atifaq Jerba School.

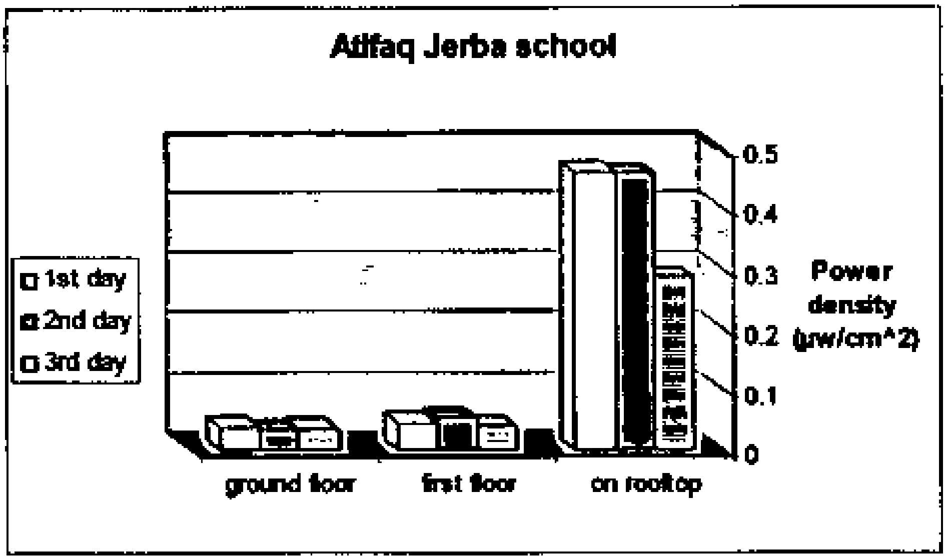


Figure (4-3) Power density level under the tower

From Figure (4-3) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in first floor decreased to 13.15% of that on rooftop, and in the ground floor decreased to 11.76% in first day. In second day in first floor decreased to 11.5% of that on rooftop, and in the ground floor decreased to 7.16%. And in third day in first floor decreased to 9.5%, and the ground floor decreased to 7.99%.

Figure (4-4) shows the power radiation level on rooftop and at different floors below for Ali Annaffati School.

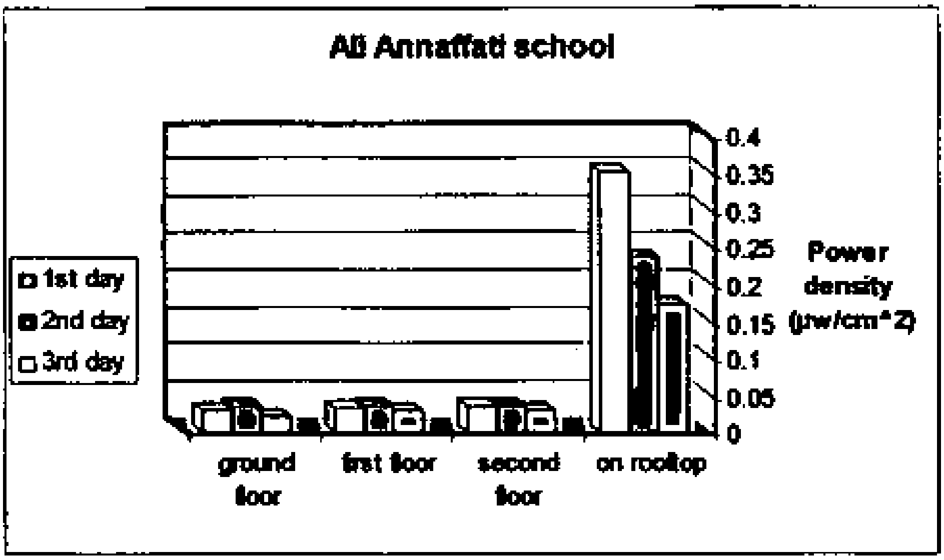


Figure (4-4) Power density level under the tower

From Figure (4-4) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 16.47% of that on rooftop, in the first floor decreased to 16.47% of that on rooftop, and in the ground floor decreased to 12.35% in first day. And in second day decreased to 14.04% in the second floor, in first floor decreased to 14.46%, and in the ground floor decreased to 14.04%. And in third day decreased to 9.69% in the second floor, in first floor decreased to 9.12%, and the ground floor decreased to 8.26%.

Figure (4-5) shows the power radiation level on rooftop and at different floors below for AL Entelaka School.

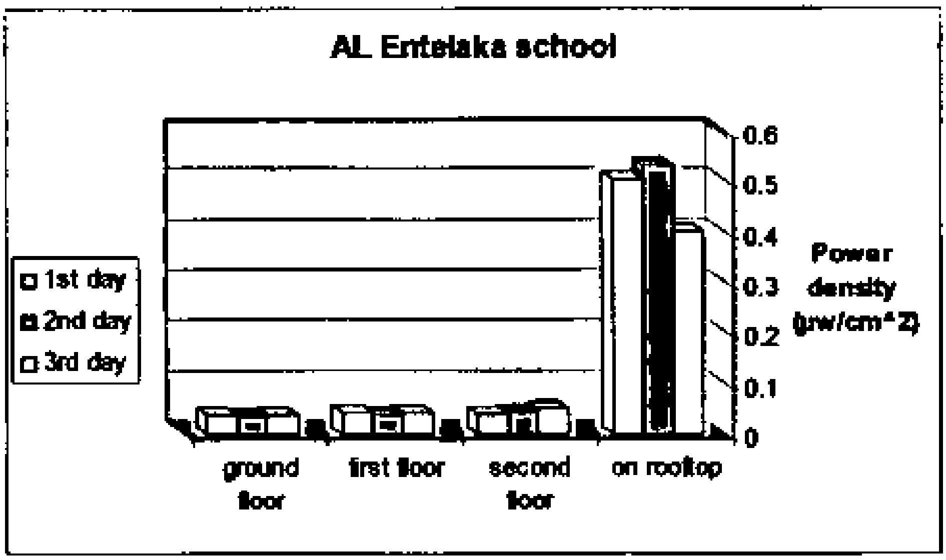


Figure (4-5) Power density level under the tower

From Figure (4-5) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 12.9% of that on rooftop, in the first floor decreased to 11.17% of that on rooftop, and in the ground floor decreased to 10.42% in first day. And in second day decreased to 8.08% in the second floor, in first floor decreased to 7.33%, and in the ground floor decreased to 6.95%. And in third day decreased to 7.92% in the second floor, in first floor decreased to 8.71%, and the ground floor decreased to 7.92%.

Figure (4-6) shows the power radiation level on rooftop and at different floors below for Shohadaabomelyana School.

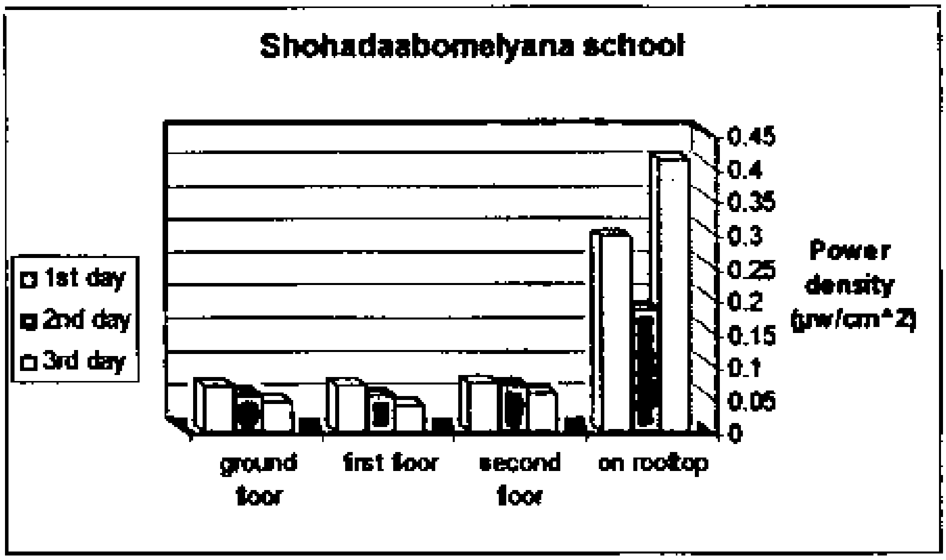


Figure (4-6) Power density level under the tower

From Figure (4-6) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 13.41% of that on rooftop, in the first floor decreased to 9.51% of that on rooftop, and in the ground floor decreased to 10.73% in first day. And in second day decreased to 23.1% in the second floor, in first floor decreased to 18.28%, and in the ground floor decreased to 18.28%. And in third day decreased to 14.67% in the second floor, in first floor decreased to 13.84%, and the ground floor decreased to 13.84%.

Figure (4-7) shows the power radiation level on rooftop and at different floors below for Azzahf AL-Mostemer School.

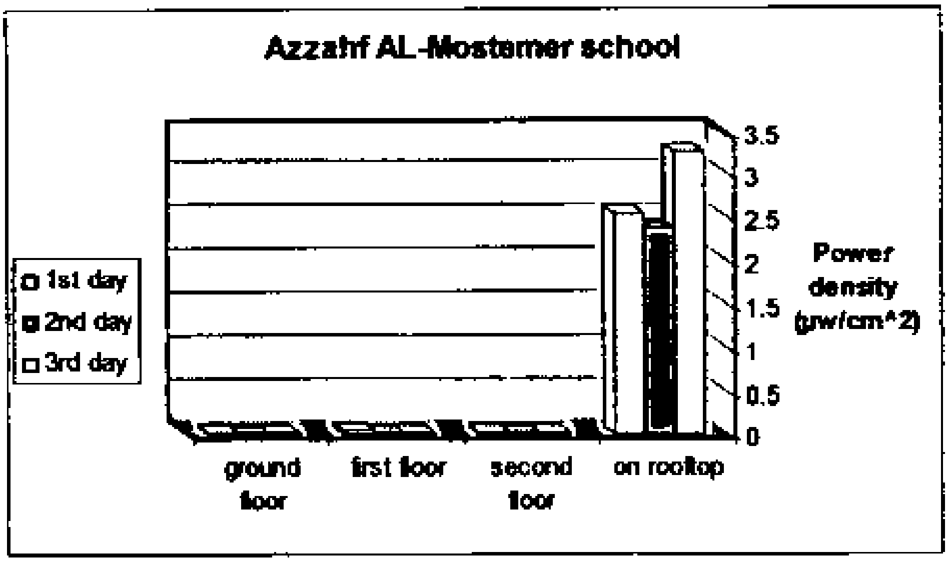


Figure (4-7) Power density level under the tower

From Figure (4-7) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors. And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 1.29% of that on rooftop, in the first floor decreased to 1.1% of that on rooftop, and in the ground floor decreased to0.98% in first day. And in second day decreased to 1.67% in the second floor, in first floor decreased to 1.46%, and in the ground floor decreased to 1.67%. And in third day decreased to 1.57% in the second floor, in first floor decreased to 1.64%, and the ground floor decreased to 1.68%.

2- Comparison of power density level between schools

The measurements were done for the previous seven selected schools and repeated along three days; Figure (4-8) shows the power density levels on rooftop for all schools at three days.

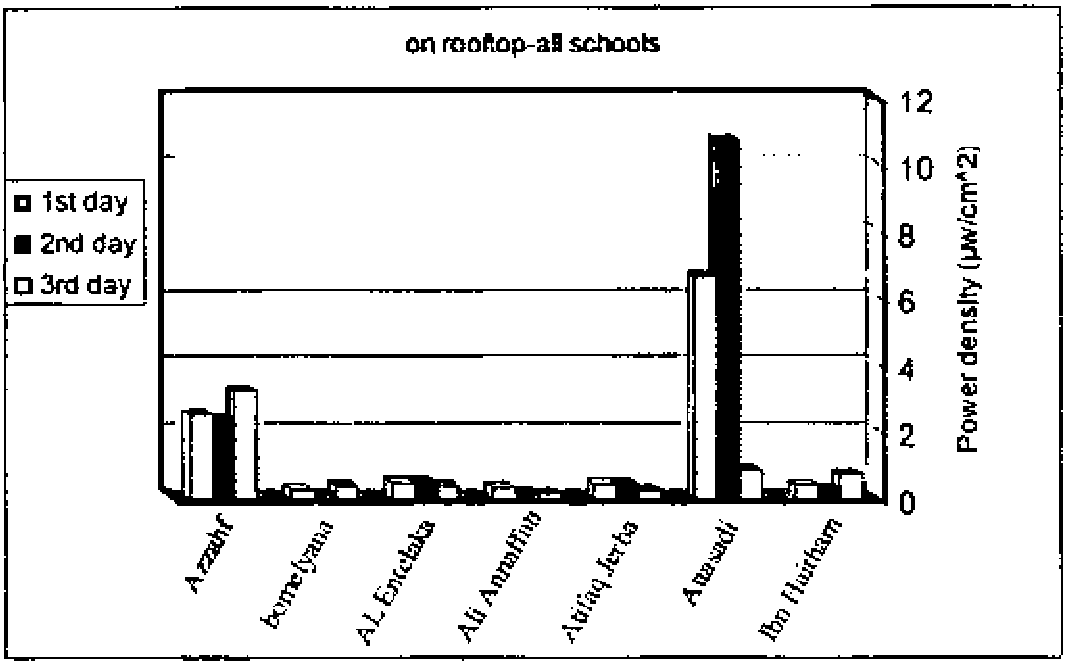


Figure (4-8) Power density level under the tower

From Figure (4-8), we can see that the radiation power density on rooftop of Attasadi School was the highest; Azzahf AL-Mostemer School is second, and if we take power density in Attasadi School as a reference then the power density in Ali Annaffati School (the lowest) was 2.189% of that in Attasadi School.

Figure (4-9) shows the power density levels at second floor for all schools at three days.

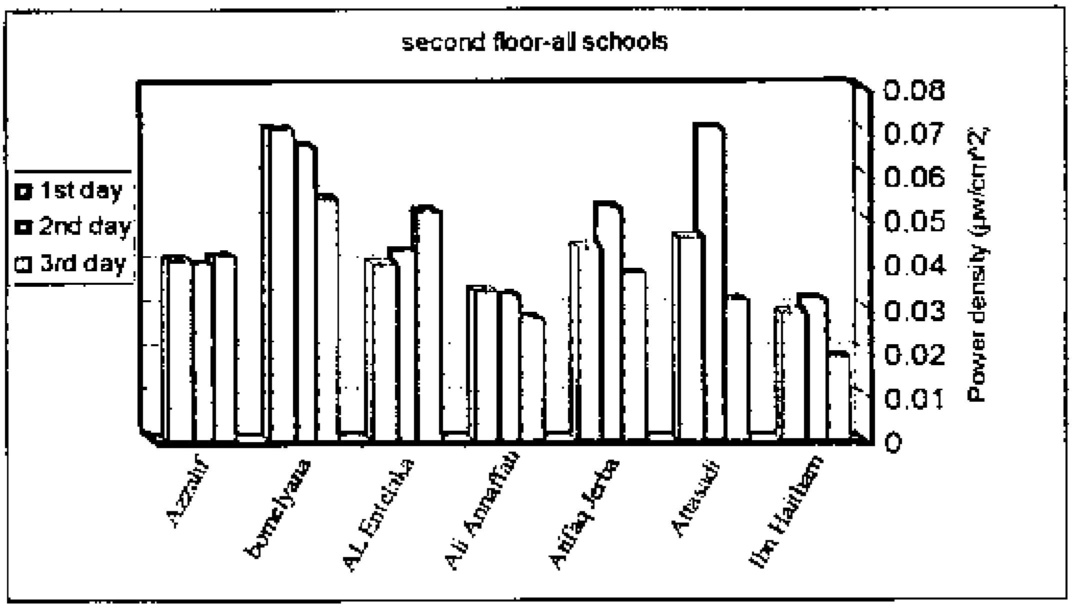


Figure (4-9) Power density level under the tower

From Figure (4-9) we can see that the radiation power density at second floor of Attasadi School and Shohadaabomelyana School were the highest.

Figure (4-10) shows the power density levels at first floor for all schools at three days.

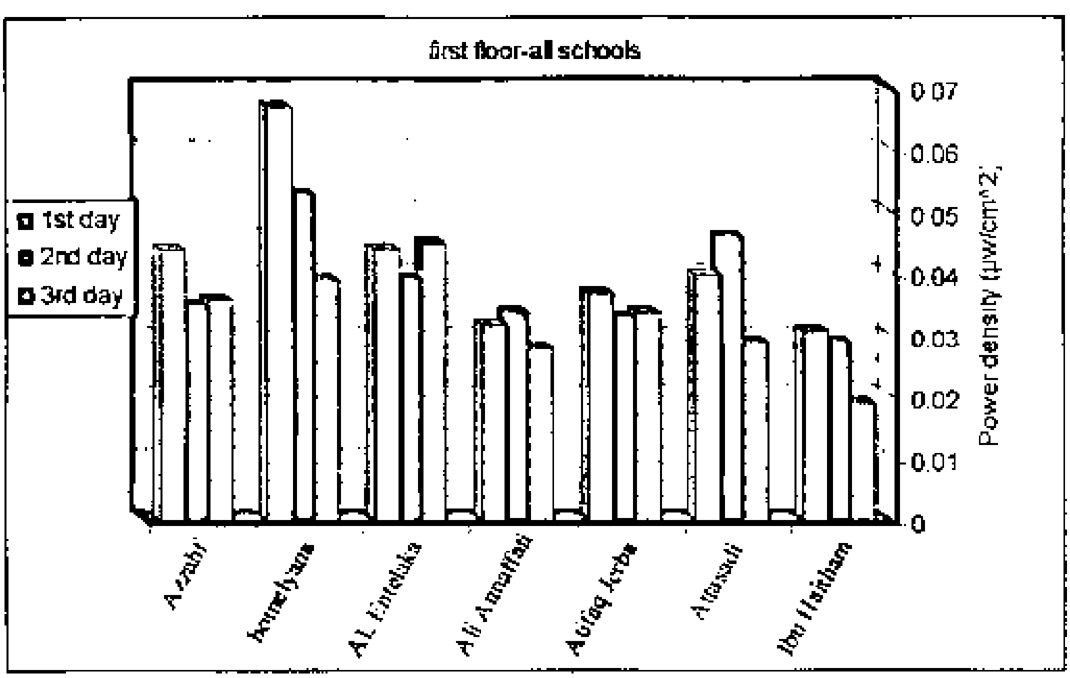


Figure (4-10) Power density level under the tower

From Figure (4-10), we can see that the radiation power density at first floor of Shohadaabomelyana School was the highest.

Figure (4-11) shows the power density levels at ground floor for all schools at three days.

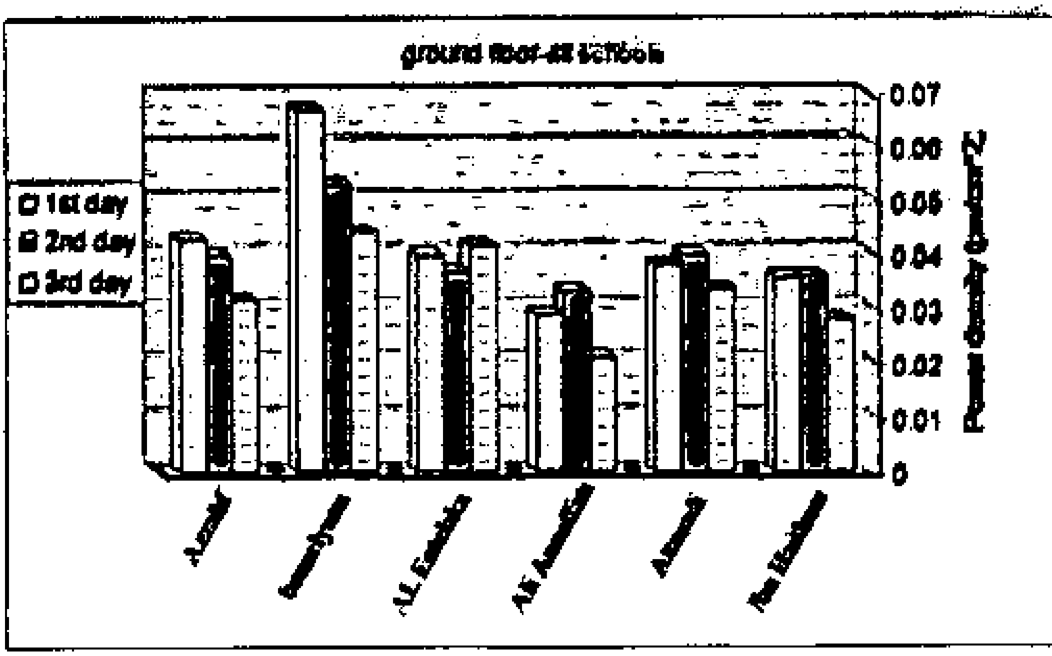


Figure (4-11) Power density level under the tower

From Figure (4-11) we can see that the radiation power density at ground floor of Shohadaabomelyana School was the highest.

3- Measurements under tower in different times of day

To help understanding the radiation level through the school hour we have measured the radiation power density in early morning about 9:00 o'clock and at 11:00 o'clock and at 1:00 o'clock. The measurement was conducted for the following schools:

- Attasadi School at 1-4-2007.
- Atifaq Jerba School at 2-4-2007.
- Ali Annaffati School at 3-4-2007.
- AL Entelaka School at 4-4-2007.

- Azzahf Al-Mostamer School at 5-4-2007.

The measurements were conducted on the rooftop and floors under the antennas in three different times; Figure (4-12) shows the power density level through the time of the day for Attasadi School.

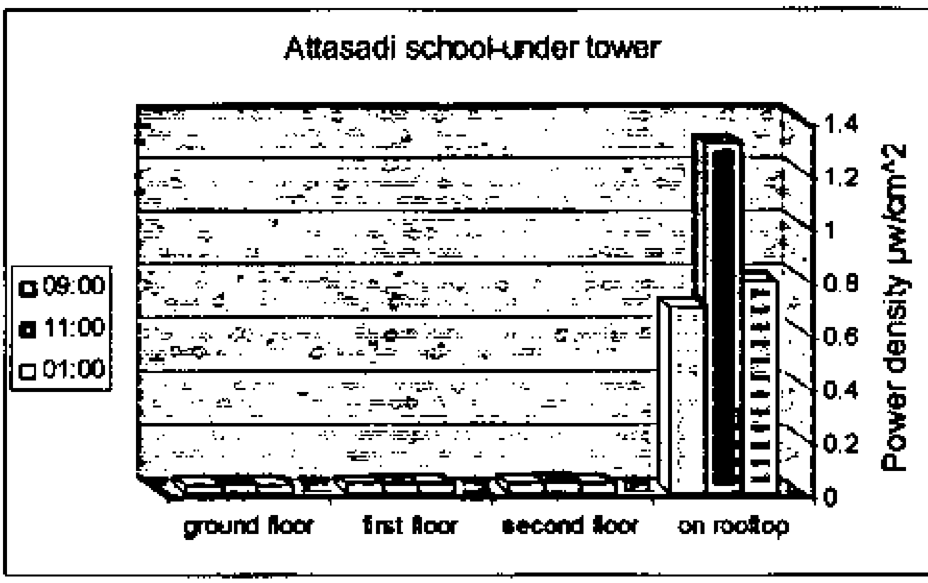


Figure (4-12) Power density radiation level in floors

From the Figure (4-12) it can be seen that the level of radiation is higher at 11:00 o'clock while it is lower at early morning and late of the day.

Figure (4-13) shows the power density level through the time of the day for Atifaq Jerba School. From the figure, it can be seen that the level of radiation is higher at 11:00 o'clock and late of day while it is lower at early morning.

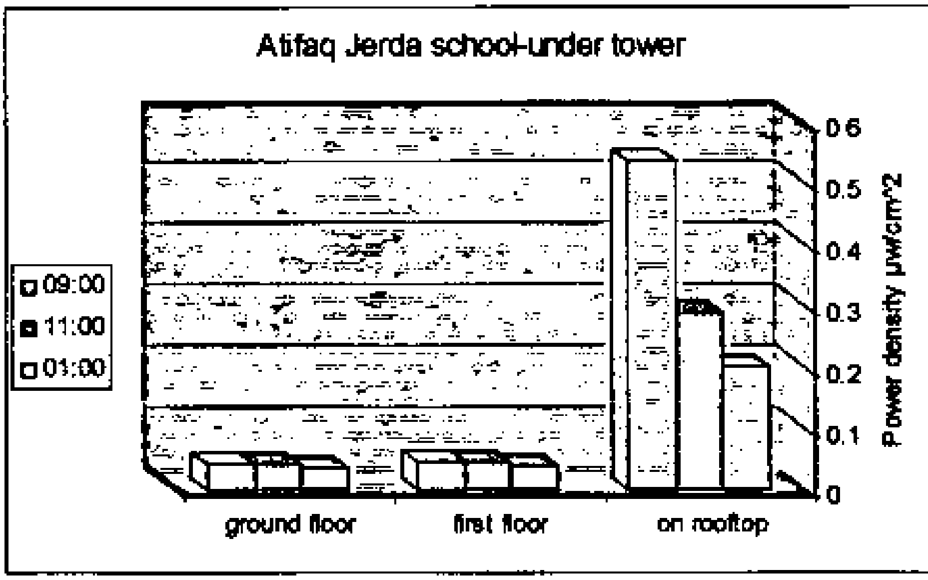


Figure (4-13) Power density radiation level in floors

Figure (4-14) shows the power density level through the time of the day for Ali Annaffati School. From the figure, it can be seen that the level of radiation is higher at 1:00 o'clock and late of day while it is lower at early morning.

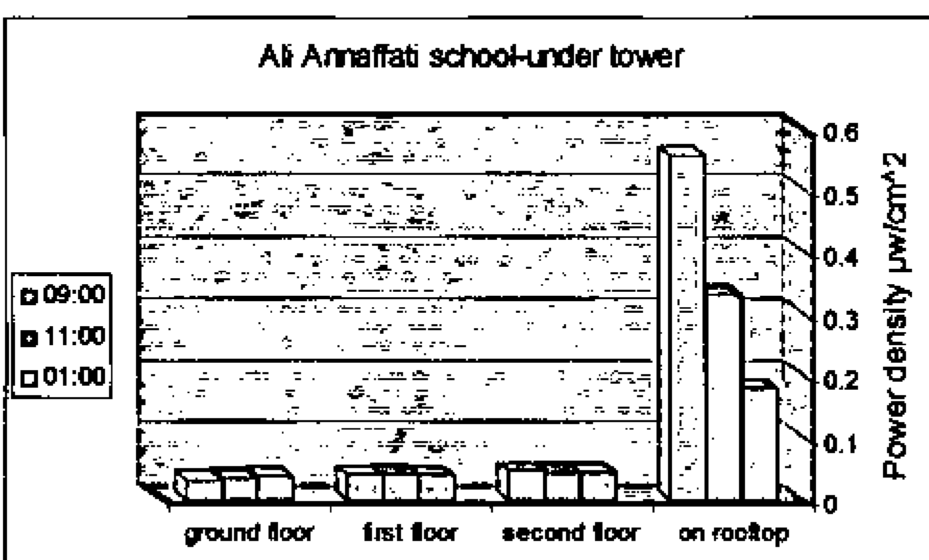


Figure (4-14) Power density radiation level in floors

Figure (4-15) shows the power density level through the time of the day for AL Entelaka School. From the figure it can be seen that the level of radiation is higher at 11:00 o'clock on rooftop while it is lower at early morning. In the lower floors the level of radiation is higher at 1:00 o'clock.

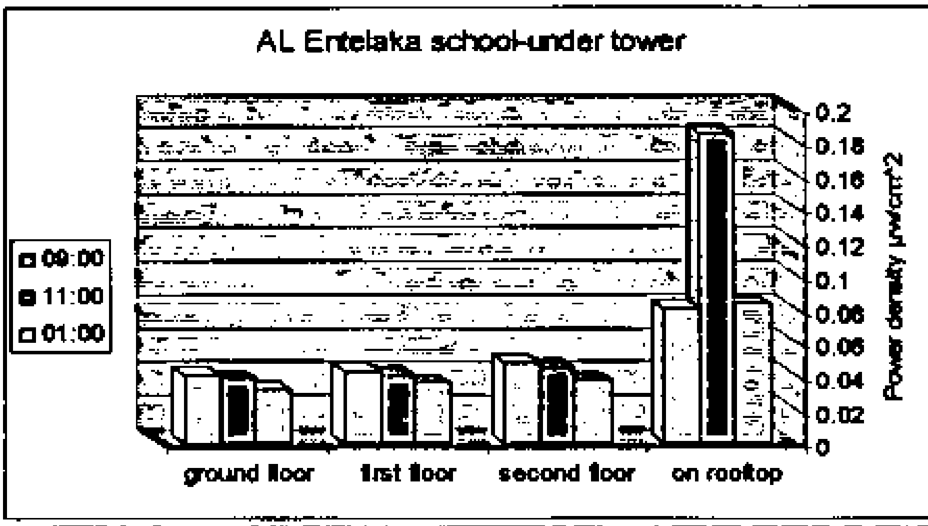


Figure (4-15) Power density radiation level in floors

Figure (4-16) and (4-17) show the power density level through the time of the day. From the figures, it can be seen that the level of radiation is highest at 9:30 o'clock on rooftop and floors below.

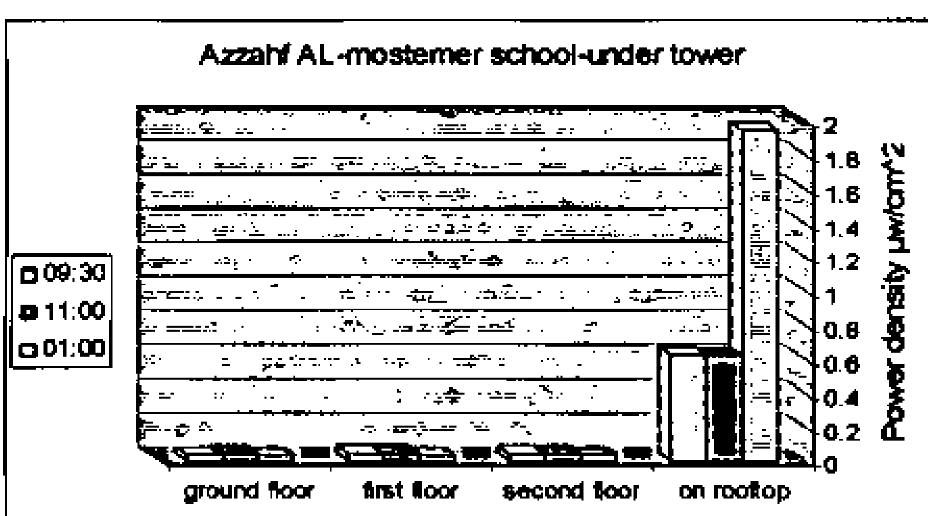


Figure (4-16) Power density radiation level in floors

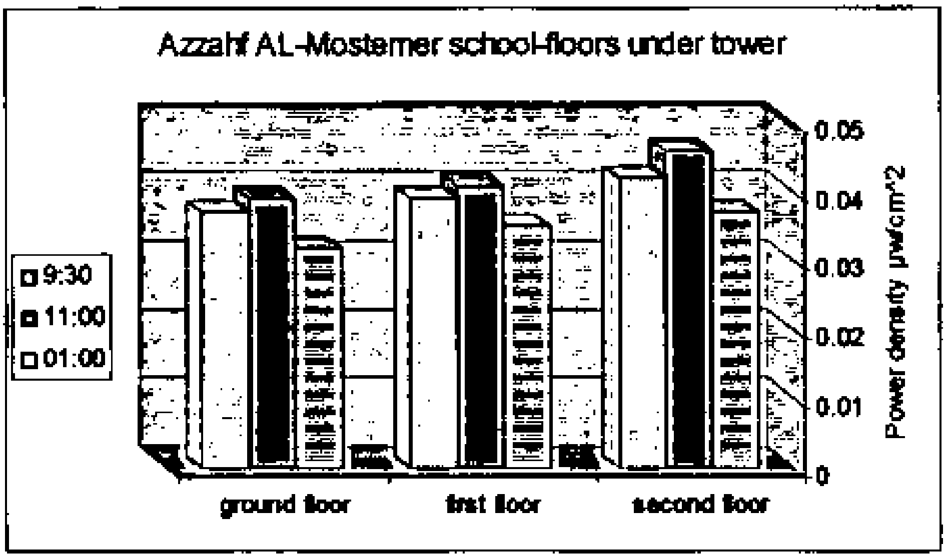


Figure (4-17) Power density radiation level in floors

Figure (4-18) shows the level of radiated power density on the rooftop for the following schools:

- Attasadi School at 1-4-2007.
- Atifaq Jerba School at 2-4-2007.
- Ali Annaffati School at 3-4-2007.
- AL Entelaka School at 4-4-2007.
- Azzahf Al-Mostamer School at 5-4-2007.

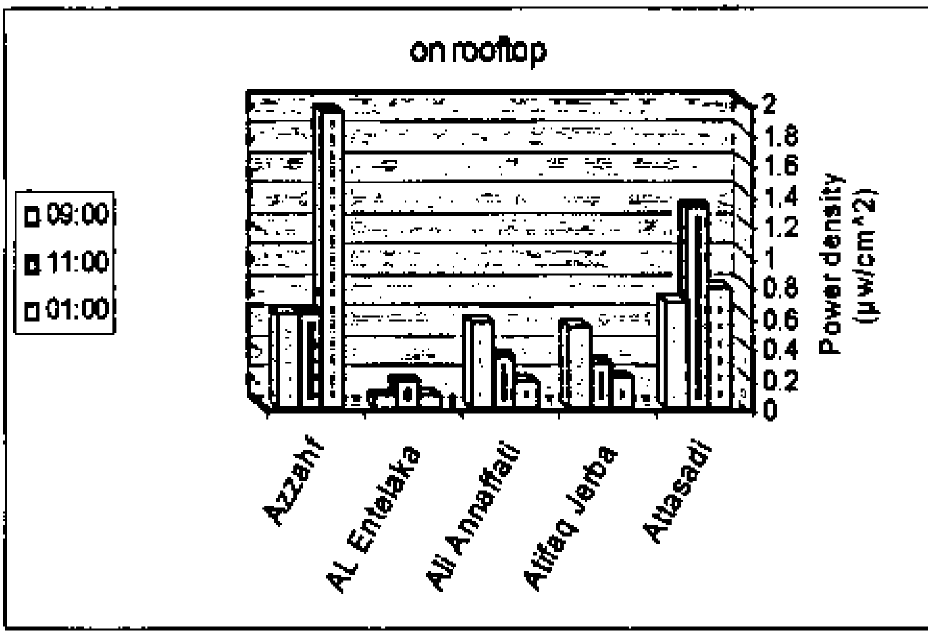


Figure (4-18) Power density radiation level on rooftop

From Figure (4-18) it can seen that the maximum value of measured power density on rooftop in Azzahf AL-Mostemer School.

Figure (4-19) shows the level of radiated power density in the second floor for the following schools:

- Attasadi School at 1-4-2007.
- Atifaq Jerba School at 2-4-2007.
- Ali Annaffati School at 3-4-2007.
- AL Entelaka School at 4-4-2007.
- Azzahf Al-Mostamer School at 5-4-2007.

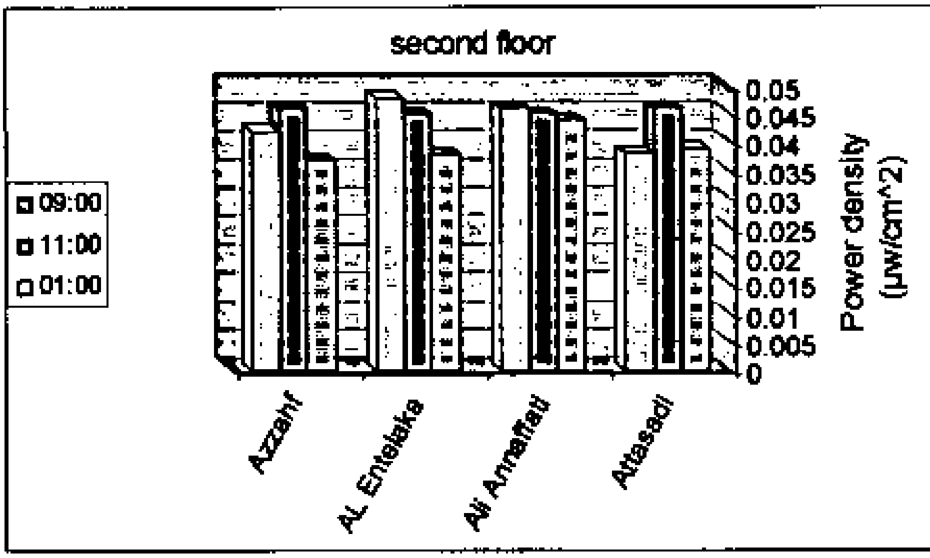


Figure (4-19) Power density radiation level in second floor

From Figure (4-19) it can seen that the value of measured power density in these schools approximately are in the same level in the second floor where it is not in the same levels in the rooftop. And it is same for the first and ground floors, that is clear from Figures (4-20) and (4-21).

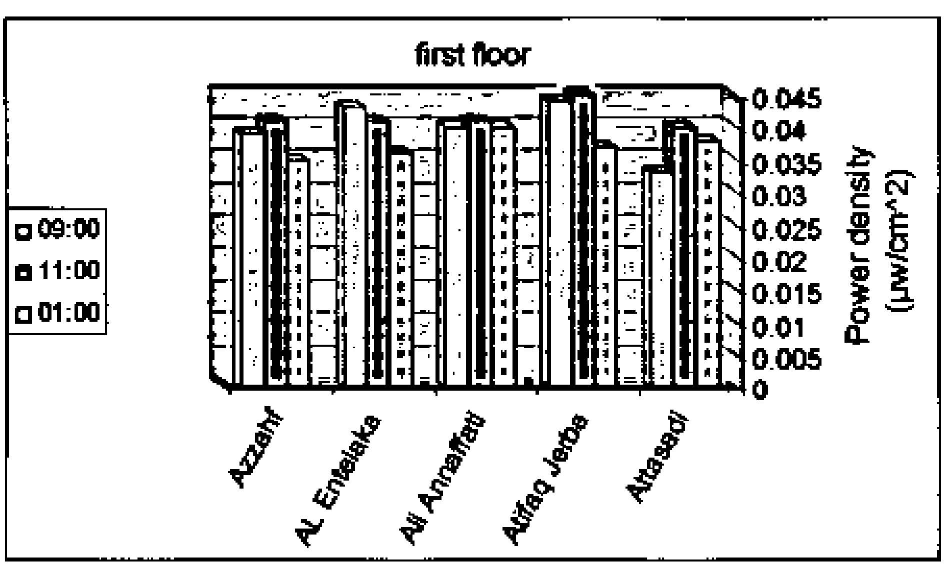


Figure (4-20) Power density radiation level in first floor

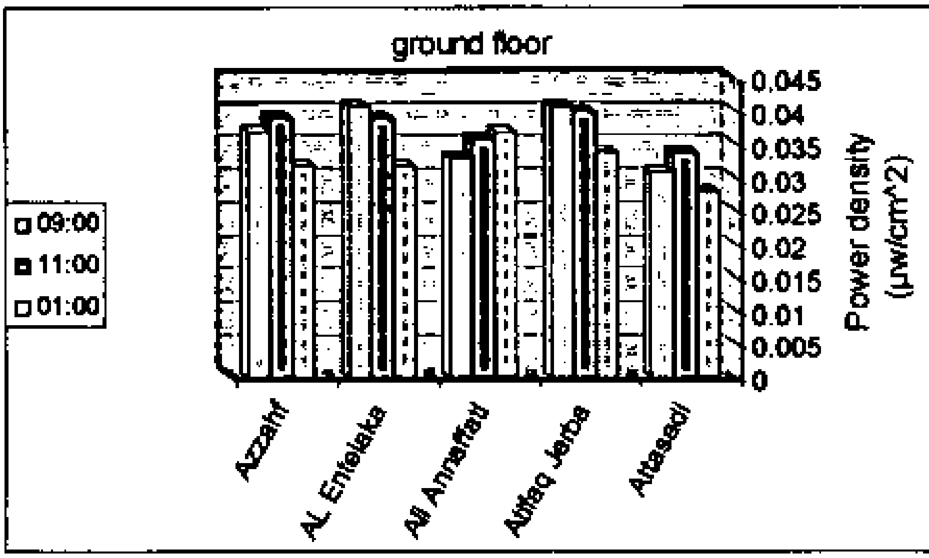


Figure (4-21) Power density radiation level in ground floor

4- Measuring on rooftop at different distances from antennas

The measurements had been conducted on rooftop at different distances from antennas in four selected schools:

- Attasadi school: the locations in which power measured, was in the east of antennas with distances shown in Figure (4-22), and it is noted that the power density increased by increasing the distance. It can be seen from the figure that the power density during midday is higher than that at early morning, and more away from the antenna up to same distance.

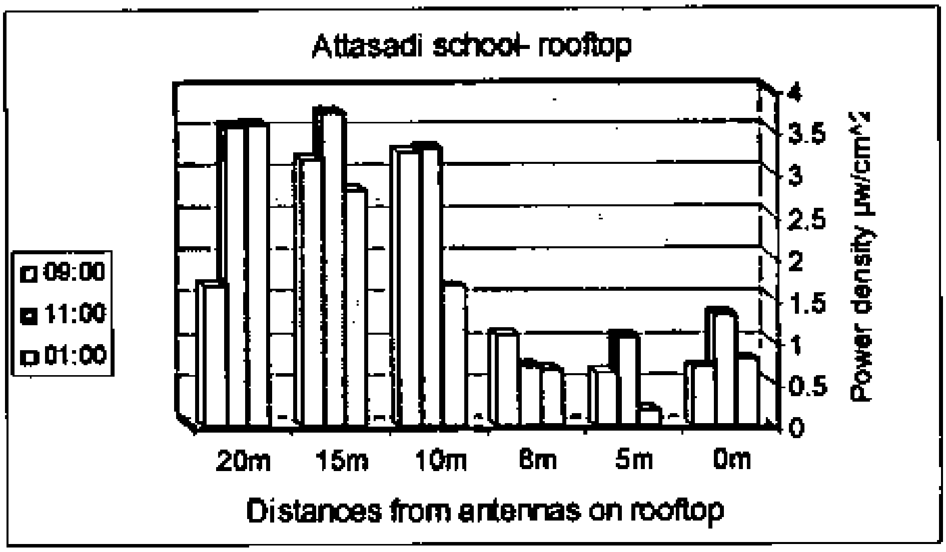


Figure (4-22) Power density level on rooftop

- Atefaq Jerba School: the measurements were done west of antennas at different distances Figure (4-23) shows variation of power density at different distances at different time.

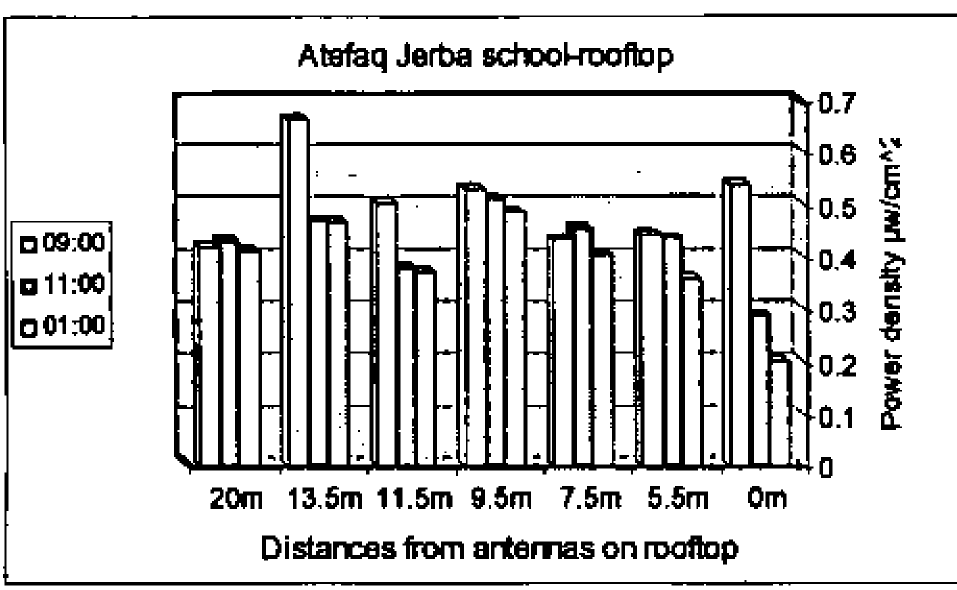


Figure (4-23) Power density level on rooftop

- AL-Entelaka school: the measurements were done south of the antennas at different distances and at different time, Figure (4-24) shows the power density variation at different distances and time. It can be also being show from figure that the power densities decreased by increased distances.

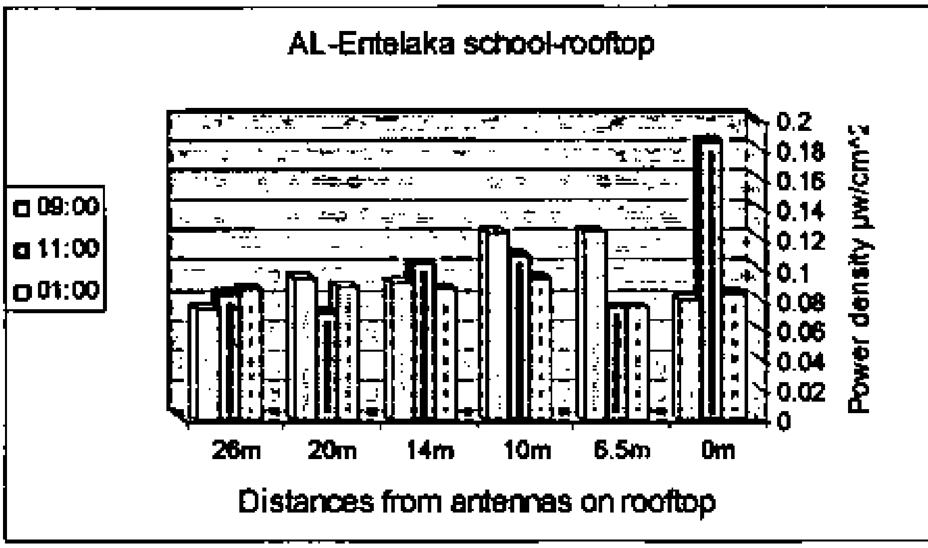


Figure (4-24) Power density level on rooftop

- Azzahf AL-Mostemer School: the measurements were done west of the antennas at different distances and at different time, Figure (4-25) shows the power density variation at different distances and time. It can be also shows from figure that the power densities increased by increased distances.

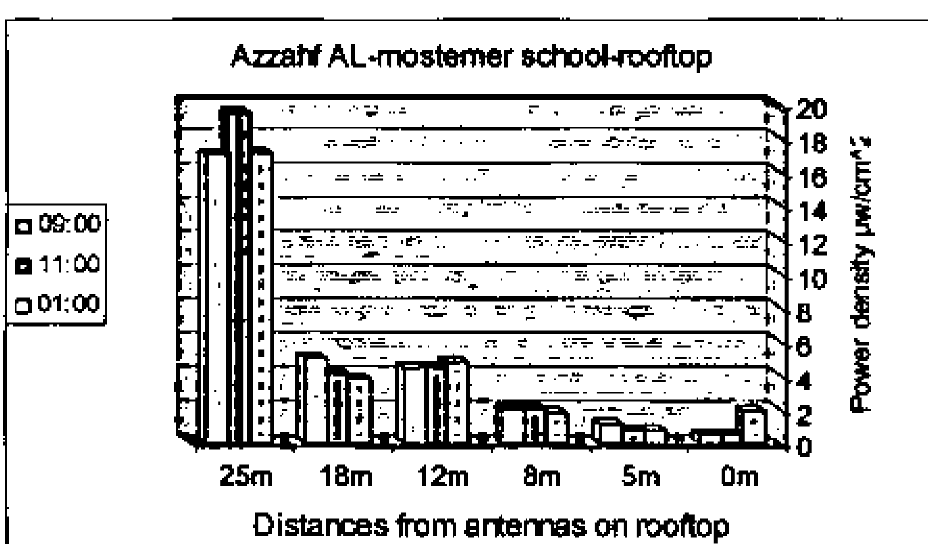


Figure (4-25) Power density level on rooftop

5- Measurements at ground level

The measurements had been done at ground level at different distances from antennas projection in the following five schools:

- Attasadi School.
- Atifaq Jerba School.
- Ali Annaffati School.
- AL Entelaka School.
- Azzahf Al-Mostamer School.

Figures (4-26) to (4-30) show the level of radiated power density increased with distances then decreased after 40m in Attasadi school, 20m in Atifaq Jerba school, 20m in Ali Annaffati school then increased, in AL Entelaka school the level of measured power densities increased with distances then decreased after 70m, in last, in Azzahf AL-Mostemer school the level of measured power densities increased with distances then decreased after 60m.

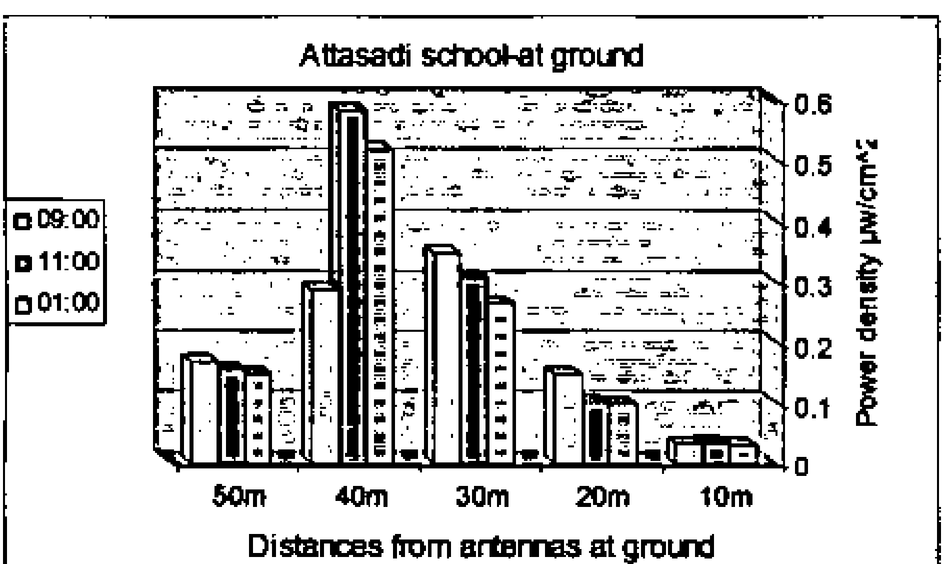


Figure (4-26) Power density level at ground

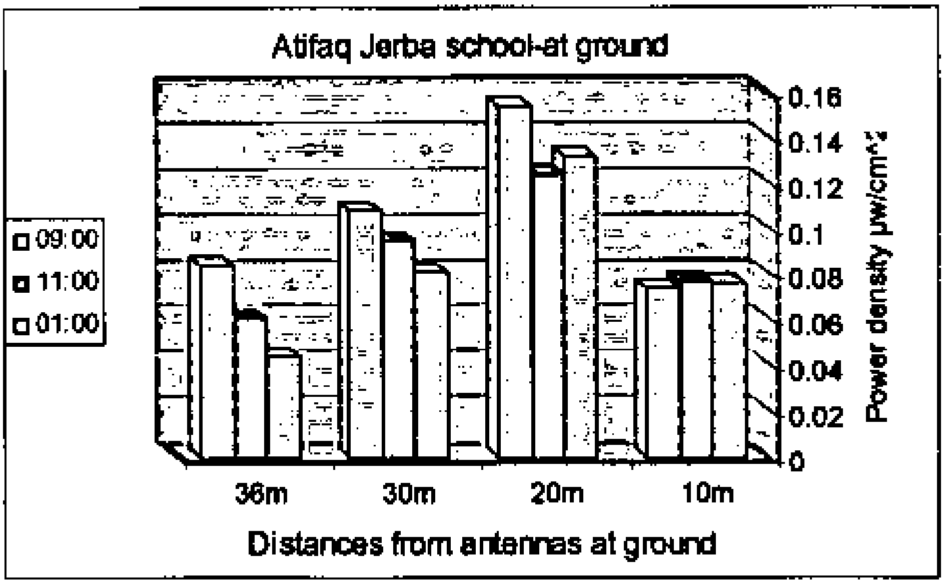


Figure (4-27) Power density level at ground

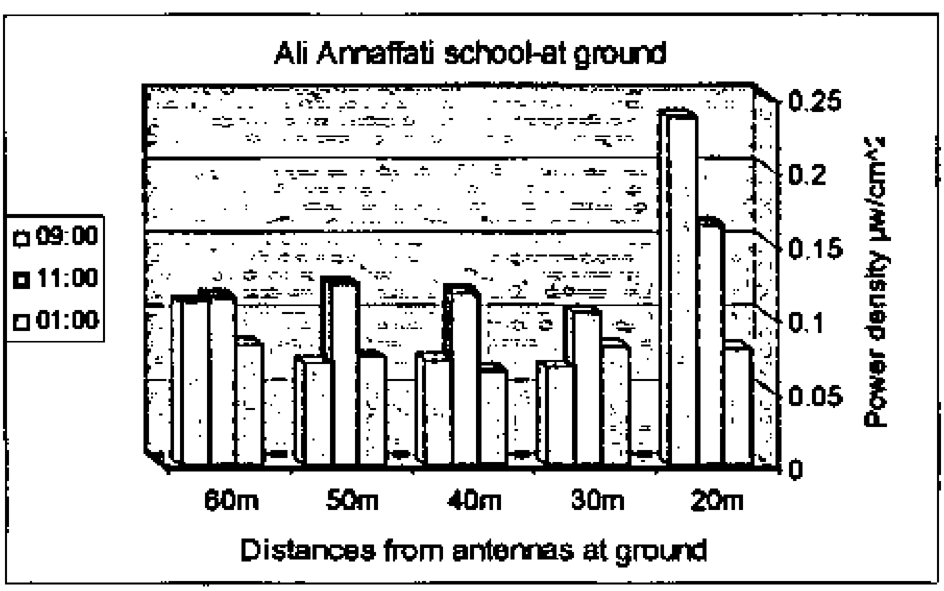


Figure (4-28) Power density level at ground

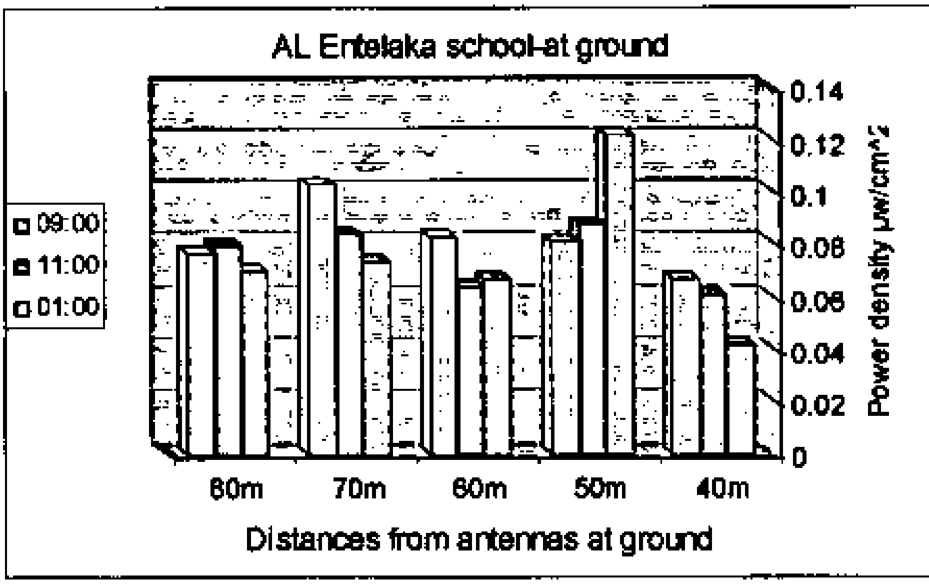


Figure (4-29) Power density level at ground

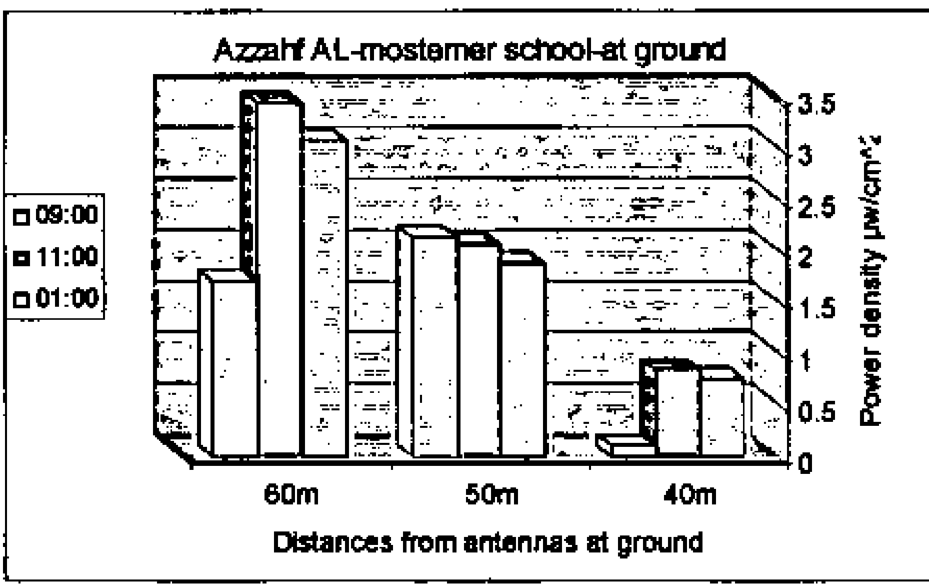


Figure (4-30) Power density level at ground

6- Measurements of the power density on rooftop at different directions

To know the radiated level at different directions of antennas we measured the power density at all directions of antennas at the same distance. The measurement was done for the following schools:

- Attasadi School: Figure (4-31) shows the power density variation at three directions at 8m. At this school, the level of radiated power density in the south is the highest.

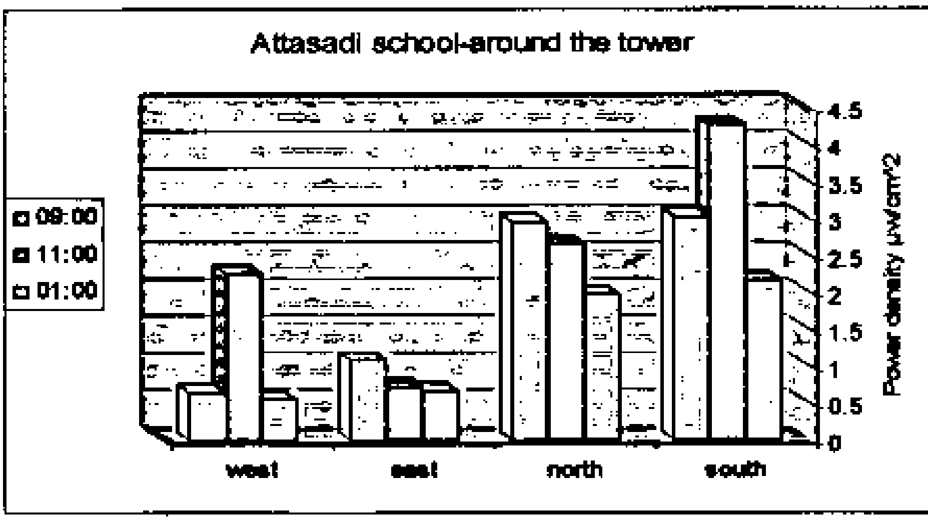


Figure (4-31) Power density level around the tower

- Atifaq Jerba School: figure (4-32) shows the power density variation at all directions at 5.5m. At this school, the level of radiated power density in the west is the highest. In this site, we could not measure the power density in the south due to the school structure, which not extended in the south.

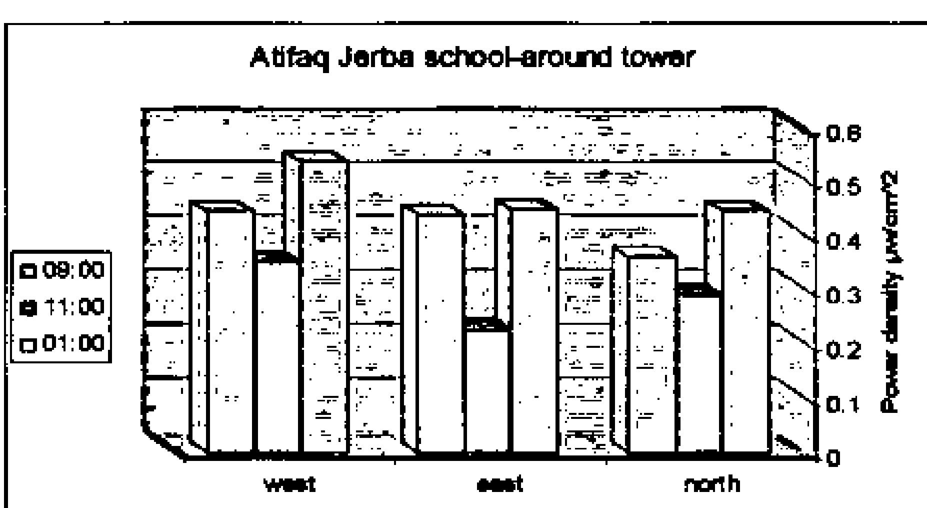


Figure (4-32) Power density level around the tower

- Ali Annaffati School: Figure (4-33) shows the power density variation at all directions at 6.75m. At this school, the level of radiated power density in the west is the highest.

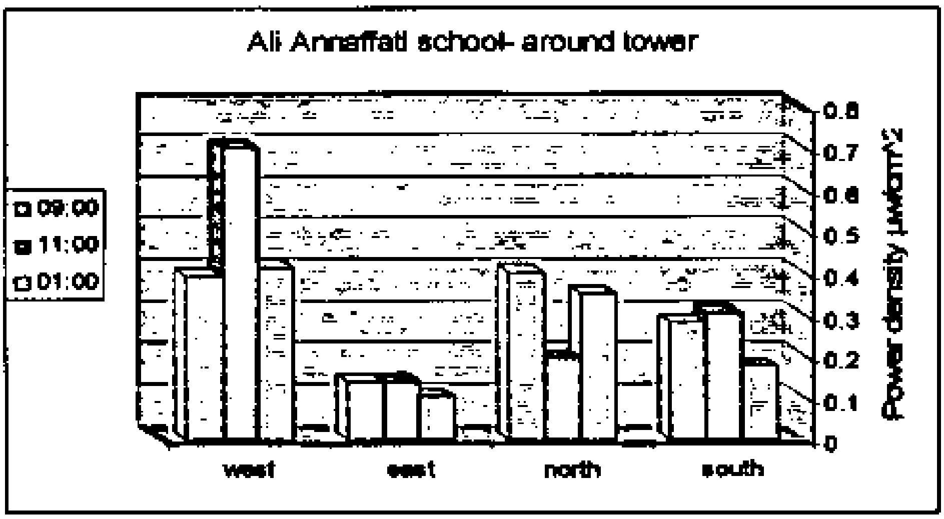


Figure (4-33) Power density level around the tower

- AL Entelaka School: Figure (4-34) shows the power density variation at all directions at 6.5m. At this school, the level of radiated power density in the south is the highest. In this site, we were not able to measure the power density in the west due to the school structure, which not extended in the west.

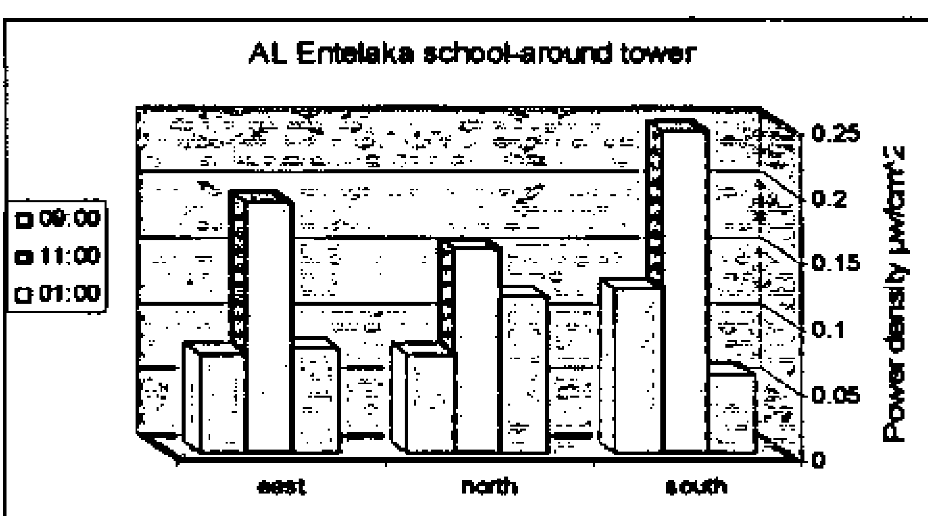


Figure (4-34) Power density level around the tower

- Azzahf Al-Mostamer School: Figure (4-35) shows the power density variation at all directions at 8m. At this school, the level of radiated power density in the south is the highest.

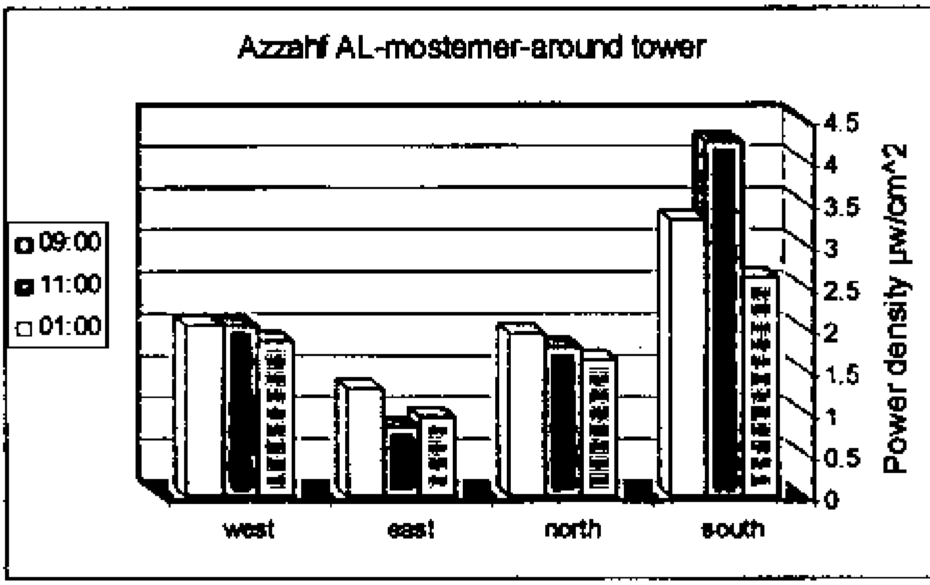


Figure (4-35) Power density level around the tower

4-4-2 Measurement of power density using Sagem OT 290

To help compare the measurements done by RF field strength meter we used another type of power density measuring device (SAGEM OT 290) this devices measure the level of signals in dBm. The measurements by this meter have been taken at the worst two cases (Azzahf Al-Mostamer School and Attasadi School), as there two sites has the most number of antennas.

Level of signals or received power was measured in dBm, and converted to watt unit, then calculation of the power density can be done by using Matlap program (see appendix D), and then sum all values in the same point to calculate the total power density, at last, the total value multiply by "Traffic& DTx factor", which is 2.5 in the case that all transmitters is busy. Tables (4-2) and (4-3) show variations in strength of measured signals.

Table (4-2) Power density level for Azzahf AL-Mostemer School

Location	Total power density $(\mu w/cm^2)$
On rooftop under the libyana tower	$5.55075*10^{-6}$
On rooftop, south of libyana tower, 8m	$2.285075*10^{-6}$
On rooftop north under of libyana tower, 8m	$2.93075*10^{-7}$
On rooftop. west of libyana tower, 30m	$2.099075*10^{-6}$
On rooftop east of libyana tower, 24.5m	$4.82075*10^{-7}$
Second floor, under the libyana tower	$1.53413*10^{-8}$
First floor, under the libyana tower	$1.3678*10^{-8}$
Ground floor, under the libyana tower	$9.1487*10^{-9}$
North courtyard, with horizontal distance 36.5m	$1.16287*10^{-6}$
West courtyard, with horizontal distance 65.5m	$3.66125*10^{-7}$
East of libyana tower, with horizontal distance 66m, "stadium"	$4.531*10^{-7}$
South of school. with horizontal distance 130 "out of school fence"	$3.7885*10^{-6}$

Table (4-3) Power density level for Attasadi School

Location	Total power density ($\mu w/cm^2$)
On rooftop under the libyana tower	$5.66125*10^{-6}$
On rooftop, south of libyana tower 8m	$8.0905*10^{-6}$
On rooftop, north of libyana tower 8m	$1.494325*10^{-5}$
On rooftop, east of libyana tower 20m	$1.680125*10^{-4}$
On rooftop, west of libyana tower 20m	$4.197*10^{-6}$
Second floor, under the libyana tower	$1.7839*10^{-7}$
First floor, under the libyana tower	$2.23*10^{-8}$
Ground floor, under the libyana tower	$5.75425*10^{-8}$
Back courtyard with horizontal distance 18.3m	$3.1865*10^{-7}$
Front courtyard "stadiums" with horizontal distance 49m, "the stadiums"	$1.92232*10^{-6}$
East of school, with horizontal distance 60m, "out of school fence".	$7.02375*10^{-7}$
North of school, with horizontal distance 60m, "out of school fence"	$1.9175*10^{-8}$

Figure (4-36) shows the power radiation level on rooftop and at different floors below for Azzahf AL-Mostemer and Attasadi Schools.

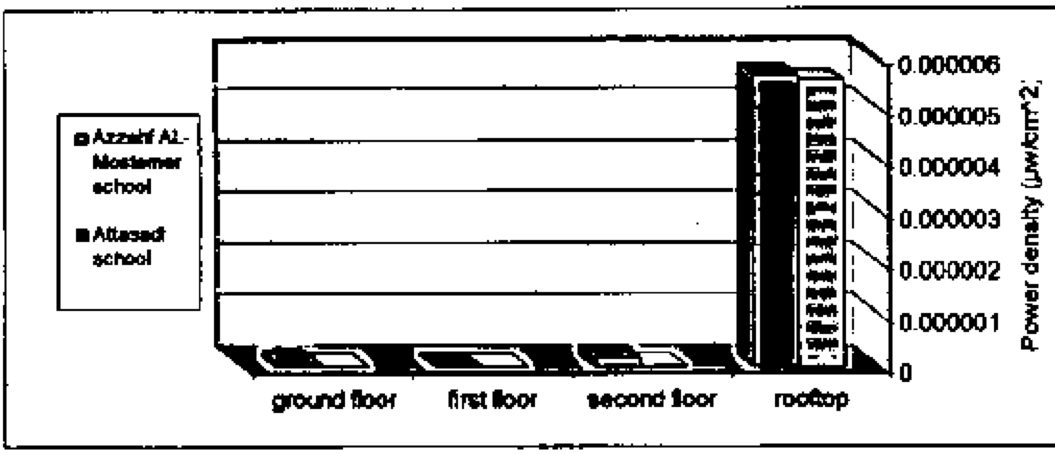


Figure (4-36) Power density level under the tower

From Figure (4-36) it can be seen that the power density were maximum on rooftop then decreased progressively in the lower floors, And if we take the power density on rooftop as reference, then the power density in the second floor decreased to 0.276% of that on rooftop, in the first floor decreased to 0.246% of that on rooftop, and in the ground floor decreased to0.165% in Azzahf AL-Mostemer School. And the power density in the second floor decreased to 3.151% of that on rooftop, in the first floor decreased to 0.394% of that on rooftop, and in the ground floor decreased to 1.016% in Attasadi School.

4-5 Radiation from home appliances and mobile handset

In this section, we selected some devices, which radiate RF power, for comparison of the radiation power density from these devices with those from base stations. We have measurements for TV, computer, microwave oven, and some Nokia and Samsung mobile handset; see Table (4-4) and Table (4-5). These tables contain values of power density level for some home appliances and mobile handset; we have done these measurements for these devices at 5cm, 10cm, 30cm, 50cm, and 100cm.

Table (4-4) Power from some home appliances and mobile handset

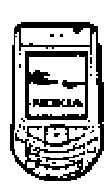
Appliances	Distances (cm)	Total power density $(\mu w / cm^2)$
TV	5	0.09
	10	0.058
	30	0.056
	50	0.033
	100	0.029
Computer	5	0.095
	10	0.085
	30	0.063
	50	0.05
	100	0.05
Microwave oven	5	1.864
	10	0.629
	30	0.186
	50	0.17
	100	0.038
Nokia 6630 	5	46.13
	10	17.822
	30	9.939
	50	0.802
	100	0.047
Nokia 6270 	5	58.106
	10	17.809
	30	9.284
	50	0.445
	100	0.036

Table (4-5) Power from some mobile handset

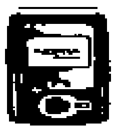
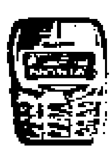
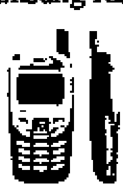
Appliances	Distances (cm)	Total power density $\mu w / cm^2$)
Nokia N71	10	7.33
	30	0.806
	50	0.131
	100	0.021
Nokia 6310i	10	1.105
	30	0.253
	50	0.111
	100	0.008
Nokia 3310	10	3.639
	30	0.232
	50	0.199
	100	0.01
Nokia 7250i	10	1.607
	30	0.204
	50	0.091
	100	0.022
Samsung R220	10	4.932
	30	1.887
	50	0.299
	100	0.097
Nokia 8250	10	6.077
	30	2.03
	50	0.455
	100	0.253
Nokia 8210	10	3.803
	30	1.01
	50	0.518
	100	0.295

Figure (4-37) shows the level of radiated power density from some home appliances and mobile handset at 5cm; from the figure we can see that the Nokia 6270 radiated highest power ; it was 58.106µw/cm.^2; for comparison of the radiation power density from this device with those from base stations we find that power density from this device was 2.275 of maximum power density from base stations.

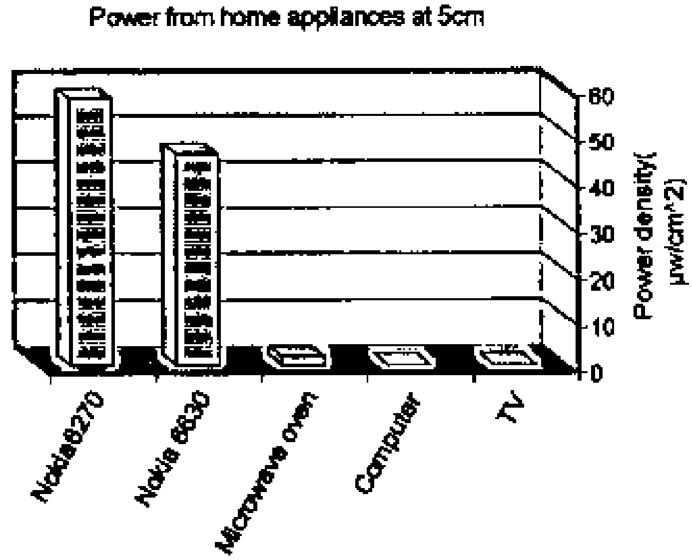


Figure (4-37) Power density level from home appliances and mobile handset

Figure (4-38) shows the level of radiated power density from some home appliances and mobile handset at 10cm; from the figure, we can see that the Nokia 6270 and Nokia 6630 radiated highest power level. Where the radiated power density by Nokia 6270 was 17.809 µw/cm^2, and it was 17.822 µw/cm^2 for Nokia 6630.

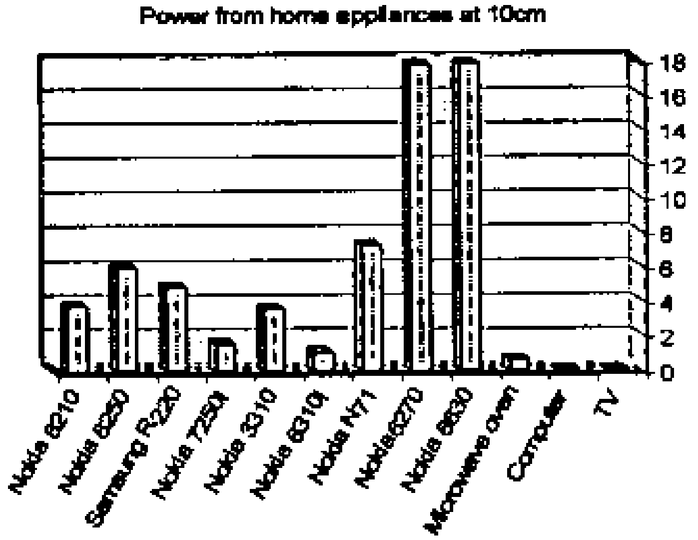


Figure (4-38) Power density radiation level for home appliances and mobile handset

Figure (4-39) shows the level of radiated power density from some home appliances and mobile handset at 30cm; from the figure, we can see that the Nokia 6270 and Nokia 6630 radiated highest power.

Where the radiated power density by Nokia 6270 was 9.284µw/cm^2, and it was 9.939 µw/cm^2 for Nokia 6630.

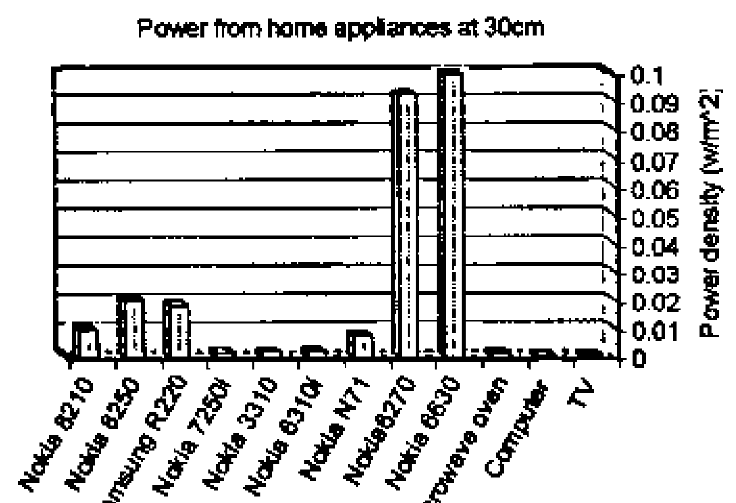


Figure (4-39) Power density radiation level for home appliances and mobile handset

Figure (4-40) shows the level of radiated power density from some home appliances and mobile handset at 50cm; from the figure, we can see that the Nokia 6630 radiated highest power. Where the radiated power density by Nokia 6630 was 0.802 μw/cm^2.

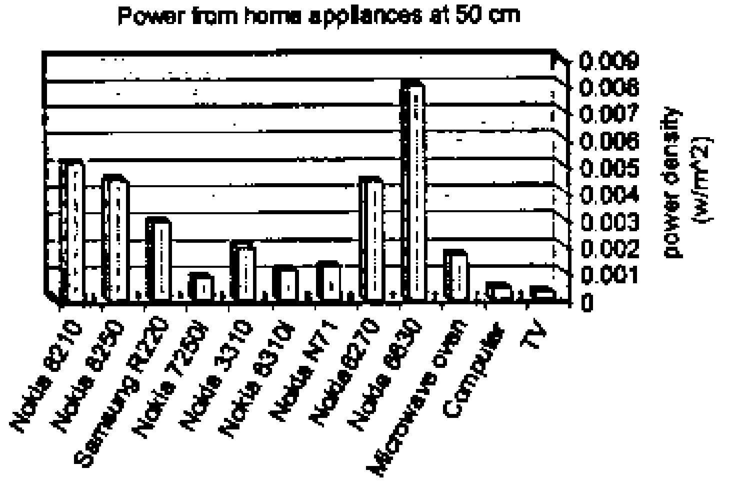


Figure (4-40) Power density radiation level for home appliances and mobile handset

Figure (4-41) shows the level of radiated power density from some home appliances and mobile handset at 100cm; from the figure, we can see that the Nokia 8250 and Nokia 8210 were radiated highest power level. Where the radiated power density by Nokia 8250 was 0.253μw/cm^2, and it was 0.295μw/cm^2 for Nokia 8210.

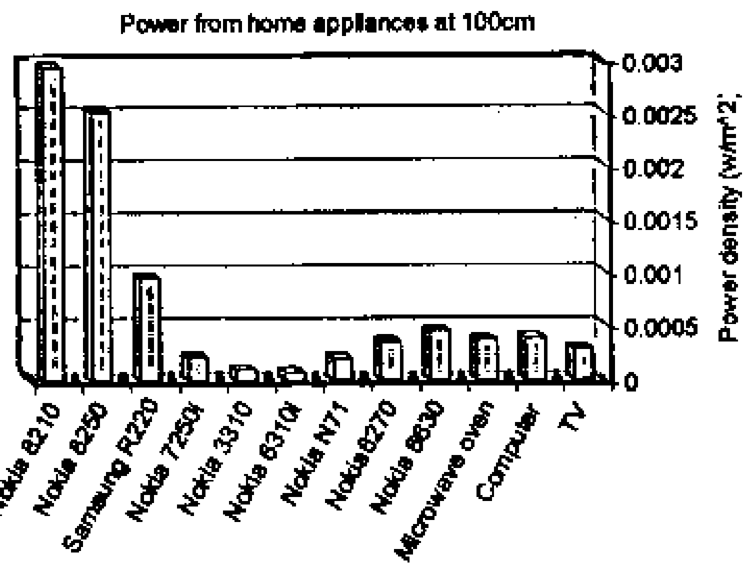


Figure (4-41) Power density radiation level for home appliances and mobile handset

4-6 Electric and Magnetic Fields

From received power, we calculated the power density by using equation below [40]:

$$S = \frac{1}{2}\mathrm{Re}[E \times H]$$

Matlap program to calculate electric and magnetic fields existing in appendix D; values of fields for all seven schools and for home appliances and mobile handset given in the Table (4-6).

Table (4-6) Maximum electric and magnetic fields

	Electric field strength (v/m)	ICNIRP Reference level (v/m)	Magnetic field strength (A/m)	ICNIRP Reference level (A/m)
Azzahf Al-Mostamer School	13.8785	41.25	0.0368	0.111
Attasadi School	11.5604	41.25	0.0307	0.111
AL Entelaka School	7.2623	41.25	0.0193	0.111
Ali Annaffati School	3.4744	41.25	0.0092	0.111
Shohadaabomelyana School	3.1404	41.25	0.0083	0.111
Ibn Haitham School	2.7044	41.25	0.0072	0.111
Atifaq Jereba School	2.0840	41.25	0.0055	0.111
Nokia 6270	20.9311	41.25	0.0555	0.111
Nokia 6630	18.6497	41.25	0.0495	0.111
Nokia N71	7.4342	41.25	0.0197	0.111
Nokia 8250	6.7690	41.25	0.0180	0.111
Samsung R220	6.0981	41.25	0.0162	0.111
Nokia 8210	5.3548	41.25	0.0142	0.111
Nokia 3310	5.2381	41.25	0.0139	0.111
Microwave oven	3.7489	41.25	0.0099	0.111
Nokia 7250i	3.4809	41.25	0.0092	0.111
Nokia 6310i	2.8864	41.25	0.0077	0.111
Computer	0.8463	41.25	0.0022	0.111
TV	0.8238	41.25	0.0022	0.111

4-7 Discussion and Results

It can be noted from conducted measurements and from all results that all values obtained of power densities was less than the international guidelines and the highest measured value is only 5.68% of ICNIRP reference level

It can be also noted that the power density under antennas decreased dramatically in the lower floors: in all schools, and the maximum level that measured was on rooftop under tower in Attasadi School and Azzahf AL-Mostemer School. While in lower floors, the power density was minimum and it was approximately constant through repeating the measurements.
The level of power density increased by increasing distances on rooftop in all schools, with distance until it reach the ground level after 50-200m away from the base station: depending on the height and title of the antenna. And the power density level increased by explicit increasing in west direction in Azzahf AL-Mostemer School. It is possible due to the existence of TV transmitters in the west of Azzahf AL-Mostemer School is one of reasons which rise the value of total power density.
When measuring the radiation power density at ground, it can be noted that the power density increased by increasing distance and then it starts to decrease with distance and the presence of other structures may shield or reflect the RF signals. In the Azzahf Al-Mostamer School, the power density level increased by explicit increasing in west direction the power density level was maximum in the west of Azzahf Al-Mostamer School. In addition, when studying location of this school we note that it is situated near TV transmitter and nearby other base stations.
Table (4-7) shows the maximum power density level on the rooftop and lower floors for all seven schools, and it can be noted that the power density levels are less than the ICNIRP limits.
By comparing the measurement of power density for some home appliances and mobile handset, we can say that there is some mobile handset radiated power density at 5cm higher than power density, which measured under the

mobile base stations. These mobile handsets are Nokia 6270 and Nokia 6630.

Table (4-7) Maximum power density level

School	Max power Density on rooftop (µw/cm^2)	Max power density second floor (µw/cm^2)	Max power density first floor (µw/cm^2)	Max power density ground floor (µw/cm^2)	ICNIRP reference level (µw/cm^2)
Ibn Haitham	0.746	0.032	0.031	0.036	450
Attasadi	10.734	0.071	0.046	0.040	450
Atifaq Jerba	0.537		0.053	0.037	450
Ali Annaffati	0.617	0.046	0.041	0.037	450
AL Entelaka	0.505	0.052	0.045	0.042	450
Shohadaabo melyana	0.484	0.071	0.067	0.067	450
Azzahf Al-Mostamer	2.554	0.064	0.041	0.043	450

Table (4-8) shows the maximum power density level for all seven schools, and maximum power density level for home appliances and mobile handset.

Table (4-8) Maximum power density level compare with ICNIRP standard

	Max measured power density (µw/cm^2)	Maximum measured power compare by ICNIRP reference level
Azzahf Al-Mostamer School	25.546	5.68%
Attasadi School	17.725	3.94%
AL Entelaka School	6.995	1.55%
Ali Annaffati School	1.601	0.36%
Shohadaabomelyana School	1.308	0.29%
Ibn Haitham School	0.97	0.22%
Atifaq Jereba School	0.576	0.128%
Nokia 6270	58.106	12.91%
Nokia 6630	46.13	10.25%
Nokia N71	7.33	1.63%
Nokia 8250	6.077	1.35%
Samsung R220	4.932	1.096%
Nokia 8210	3.803	0.845%
Nokia 3310	3.639	0.809%
Microwave oven	1.864	0.414%
Nokia 7250i	1.607	0.357%
Nokia 6310i	1.105	0.246%
Computer	0.095	0.021%
TV	0.09	0.02%

In comparison of these measurements with the ICNIRP limits, it can be said that the highest ratio between the measured power density and the ICNIRP reference level was in the Azzahf Al-Mostamer School on rooftop south of antennas at 8m .and the highest ratio between the measured power density and the ICNIRP reference level was for Nokia 6270 at 5cm.

Chapter five

Conclusion and Recommendations

5-1 Conclusion

In this thesis, the measurement of radiated power density from mobile phone base station antennas for seven schools in Tripoli city was conducted during the period 8-8-2006 to 19-8-2006 and repeated during the period 1-4-2007 to 5-4-2007; to ensure the safety level of the radiation in comparison with adopted standard that we compare the radiation level to its reference level we adopted ICNIRP standard.

The measurements conducted using two types of measurement devices. the highest level of radiation was on the rooftop of Azzahf AL-Mostemr School, and the level of radiation is only 5.68% of ICNIRP standard. In comparison with the measurement conducted in Canada a survey of five Vancouver schools, the maximum RF level measured at any school was 0.036% of the ICNIRP standard, it is 157.78 of maximum power density obtained from conducted measurements. In comparison of our results with the measurement conducted in UK, the maximum RF level measured was in the range 0.002-2% of the ICNIRP standard, it is 2840-2.84 of maximum power density obtained from conducted measurements.

The level of radiation of power density is higher on the midday time of the school hours than that at early morning or late of day.

The measurement of radiation level for some mobile handset was conducted for comparison. and it was found that the maximum power density from these devices at 5cm was 2.275 of maximum power density from base stations.

5-2 Recommendations

Prime goal of the thesis is to know if the power radiation level radiated by base station antennas over schools is within the level of radiation permitted by the international health organization or not. This was done by measuring the levels of radiation exposure for these antennas.

From this work, it can be recommend the follow:

- Students, handlers, and any body in schools must be forbidden from coming near of base station antennas.
- A survey should be conducted by measuring the EM power density before installing any base stations to ensure that the total power will not exceed the ICNIRP reference level.
- The government must be concerned about possible health effects from electromagnetic radiations; and putting the safety standards.
- Putting law for protection the population from radiation; and correcting the discordant.
- More studies should be conducted to establish Libyan safety guidelines.
- More studies for uniting the safety guidelines.
- Periodical check of radiation that emitted by base station antennas.
- Mobile phone companies must be Cooperating with researchers and encourage studies and researches by introducing the necessary information and facilitations. Depending on specialized scientific crew in mapping, designing and constructing these base stations.
- The height of the antennas must be higher than the neighboring buildings in area.

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Appendices

Appendix A: equipment of measurements

The equipments used in the measurements in this work and its characteristic illustrated in this appendix.

A-1 "RF Field Strength Meter

The equipment used for the measurements in this research is power meter "RF Field Strength Meter ". This meter detects the electric field of radio and microwaves (RF) from 0.5MHz to 3GHz, and expresses the field strength as power density from 0.001 to 200 microwatts/cm2.

The instrument is extremely sensitive RF and microwave radiation detectors, which can accurately measure RF background, even in rural far from any transmitters. The meter reads true power density directly on the display.

Unlike other low-cost field strength meters, this meter's frequency response does not depend on the characteristics of an external antenna; the internal detection system yields a flat response over a very wide range of frequencies.

Accuracy in the FM, TV and cellular phone radiation frequency range of 30MHz to 2.4GHz is ±5%. Sensitivity is low by 50%,-3dBm, at the frequency limits .5MHz and 3GHz.

Figure (A-1) "RF field strength meter"

A High-Pass selector switch allows you to measure either the full bandwidth ("Wide" = 0.5 MHz – 3 GHz) or to apply a high-pass filter ("Narrow" = 6 dB/ octive rolloff with a knee at 100 MHz) that effectively allows only 100 MHz to 3 GHz through. The RF Field Strength Meter is directional and it detects only the component of the electric field that has the same polarization as the long axis of the meter. That is, if only a vertically polarized RF wave is present, but you turn the meter in the horizontal direction, it will essentially read zero. If you subsequently rotate the meter to vertical, it will then read the full power density of the RF wave. Most RF radiation has only vertical electric field, so the full strength can be read by holding the meter vertically. (At the end of this page is more information on how to read radio waves with other polarizations).

The meter has a 4 ½ digit display, which reads in three ranges: .001 to 19.999, .01 to 199.99. and .1 to 1999.9 microwatts/cm2. For comparison, a low power 100-milliwatt dipole transmitter (typical 49 MHz cordless phone) produces about .010 microwatts/cm2 at a distance of 50 feet. This is 10x the minimum sensitivity of the meter. A FAST/SLOW update switch is normally set.in the FAST position so you.can quickly measure changes in the RF level. However, if the field strength is fluctuating rapidly, this switch can be set to the SLOW position, which averages the reading over several seconds.

The "zero" level will shift slightly with temperature. This shift is no more than +/- .010 microwatts/cm2 over the meter's operating temperature range of 30° F to 110° F (-1 to 43° C). Two controls on the right side of the meter correct for this: a button, when pressed, turns off the pre-amplifier, so it is the equivalent of zero field. Then an offset control is rotated until the meter reads zero in the most sensitive "19.999" setting. After one minute or more of warm-up, this should be adjusted. Once adjusted, this need not be readjusted unless the temperature changes by more than 5° F. (Then a shift of about .001microwatt /cm2 will occur).

The RF Field Strength Meter comes with a standard 9-volt battery and a one-year warranty. A low-battery indicator shows on the display when approximately 10 minutes of battery life remain. Electric current consumption from the battery is about 15 ma, with low battery indication at about 7.6 volts. Price of the meter is $320 (US), which includes shipping in North America. Outside North America, the price is $340, which includes Express Post (EMS) shipping. Although most commercial RF transmitters radiate with a vertical antenna and thus a vertical electric field (so you can hold the meter vertically to measure the full power density), some RF radiation also has some horizontal component, due to reflections or transmitters that have antennas not pointed vertical. If you know where the transmitter is, you will only have to perform two readings to find the transmitter's total power density at your position. These correspond to "Z" (vertical) and "X" (horizontal, but perpendicular to the direction of the transmitter). In theory, if you point the meter's long axis toward the antenna (the "Y" direction), you will not detect any radiation from that antenna. This seems counterintuitive. (In fact, there may be some diagonal reflectors near you that produce a small "Y" component coming from the transmitter, but this is not usually significant).

In practice, if the back face of the meter is facing the RF source, and the meter is read first in the vertical orientation and then it is read after being rotated 90° to the horizontal position (with the back face still facing the RF source), the sum of those two numbers will be the true power density from that transmitter. (This addition is a "sum of squares". That is, because power density is proportional to the square of the electric field, then the direct sum of these two numbers, and not the square root of the direct sum, will be the correct magnitude of the power density.) Most RF field sources are principally vertically polarized, in which case only the vertical reading needs to be done. To measure the full power density at a certain point in space, regardless of the sources' locations, measure the vertical first (meter pointed upward). This will usually be the majority of the RF power density. Then make two measurements 90° apart, with the meter's long axis pointed in the horizontal direction. For example, after the vertical measurement, measure holding the meter in a north-south orientation and then in an east-west orientation. The sum of these three numbers is the total power density at that point in space, regardless of the position of the transmitter or transmitters. An accuracy problem arises however, because your body can block RF radiation, so if an unseen transmitter is located on the opposite side of your body from the meter, the reading will be falsely low. If you hold the meter higher than your head, this problem disappears. The presence of your hand and arm will have some effect on the field strength at the meter, so the most accurate reading is taken by setting the meter on a non-metallic surface or using, for example, a plastic holder.

A-2 Sagem OT 290"

The SAGEM test tools are designed to fulfil the operators and integrators requirements and to provide the best solution to operate and maintain GSM and GPRS networks.

SAGEM OT 200 range gives all trace information for investigation or quality monitoring. GSM/GRPS software provided with the mobile enables visualisation, recording, replay of all information, and capability to store in the mobile alone measurements made in real time.

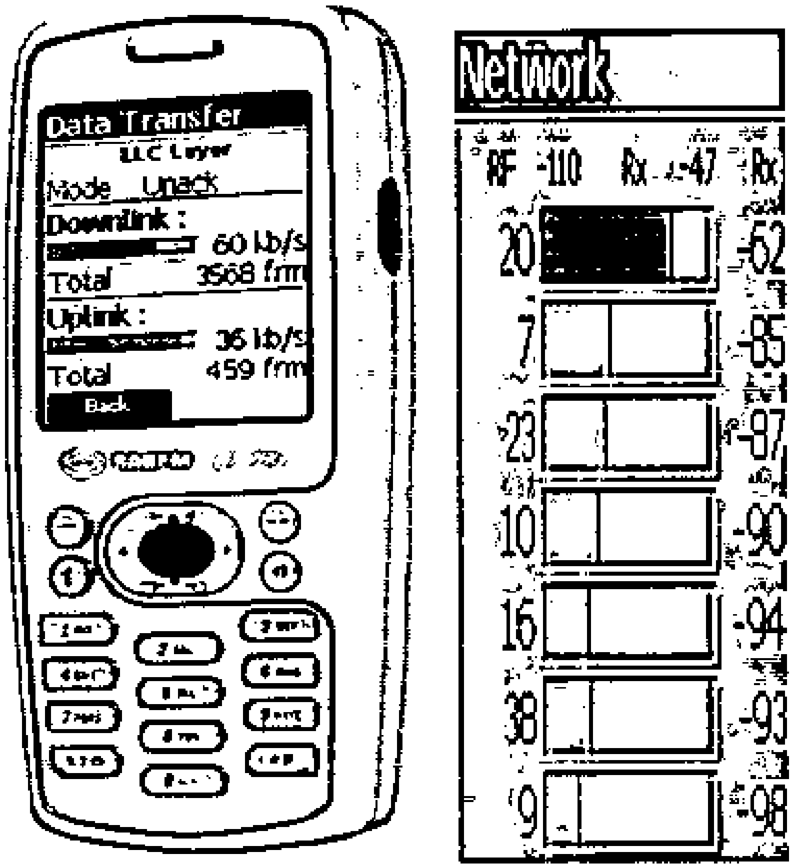


Figure (A-2) SAGEM OT 290 meter

Appendix B: Measurements

B-1- power density using RF Field strength meter

This appendix presents all complete measured power at all seven locations during the period 8-8-2006 to 19-8-2006.

Table (B-1-1) Measured power density in Ibn Haitham School

Location	Date	Power density (μw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	8-8-2006	0.078	0.668	0.7460
	15-8-2006	0.185	0.147	0.3320
	17-8-2006	0.167	0.249	0.4160
on rooftop, south of libyana tower 20m	8-8-2006	0.033	0.081	0.1140
	15-8-2006	0.046	0.065	0.1110
	17-8-2006	0.083	0.067	0.1500
on rooftop, west of libyana tower 40m	8-8-2006	0.490	0.189	0.6790
	15-8-2006	0.316	0.419	0.7350
	17-8-2006	0.328	0.286	0.6140
on rooftop, south-west of libyana tower 50m	8-8-2006	0.358	0.337	0.695
	15-8-2006	0.204	0.215	0.4190
	17-8-2006	0.512	0.458	0.9700
on rooftop, south-east of libyana tower 50m	8-8-2006	0.283	0.20	0.483
	15-8-2006	0.232	0.173	0.4050
	17-8-2006	0.334	0.227	0.5610
second floor, under the libyana tower	8-8-2006	0.010	0.009	0.0190
	15-8-2006	0.017	0.015	0.0320
	17-8-2006	0.015	0.014	0.0290
First floor, under the libyana tower	8-8-2006	0.010	0.009	0.0190
	15-8-2006	0.015	0.014	0.0290
	17-8-2006	0.017	0.014	0.0310
ground floor, under the libyana tower	8-8-2006	0.015	0.014	0.029
	15-8-2006	0.011	0.010	0.0210
	17-8-2006	0.019	0.017	0.0360
flying ball stadium, north-west of libyana tower 52.5m	8-8-2006	0.027	0.024	0.0510
	15-8-2006	0.026	0.025	0.0510
	17-8-2006	0.038	0.037	0.0750
east of libyana tower with horizontal distance 26.5m	8-8-2006	0.018	0.016	0.034
	15-8-2006	0.018	0.016	0.0340
	17-8-2006	0.018	0.016	0.0340
east of libyana tower with horizontal distance 50m " out of school fence"	8-8-2006	0.022	0.018	0.040
	15-8-2006	0.022	0.017	0.0390
	17-8-2006	0.021	0.019	0.0400
east of libyana tower with horizontal distance 100m" out of school fence"	8-8-2006	0.025	0.018	0.0430
	15-8-2006	0.052	0.048	0.1000
	17-8-2006	0.025	0.022	0.0470

Table (B-1-2) Measured power density in Attasadi School

Location	Date	Power density (µw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	13-8-2006	0.317	0.528	0.8450
	15-8-2006	4.024	6.710	10.7340
	17-8-2006	3.609	3.028	6.6370
on rooftop, south of libyana tower 20m	13-8-2006	1.129	0.896	2.0250
	15-8-2006	3.522	3.224	6.7460
	17-8-2006	4.969	3.845	8.8140
on rooftop, north of libyana tower 9m	13-8-2006	8.400	6.851	15.2510
	15-8-2006	2.817	5.096	7.9130
	17-8-2006	5.868	4.169	10.0370
on rooftop, south of libyana tower 8m	13-8-2006	11.057	5.981	17.0380
	15-8-2006	5.409	4.721	10.1300
	17-8-2006	6.807	4.017	10.8240
on rooftop, west of libyana tower 20m	13-8-2006	10.024	7.701	17.7250
	15-8-2006	4.719	3.870	8.5890
	17-8-2006	5.113	5.074	10.1870
second floor, under the libyana tower	13-8-2006	0.016	0.016	0.0320
	15-8-2006	0.036	0.035	0.0710
	17-8-2006	0.024	0.022	0.0460
First floor, under the libyana tower	13-8-2006	0.015	0.014	0.0290
	15-8-2006	0.024	0.022	0.0460
	17-8-2006	0.021	0.019	0.0400
ground floor, under the libyana tower	13-8-2006	0.018	0.016	0.0340
	15-8-2006	0.021	0.019	0.0400
	17-8-2006	0.020	0.018	0.0380
back court-yard with horizontal distance 18.3m	13-8-2006	0.056	0.041	0.0970
	15-8-2006	0.052	0.047	0.0990
	17-8-2006	0.061	0.059	0.1200
front court-yard "stadiums" with horizontal distance 49m, " the stadiums"	13-8-2006	0.118	0.222	0.3400
	15-8-2006	0.165	0.158	0.3230
	17-8-2006	0.164	0.143	0.3070
East of school, with horizontal distance 60m, " out of school fence"	13-8-2006	0.205	0.155	0.3600
	15-8-2006	0.402	0.194	0.5960
	17-8-2006	0.297	0.146	0.4430
north of school, with horizontal distance 60m, " out of school fence"	13-8-2006	0.045	0.042	0.0870
	15-8-2006	0.053	0.049	0.1020
	17-8-2006	0.054	0.049	0.1030

Table (B-1-3) Measured power density in Atifaq Jerba School

Location	Date	Power density (μw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	13-8-2006	0.132	0.157	0.2890
	15-8-2006	0.292	0.169	0.4610
	17-8-2006	0.145	0.318	0.4630
on rooftop, east of libyana tower 11.5m " under Al-Madar tower"	13-8-2006	0.083	0.093	0.1760
	15-8-2006	0.258	0.318	0.5760
	17-8-2006	0.241	0.178	0.4190
On rooftop, west of libyana tower 24.5	13-8-2006	0.082	0.078	0.1600
	15-8-2006	0.129	0.081	0.2100
	17-8-2006	0.089	0.066	0.1550
First floor, under the libyana tower	13-8-2006	0.20	0.018	0.2180
	15-8-2006	0.029	0.024	0.0530
	17-8-2006	0.023	0.021	0.0440
ground floor, under the libyana tower	13-8-2006	0.018	0.016	0.0340
	15-8-2006	0.017	0.016	0.0330
	17-8-2006	0.019	0.018	0.0370
flag stead with horizontal distance 24.5m	13-8-2006	0.093	0.067	0.1600
	15-8-2006	0.107	0.084	0.1910
	17-8-2006	0.106	0.102	0.2080
the school section which is in front of tower's downstairs, 42m	13-8-2006	0.022	0.019	0.0410
	15-8-2006	0.023	0.021	0.0440
	17-8-2006	0.017	0.016	0.0330
the school section which is in front of tower's upstairs, 42m	13-8-2006	0.016	0.016	0.0320
	15-8-2006	0.025	0.020	0.0450
	17-8-2006	0.026	0.024	0.0500
west of school, with horizontal distance 64m, "stadiums"	13-8-2006	0.028	0.024	0.0520
	15-8-2006	0.030	0.028	0.0580
	17-8-2006	0.035	0.033	0.0680
south-west of school, with horizontal distance 64m, "stadiums"	13-8-2006	0.085	0.047	0.1320
	15-8-2006	0.060	0.046	0.1060
	17-8-2006	0.067	0.059	0.1260
south court-yard, with horizontal distance 20m	13-8-2006	0.097	0.071	0.1680
	15-8-2006	0.098	0.141	0.2390
	17-8-2006	0.069	0.067	0.1360
west of school, with horizontal distance 77m, " out of school fence"	13-8-2006	0.033	0.022	0.0550
	15-8-2006	0.053	0.046	0.0990
	17-8-2006	0.034	0.029	0.0630

Table (B-1-4) Measured power density in Ali Annaffati School

Location	Date	Power density (uw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	14-8-2006	0.033	0.137	0.1700
	16-8-2006	0.156	0.079	0.2350
	19-8-2006	0.135	0.216	0.3510
on rooftop, west of libyana tower 13.5m."under AL-Madar tower"	14-8-2006	0.047	0.703	0.7500
	16-8-2006	0.786	0.579	1.3650
	19-8-2006	1.032	0.569	1.6010
on rooftop, west of libyana tower 23.8m	14-8-2006	0.054	0.078	0.1320
	16-8-2006	0.028	0.060	0.0880
	19-8-2006	0.047	0.043	0.0900
On rooftop, east of libyana tower 22m	14-8-2006	0.052	0.150	0.2020
	16-8-2006	0.031	0.068	0.0990
	19-8-2006	0.034	0.076	0.1100
On rooftop, south of libyana tower, 8m	14-8-2006	0.092	0.223	0.3150
	16-8-2006	0.079	0.059	0.1380
	19-8-2006	0.034	0.028	0.0620
On rooftop, north of libyana tower, 11m	14-8-2006	0.046	0.130	0.1760
	16-8-2006	0.079	0.113	0.1920
	19-8-2006	0.052	0.122	0.1740
second floor, under the libyana tower	14-8-2006	0.015	0.013	0.0280
	16-8-2006	0.017	0.016	0.0330
	19-8-2006	0.018	0.016	0.0340
First floor, under the libyana tower	14-8-2006	0.015	0.013	0.0280
	16-8-2006	0.018	0.016	0.0340
	19-8-2006	0.017	0.015	0.0320
ground floor, under the libyana tower	14-8-2006	0.011	0.010	0.0210
	16-8-2006	0.017	0.016	0.0330
	19-8-2006	0.016	0.013	0.0290
north court-yard, with horizontal distance 43m	14-8-2006	0.018	0.018	0.0360
	16-8-2006	0.022	0.024	0.0460
	19-8-2006	0.034	0.031	0.0650
south court-yard, with horizontal distance	14-8-2006	0.022	0.033	0.0550
	16-8-2006	0.026	0.034	0.0600
	19-8-2006	0.041	0.040	0.0810
west court-yard, with horizontal distance 55m	14-8-2006	0.024	0.014	0.0380
	16-8-2006	0.020	0.019	0.0390
	19-8-2006	0.026	0.021	0.0470

Table (B-1-5) Measured power density AL Entelaka School

Location	Date	Power density (μw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	14-8-2006	0.311	0.092	0.4030
	16-8-2006	0.454	0.078	0.5320
	19-8-2006	0.314	0.191	0.5050
on rooftop, west of libyana tower 22.7m. "under AL-Madar tower"	14-8-2006	0.971	2.618	3.5890
	16-8-2006	3.882	1.369	5.2510
	19-8-2006	4.747	2.248	6.9950
on rooftop, west of libyana tower 31.7m	14-8-2006	0.412	0.348	0.7600
	16-8-2006	0.485	0.424	0.9090
	19-8-2006	0.611	0.408	1.0190
on rooftop, south of libyana tower 27m	14-8-2006	0.111	0.067	0.1780
	16-8-2006	0.134	0.038	0.1720
	19-8-2006	0.132	0.083	0.2150
on rooftop, south-west of libyana tower 39.5m	14-8-2006	0.112	0.067	0.1790
	16-8-2006	0.110	0.073	0.1830
	19-8-2006	0.096	0.048	0.1440
on rooftop, east of libyana tower, 7m	14-8-2006	0.095	0.436	0.5310
	16-8-2006	0.083	0.177	0.2600
	19-8-2006	0.254	0.229	0.4830
on rooftop, north of libyana tower 14.4m	14-8-2006	0.121	0.092	0.2130
	16-8-2006	0.139	0.094	0.2330
	19-8-2006	0.106	0.154	0.2600
second floor, under the libyana tower	14-8-2006	0.024	0.028	0.0520
	16-8-2006	0.022	0.021	0.0430
	19-8-2006	0.021	0.019	0.0400
First floor, under the libyana tower	14-8-2006	0.023	0.022	0.0450
	16-8-2006	0.020	0.019	0.0390
	19-8-2006	0.023	0.021	0.0440
ground floor, under the libyana tower	14-8-2006	0.023	0.019	0.0420
	16-8-2006	0.019	0.018	0.0370
	19-8-2006	0.021	0.019	0.0400
first floor, south-west classroom	14-8-2006	0.021	0.019	0.0400
	16-8-2006	0.020	0.019	0.0390
	19-8-2006	0.019	0.016	0.0350
west court-yard, with horizontal distance 94m	14-8-2006	0.030	0.035	0.0650
	16-8-2006	0.041	0.037	0.0780
	19-8-2006	0.035	0.048	0.0830

South-west court-yard, with horizontal distance63m	**14-8-2006**	**0.043**	**0.032**	**0.0750**
	16-8-2006	**0.024**	**0.023**	**0.0470**
	19-8-2006	0.031	0.028	0.0590
east of school, with horizontal distance 26.5m, " out of school fence"	14-8-2006	0.024	0.022	0.0460
	16-8-2006	0.023	0.022	0.0450
	19-8-2006	**0.016**	0.024	0.0400

Table (B-1-6) Measured power density Shohadaabomelyana School

Location	Date	Power density (µw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	14-8-2006	0.145	0.265	0.41
	16-8-2006	0.108	0.182	0.29
	19-8-2006	0.191	0.293	0.484
on rooftop, west of libyana tower 12m. "under AL-Madar tower"	14-8-2006	0.210	0.8980	1.108
	16-8-2006	0.237	1.111	1.348
	19-8-2006	0.247	1.308	1.555
on rooftop, west of libyana tower 36.2m	14-8-2006	0.165	0.262	0.427
	16-8-2006	0.193	0.282	0.475
	19-8-2006	0.203	0.327	0.53
on rooftop, east of libyana tower 18.5m	14-8-2006	0.150	0.298	0.448
	16-8-2006	0.144	0.286	0.442
	19-8-2006	0.154	0.311	0.465
on rooftop, south of libyana tower7.2mm	14-8-2006	0.214	0.367	0.581
	16-8-2006	0.171	0.343	0.514
	19-8-2006	0.184	0.341	0.525
on rooftop, north of libyana tower 11.15m	14-8-2006	0.167	0.325	0.492
	16-8-2006	0.184	0.322	0.506
	19-8-2006	0.154	0.286	0.43
second floor, under the libyana tower	14-8-2006	0.018	0.037	0.055
	16-8-2006	0.023	0.044	0.067
	19-8-2006	0.024	0.047	0.071
First floor, under the libyana tower	14-8-2006	0.013	0.026	0.039
	16-8-2006	0.018	0.035	0.053
	19-8-2006	0.023	0.044	0.067
ground floor, under the libyana tower	14-8-2006	0.015	0.029	0.044
	16-8-2006	0.018	0.035	0.053
	19-8-2006	0.023	0.044	0.067
south of libyana tower, with horizontal distance 82.5m,"stadium"	14-8-2006	0.095	0.173	0.268
	16-8-2006	0.076	0.141	0.217
	19-8-2006	0.089	0.148	0.237
South-west of libyana tower, with horizontal distanc 55m, "stadium"	14-8-2006	0.042	0.083	0.125
	16-8-2006	0.055	0.103	0.158
	19-8-2006	0.054	0.097	.0151
north of libyana tower, with horizontal distance 61.15m, "football stadium"	14-8-2006	0.080	0.151	0.231
	16-8-2006	0.081	0.157	0.238
	19-8-2006	0.078	0.155	0.233

Table (B-1-7) Measured power density Azzahf Al-Mostamer School

Location	Date	Power density (µw/cm^2)		
		X	Y	Total
on rooftop under the libyana tower	15-8-2006	2.207	1.060	3.2670
	16-8-2006	1.342	1.055	2.3970
	19-8-2006	1.441	1.113	2.5540
on rooftop, south of libyana tower,8m	15-8-2006	9.317	5.617	14.9340
	16-8-2006	10.922	9.611	20.5330
	19-8-2006	17.118	8.128	25.2460
on rooftop north under of libyana tower. 8m	15-8-2006	11.117	6.929	18.0460
	16-8-2006	10.094	6.453	16.5470
	19-8-2006	9.013	6.542	15.5550
on rooftop west of libyana tower. 30m	15-8-2006	4.556	1.683	6.2390
	16-8-2006	9.981	2.130	12.1110
	19-8-2006	7.406	3.052	10.4580
on rooftop east of libyana tower, 24.5m	15-8-2006	6.540	3.570	10.1100
	16-8-2006	9.853	8.720	18.5730
	19-8-2006	9.207	7.647	16.8540
second floor, under the libyana tower	15-8-2006	0.023	0.019	0.0420
	16-8-2006	0.021	0.019	0.0400
	19-8-2006	0.022	0.019	0.0410
First floor, under the libyana tower	15-8-2006	0.019	0.017	0.0360
	16-8-2006	0.018	0.017	0.0350
	19-8-2006	0.022	0.20	0.2220
ground floor, under the libyana tower	15-8-2006	0.017	0.015	0.0320
	16-8-2006	0.021	0.019	0.0400
	19-8-2006	0.022	0.021	0.0430
north court-yard, with horizontal distance 36.5m	15-8-2006	0.051	0.045	0.0960
	16-8-2006	0.079	0.084	0.1630
	19-8-2006	0.063	0.054	0.1170
West court-yard, with horizontal distance 65.5m	15-8-2006	0.671	0.485	1.1560
	16-8-2006	0.651	0.563	1.2140
	19-8-2006	0.732	0.613	1.3450
east of libyana tower, with horizontal distance 66m. " stadium"	15-8-2006	4.881	2.312	7.1930
	16-8-2006	3.280	1.971	5.2510
	19-8-2006	3.605	2.132	5.7370
south of school, with horizontal distance 130 " out of school fence"	15-8-2006	1.230	0.413	1.6430
	16-8-2006	1.023	0.873	1.8960
	19-8-2006	0.511	0.362	0.8730

B-2 measured power density using SAGEM meter OT290

This appendix presents all complete measured power at two worst cases (Azzahf Al-Mostamer School and Attasadi School) during the period 14-2-2006 to 16-2-2006.

Table (B-2-1) Power density on rooftop under the tower at

Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
949.2	-30	$1*10^{-6}$	2.5	$314.5016*10^{-6}$
950.6	-35	$0.3162*10^{-6}$	2.5	$99.7477*10^{-6}$
951.8	-34	$0.3981*10^{-6}$	2.5	$125.8922*10^{-6}$
949.8	-49	$0.0126*10^{-6}$	2.5	$3.9643*10^{-6}$
950.8	-53	$0.005*10^{-6}$	2.5	$1.5816*10^{-6}$
951.4	-57	$0.002*10^{-6}$	2.5	$0.6304*10^{-6}$
949.6	-48	$0.0158*10^{-6}$	2.5	$4.9887*10^{-6}$
937.2	-50	$0.01*10^{-6}$	2.5	$3.066*10^{-6}$
936.4	-68	$0.0002*10^{-6}$	2.5	$0.0485*10^{-6}$
937.2	-68	$0.0002*10^{-6}$	2.5	$0.0486*10^{-6}$
935.6	-65	$0.0003*10^{-6}$	2.5	$0.0966*10^{-6}$
938.2	-59	$0.0013*10^{-6}$	2.5	$0.3868*10^{-6}$
938.8	-67	$0.0002*10^{-6}$	2.5	$0.0614*10^{-6}$
936	-67	$0.0002*10^{-6}$	2.5	$0.061*10^{-6}$
total				$5.55075*10^{-4}$

Table (B-2-2) Power density on rooftop, south of tower, 8m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-38	$0.585*10^{-6}$	2.5	$49.9923*10^{-6}$
949.4	-48	$0.015*10^{-6}$	2.5	$4.9866*10^{-6}$
951.8	-33	$0.5012*10^{-6}$	2.5	$158.4889*10^{-6}$
949.8	-50	$0.01*10^{-6}$	2.5	$3.149*10^{-6}$
951	-55	$0.0032*10^{-6}$	2.5	$0.9983*10^{-6}$
952.2	-52	$0.0063*10^{-6}$	2.5	$1.9969*10^{-6}$
1745.2	-53	$0.005*10^{-6}$	2.5	$5.3284*10^{-6}$
937.2	-58	$0.0016*10^{-6}$	2.5	$0.4859*10^{-6}$
936.4	-70	$0.0001*10^{-6}$	2.5	$0.0306*10^{-6}$
936	-67	$0.0002*10^{-6}$	2.5	$0.061*10^{-6}$
935.6	-55	$0.0032*10^{-6}$	2.5	$0.9662*10^{-6}$
938.2	-52	$0.0063*10^{-6}$	2.5	$1.9386*10^{-6}$
938.8	-71	$0.0001*10^{-6}$	2.5	$0.0244*10^{-6}$
937.4	-67	$0.0002*10^{-6}$	2.5	$0.612*10^{-6}$
total			2.5	$2.285075*10^{-4}$

Table ((B-2-3) Power density on rooftop north of tower. 8m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
949.4	-63	$0.005*10^{-7}$	2.5	$0.1577*10^{-6}$
950.6	-59	$0.0126*10^{-7}$	2.5	$0.3971*10^{-6}$
951.8	-47	$0.1995*10^{-7}$	2.5	$6.3096*10^{-6}$
952.2	-50	$0.1*10^{-7}$	2.5	$3.1649*10^{-6}$
1710.4	-54	$0.0398*10^{-7}$	2.5	$4.0654*10^{-6}$
951.2	-51	$0.0794*10^{-7}$	2.5	$2.5087*10^{-6}$
949.6	-48	$0.1585*10^{-7}$	2.5	$4.9887*10^{-6}$
937.2	-47	$0.1995*10^{-7}$	2.5	$6.1175*10^{-6}$
936.4	-66	$0.0025*10^{-7}$	2.5	$0.0769*10^{-6}$
937.8	-62	$0.0063*10^{-7}$	2.5	$0.1937*10^{-6}$
935.6	-56	$0.0251*10^{-7}$	2.5	$0.7675*10^{-6}$
938.2	-59	$0.0126*10^{-7}$	2.5	$0.3868*10^{-6}$
938.8	-65	$0.032*10^{-7}$	2.5	$0.0973*10^{-6}$
936	-66	$0.0025*10^{-7}$	2.5	$0.0768*10^{-6}$
total				**$2.93075*10^{-5}$**

Table (B-2-4) Power density on rooftop, west of tower, 30m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
1712	-63	$0.0005*10^{-6}$	2.5	$0.5128*10^{-6}$
949.4	-65	$0.0003*10^{-6}$	2.5	$0.0995*10^{-6}$
950.6	-61	$0.0008*10^{-6}$	2.5	$0.2506*10^{-6}$
951.8	-64	$0.0004*10^{-6}$	2.5	$0.1259*10^{-6}$
952.2	-32	$0.6310*10^{-6}$	2.5	$199.6934*10^{-6}$
1710.4	-63	$0.0005*10^{-6}$	2.5	$0.5118*10^{-6}$
949.6	-49	$0.0126*10^{-6}$	2.5	$3.9627*10^{-6}$
938.4	-72	$0.0001*10^{-6}$	2.5	$0.0194*10^{-6}$
937.8	-69	$0.0001*10^{-6}$	2.5	$0.0386*10^{-6}$
936	-68	$0.0002*10^{-6}$	2.5	$0.0485*10^{-6}$
937.2	-57	$0.0002*10^{-6}$	2.5	$0.6117*10^{-6}$
938.2	-55	$0.0032*10^{-6}$	2.5	$0.9716*10^{-6}$
935.6	-50	$0.01*10^{-6}$	2.5	$3.0555*10^{-6}$
935.2	-78	$0.0000158*10^{-6}$	2.5	$0.0048*10^{-6}$
total				$2.099075*10^{-4}$

Table (B-2-5) Power density on rooftop east of tower, 24.5m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-63	$0.005*10^{-7}$	2.5	$0.1581*10^{-6}$
949.4	-61	$0.0079*10^{-7}$	2.5	$0.2499*10^{-6}$
951.8	-55	$0.0316*10^{-7}$	2.5	$1*10^{-6}$
950	-44	$0.3981*10^{-7}$	2.5	$12.5416*10^{-6}$
952.2	-49	$0.1259*10^{-7}$	2.5	$3.9844*10^{-6}$
949	-43	$0.5012*10^{-7}$	2.5	$15.7558*10^{-6}$
951.2	-44	$0.3981*10^{-7}$	2.5	$12.5734*10^{-6}$
937.2	-60	$0.01*10^{-7}$	2.5	$0.3066*10^{-6}$
936.4	-72	$0.0006*10^{-7}$	2.5	$0.0193*10^{-6}$
937.8	-73	$0.0005*10^{-7}$	2.5	$0.0154*10^{-6}$
935.6	-56	$0.0251*10^{-7}$	2.5	$0.7675*10^{-6}$
938.2	-56	$0.0251*10^{-7}$	2.5	$0.7718*10^{-6}$
938.8	-73	$0.0005*10^{-7}$	2.5	$0.0154*10^{-6}$
936	-68	$0.0016*10^{-7}$	2.5	$0.0485*10^{-6}$
total				$4.82075*10^{-5}$

Table (B-2-6) Power density in second floor, under the tower at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-60	$0.1*10^{-8}$	2.5	$0.3154*10^{-6}$
949.4	-56	$0.2512*10^{-8}$	2.5	$0.7903*10^{-6}$
949.6	-75	$0.0032*10^{-8}$	2.5	$0.01*10^{-6}$
951.8	-60	$0.1*10^{-8}$	2.5	$0.3162*10^{-6}$
952.2	-72	$0.0063*10^{-8}$	2.5	$0.020*10^{-6}$
951.2	-72	$0.0063*10^{-8}$	2.5	$0.019*10^{-6}$
949.8	-72	$0.0063*10^{-8}$	2.5	$0.0199*10^{-6}$
937.2	-69	$0.0126*10^{-8}$	2.5	$0.0386*10^{-6}$
938.8	-93	$0.0001*10^{-8}$	2.5	$0.0002*10^{-6}$
939.2	-84	$0.0004*10^{-8}$	2.5	$0.0012*10^{-6}$
935.6	-86	$0.0003*10^{-8}$	2.5	$0.0008*10^{-6}$
938.2	-86	$0.0003*10^{-8}$	2.5	$0.0008*10^{-6}$
936.4	-90	$0.0001*10^{-8}$	2.5	$0.0003*10^{-6}$
936.6	-87	$0.0002*10^{-8}$	2.5	$0.0006*10^{-6}$
total				$1.53413*10^{-6}$

Table (B-2-7) Power density in first floor, under the tower at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
949.4	-66	$0.0251*10^{-8}$	2.5	$0.079*10^{-6}$
951.8	-65	$0.316*10^{-8}$	2.5	$0.1*10^{-6}$
949.6	-81	$0.0008*10^{-8}$	2.5	$0.0025*10^{-6}$
950	-70	$0.01*10^{-8}$	2.5	$0.0315*10^{-6}$
952.2	-78	$0.0016*10^{-8}$	2.5	$0.005*10^{-6}$
949.8	-76	$0.0025*10^{-8}$	2.5	$0.0079*10^{-6}$
950	-91	$0.0001*10^{-8}$	2.5	$0.0003*10^{-6}$
935.2	-64	$0.0398*10^{-8}$	2.5	$0.1215*10^{-6}$
935.6	-56	$0.2512*10^{-8}$	2.5	$0.7675*10^{-6}$
937.2	-76	$0.0025*10^{-8}$	2.5	$0.0077*10^{-6}$
939.2	-61	$0.0794*10^{-8}$	2.5	$0.2446*10^{-6}$
938.2	-96	$0.0003*10^{-8}$	2.5	$0.0001*10^{-6}$
937.4	-93	$0.001*10^{-8}$	2.5	$0.0002*10^{-6}$
938.8	-101	$0.0001*10^{-8}$	2.5	$0.00002*10^{-6}$
total				$1.3678*10^{-6}$

Table (B-2-8) Power density in ground floor, under the tower at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-60	$1*10^{-9}$	2.5	$0.3154*10^{-6}$
949.4	-64	$0.3981*10^{-9}$	2.5	$0.1253*10^{-6}$
949.6	-77	$0.02*10^{-9}$	2.5	$0.0063*10^{-6}$
951.8	-63	$0.5012*10^{-9}$	2.5	$0.1585*10^{-6}$
952.2	-78	$0.0158*10^{-9}$	2.5	$0.005*10^{-6}$
1710.4	-71	$0.0794*10^{-9}$	2.5	$0.0811*10^{-6}$
1712	-83	$0.005*10^{-9}$	2.5	$0.0051*10^{-6}$
935.2	-67	$0.1995*10^{-9}$	2.5	$0.0609*10^{-6}$
939.2	-67	$0.1995*10^{-9}$	2.5	$0.0614*10^{-6}$
937.2	-70	$0.1*10^{-9}$	2.5	$0.0307*10^{-6}$
935.6	-67	$0.1995*10^{-9}$	2.5	$0.0610*10^{-6}$
938.2	-81	$0.0079*10^{-9}$	2.5	$0.0024*10^{-6}$
936.4	-86	$0.0025*10^{-9}$	2.5	$0.0008*10^{-6}$
936.8	-85	$0.0032*10^{-9}$	2.5	$0.001*10^{-6}$
total				$9.1487*10^{-7}$

Table (B-2-9) Power density in north courtyard, with horizontal distance 36.5m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
949.4	-41	$0.0794*10^{-6}$	2.5	$24.9923*10^{-6}$
1710.4	-57	$0.002*10^{-6}$	2.5	$2.0375*10^{-6}$
951.8	-54	$0.004*10^{-6}$	2.5	$1.2589*10^{-6}$
950.6	-56	$0.0025*10^{-6}$	2.5	$0.7923*10^{-6}$
1745.2	-59	$0.0013*10^{-6}$	2.5	$1.3384*10^{-6}$
1712	-62	$0.0006*10^{-6}$	2.5	$0.6455*10^{-6}$
949.6	-59	$0.0013*10^{-6}$	2.5	$0.3963*10^{-6}$
935.2	-36	$0.2512*10^{-6}$	2.5	$76.686*10^{-6}$
937.2	-59	$0.0013*10^{-6}$	2.5	$0.386*10^{-6}$
939.2	-49	$0.0126*10^{-6}$	2.5	$3.8764*10^{-6}$
935.6	-49	$0.0126*10^{-6}$	2.5	$3.8467*10^{-6}$
936.4	-78	$0.0000158*10^{-6}$	2.5	$0.0049*10^{-6}$
937	-76	$0.0000251*10^{-6}$	2.5	$0.0077*10^{-6}$
938	-72	$0.001*10^{-6}$	2.5	$0.0194*10^{-6}$
total				$1.16287*10^{-4}$

Table (B-2-10) Power density west courtyard. with horizontal distance 65.5m at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
1712	-46	$0.2512*10^{-7}$	2.5	$25.6989*10^{-6}$
951.8	-51	$0.0794*10^{-7}$	2.5	$2.5119*10^{-6}$
949.4	-59	$0.0126*10^{-7}$	2.5	$0.3961*10^{-6}$
950.2	-50	$0.1*10^{-7}$	2.5	$3.1516*10^{-6}$
1710.4	-57	$0.02*10^{-7}$	2.5	$2.0375*10^{-6}$
1745.2	-61	$0.0079*10^{-7}$	2.5	$0.8445*10^{-6}$
952.2	-69	$0.0013*10^{-7}$	2.5	$0.0398*10^{-6}$
935.6	-53	$0.0501*10^{-7}$	2.5	$1.5314*10^{-6}$
937.2	-73	$0.0005*10^{-7}$	2.5	$0.0154*10^{-6}$
939.2	-66	$0.0025*10^{-7}$	2.5	$0.0773*10^{-6}$
935.2	-60	$0.01*10^{-7}$	2.5	$0.3053*10^{-6}$
936	-86	$0.000025*10^{-7}$	2.5	$0.0008*10^{-6}$
937.4	-85	$0.0000316*10^{-7}$	2.5	$0.001*10^{-6}$
937.8	-87	$0.00002*10^{-7}$	2.5	$0.0006*10^{-6}$
total				$3.66125*10^{-5}$

Table (B-2-11) Power density east of tower, with horizontal distance 66m, "stadium" at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-47	$0.1995*10^{-7}$	2.5	$6.2937*10^{-6}$
950.4	-59	$0.0126*10^{-7}$	2.5	$0.3969*10^{-6}$
1745.2	-55	$0.0316*10^{-7}$	2.5	$3.362*10^{-6}$
949.4	-53	$0.0501*10^{-7}$	2.5	$1.5769*10^{-6}$
951.8	-47	$0.1995*10^{-7}$	2.5	$6.3096*10^{-6}$
1710.4	-66	$0.0025*10^{-7}$	2.5	$0.2565*10^{-6}$
1712	-57	$0.02*10^{-7}$	2.5	$2.0413*10^{-6}$
935.2	-41	$0.7943*10^{-7}$	2.5	$24.2503*10^{-6}$
937.2	-71	$0.0008*10^{-7}$	2.5	$0.0244*10^{-6}$
939.2	-60	$0.01*10^{-7}$	2.5	$0.3079*10^{-6}$
935.6	-58	$0.0158*10^{-7}$	2.5	$0.4843*10^{-6}$
938.4	-82	$0.0001*10^{-7}$	2.5	$0.0019*10^{-6}$
938.2	-81	$0.0001*10^{-7}$	2.5	$0.0024*10^{-6}$
936.6	-84	$0.00004*10^{-7}$	2.5	$0.0012*10^{-6}$
total				$4.531*10^{-5}$

Table (B-2-12) Power density south of school, with horizontal distance 130 "out of school fence" at Azzahf Al-Mostamer School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
1745.2	-40	$0.1*10^{-6}$	2.5	$106.3158*10^{-6}$
1712	-50	$0.01*10^{-6}$	2.5	$10.2309*10^{-6}$
950.6	-35	$0.3162*10^{-6}$	2.5	$99.7477*10^{-6}$
951.8	-36	$0.2512*10^{-6}$	2.5	$79.4326*10^{-6}$
1712.2	-65	$0.0003*10^{-6}$	2.5	$0.3236*10^{-6}$
951.6	-58	$0.0016*10^{-6}$	2.5	$0.501*10^{-6}$
950.4	-57	$0.002*10^{-6}$	2.5	$0.6291*10^{-6}$
939.2	-36	$0.2512*10^{-6}$	2.5	$77.3434*10^{-6}$
935.6	-50	$0.01*10^{-6}$	2.5	$3.0555*10^{-6}$
935.2	-54	$0.004*10^{-6}$	2.5	$1.2154*10^{-6}$
937.2	-71	$0.000079*10^{-6}$	2.5	$0.0244*10^{-6}$
935.8	-70	$0.0001*10^{-6}$	2.5	$0.0306*10^{-6}$
936.4	-86	$0.0000025*10^{-6}$	2.5	$0.0008*10^{-6}$
938.2	-84	$0.000004*10^{-6}$	2.5	$0.0012*10^{-6}$
total				$3.7885*10^{-4}$

Table (B-2-13) Power density on rooftop under the tower at Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
951.2	-43	$0.0501*10^{-6}$	2.5	$15.8289*10^{-6}$
948.8	-40	$0.1*10^{-6}$	2.5	$31.4237*10^{-6}$
950	-41	$0.0794*10^{-6}$	2.5	$25.0239*10^{-6}$
1711.8	-55	$0.0032*10^{-6}$	2.5	$3.2345*10^{-6}$
948.6	-56	$0.0025*10^{-6}$	2.5	$0.789*10^{-6}$
949.4	-54	$0.004*10^{-6}$	2.5	$1.2526*10^{-6}$
949	-57	$0.002*10^{-6}$	2.5	$0.6272*10^{-6}$
937.4	-31	$0.7943*10^{-6}$	2.5	$243.6449*10^{-6}$
935.6	-56	$0.0025*10^{-6}$	2.5	$0.7675*10^{-6}$
938.4	-57	$0.002*10^{-6}$	2.5	$0.6133*10^{-6}$
935.8	-38	$0.1585*10^{-6}$	2.5	$48.4477*10^{-6}$
938	-32	$0.631*10^{-6}$	2.5	$193.7818*10^{-6}$
937.2	-59	$0.0013*10^{-6}$	2.5	$0.386*10^{-6}$
936	-60	$0.001*10^{-6}$	2.5	$0.3058*10^{-6}$
total				$5.66125*10^{-4}$

Table (B-2-14) Power density on rooftop, south of tower 8m Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-30	$1*10^{-6}$	2.5	$315.0319*10^{-6}$
948.8	-43	$0.0501*10^{-6}$	2.5	$15.7491*10^{-6}$
951.2	-40	$0.1*10^{-6}$	2.5	$31.5828*10^{-6}$
1742.6	-43	$0.0501*10^{-6}$	2.5	$53.1255*10^{-6}$
949.4	-53	$0.005*10^{-6}$	2.5	$1.5769*10^{-6}$
1711.8	-43	$0.0501*10^{-6}$	2.5	$51.2641*10^{-6}$
1746.6	-49	$0.0126*10^{-6}$	2.5	$13.4058*10^{-6}$
937.6	-31	$0.7943*10^{-6}$	2.5	$243.7488*10^{-6}$
935.6	-54	$0.004*10^{-6}$	2.5	$1.2164*10^{-6}$
938.4	-56	$0.0025*10^{-6}$	2.5	$0.7721*10^{-6}$
935.8	-36	$0.2512*10^{-6}$	2.5	$76.7845*10^{-6}$
938	-49	$0.0126*10^{-6}$	2.5	$3.8665*10^{-6}$
935.2	-60	$0.001*10^{-6}$	2.5	$0.3053*10^{-6}$
936	-57	$0.002*10^{-6}$	2.5	$0.6102*10^{-6}$
total				$8.0905*10^{-4}$

Table (B-2-15) Power density on rooftop, north of tower 8m Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
951.2	-42	$0.0063*10^{-5}$	2.5	$0.0199*10^{-3}$
1711.8	-43	$0.005*10^{-5}$	2.5	$0.0513*10^{-3}$
948.8	-34	$0.0398*10^{-5}$	2.5	$0.1251*10^{-3}$
950	-45	$0.0032*10^{-5}$	2.5	$0.01*10^{-3}$
948.6	-51	$0.0008*10^{-5}$	2.5	$0.0025*10^{-3}$
949	-53	$0.0005*10^{-5}$	2.5	$0.0016*10^{-3}$
950.6	-56	$0.0003*10^{-5}$	2.5	$0.0008*10^{-3}$
935.8	-24	$0.3981*10^{-5}$	2.5	$1.217*10^{-3}$
938.8	-62	$0.0001*10^{-5}$	2.5	$0.0002*10^{-3}$
938.4	-60	$0.0001*10^{-5}$	2.5	$0.0003*10^{-3}$
937.6	-50	$0.001*10^{-5}$	2.5	$0.0031*10^{-3}$
938	-37	$0.02*10^{-5}$	2.5	$0.0613*10^{-3}$
937.2	-54	$0.0004*10^{-5}$	2.5	$0.0012*10^{-3}$
935.4	-62	$0.0001*10^{-5}$	2.5	$0.0002*10^{-3}$
total				$1.494325*10^{-3}$

Table (B-2-16) Power density on rooftop. east of tower 20m Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-40	$1*10^{-7}$	2.5	$31.5032*10^{-6}$
948.8	-40	$1*10^{-7}$	2.5	$31.4237*10^{-6}$
951.2	-51	$0.0794*10^{-7}$	2.5	$2.5087*10^{-6}$
951.6	-57	$0.02*10^{-7}$	2.5	$0.6307*10^{-6}$
1742	-45	$0.3162*10^{-7}$	2.5	$33.4968*10^{-6}$
951.8	-52	$0.631*10^{-7}$	2.5	$1.9953*10^{-6}$
949	-51	$0.0794*10^{-7}$	2.5	$2.4971*10^{-6}$
937.6	-40	$1*10^{-7}$	2.5	$30.6862*10^{-6}$
935.6	-55	$0.0316*10^{-7}$	2.5	$0.9662*10^{-6}$
937.2	-47	$0.1995*10^{-7}$	2.5	$6.1175*10^{-6}$
935.8	-43	$0.5012*10^{-7}$	2.5	$15.3205*10^{-6}$
935.2	-54	$0.0398*10^{-7}$	2.5	$1.2154*10^{-6}$
938.4	-46	$0.2512*10^{-7}$	2.5	$7.7212*10^{-6}$
936	-52	$0.0631*10^{-7}$	2.5	$1.9296*10^{-6}$
total				$1.680125*10^{-4}$

Table (B-2-17) Power density on rooftop, west of tower 20m Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
948.8	-54	$0.004*10^{-6}$	2.5	$1.251*10^{-6}$
951.2	-40	$0.1*10^{-6}$	2.5	$31.5828*10^{-6}$
950	-46	$0.0251*10^{-6}$	2.5	$7.9132*10^{-6}$
950.6	-54	$0.004*10^{-6}$	2.5	$1.2557*10^{-6}$
951.6	-53	$0.005*10^{-6}$	2.5	$1.5842*10^{-6}$
1711.8	-44	$0.0398*10^{-6}$	2.5	$40.7205*10^{-6}$
1745.2	-51	$0.0079*10^{-6}$	2.5	$8.445*10^{-6}$
938	-30	$1*10^{-6}$	2.5	$307.1235*10^{-6}$
938.8	-57	$0.002*10^{-6}$	2.5	$0.6138*10^{-6}$
938.4	-57	$0.002*10^{-6}$	2.5	$0.6133*10^{-6}$
937.6	-44	$0.0398*10^{-6}$	2.5	$12.2164*10^{-6}$
935.8	-49	$0.0126*10^{-6}$	2.5	$3.8483*10^{-6}$
935.2	-52	$0.0063*10^{-6}$	2.5	$1.9263*10^{-6}$
935.4	-57	$0.002*10^{-6}$	2.5	$0.6094*10^{-6}$
total				$4.197*10^{-4}$

Table (B-2-18) Power density in second floor. under the tower Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-49	$0.1259*10^{-7}$	2.5	$3.966*10^{-6}$
948.8	-50	$0.1*10^{-7}$	2.5	$3.1424*10^{-6}$
951.2	-64	$0.004*10^{-7}$	2.5	$0.1257*10^{-6}$
950.6	-75	$0.0003*10^{-7}$	2.5	$0.01*10^{-6}$
949.4	-71	$0.0008*10^{-7}$	2.5	$0.025*10^{-6}$
948.6	-64	$0.004*10^{-7}$	2.5	$0.125*10^{-6}$
949	-66	$0.0025*10^{-7}$	2.5	$0.079*10^{-6}$
935.8	-49	$0.1259*10^{-7}$	2.5	$3.8483*10^{-6}$
938	-62	$0.0063*10^{-7}$	2.5	$0.1938*10^{-6}$
937.2	-78	$0.0002*10^{-7}$	2.5	$0.0049*10^{-6}$
937.6	-47	$0.1995*10^{-7}$	2.5	$6.1227*10^{-6}$
938.8	-89	$0.000013*10^{-7}$	2.5	$0.0004*10^{-6}$
935.4	-82	$0.0001*10^{-7}$	2.5	$0.0019*10^{-6}$
938.4	-62	$0.0063*10^{-7}$	2.5	$0.1939*10^{-6}$
total				$1.7839*10^{-5}$

Table (B-2-49) Power density in first floor, under the tower Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-62	$0.0631*10^{-8}$	2.5	$0.1988*10^{-6}$
948.8	-66	$0.0251*10^{-8}$	2.5	$0.0789*10^{-6}$
951.2	-70	$0.01*10^{-8}$	2.5	$0.0316*10^{-6}$
949	-77	$0.002*10^{-8}$	2.5	$0.0063*10^{-6}$
949.4	-77	$0.002*10^{-8}$	2.5	$0.0063*10^{-6}$
948.6	-74	$0.004*10^{-8}$	2.5	$0.0125*10^{-6}$
951.8	-75	$0.0032*10^{-8}$	2.5	$0.01*10^{-6}$
935.6	-53	$0.5012*10^{-8}$	2.5	$1.5314*10^{-6}$
938	-64	$0.0398*10^{-8}$	2.5	$0.1223*10^{-6}$
937.2	-80	$0.001*10^{-8}$	2.5	$0.0031*10^{-6}$
937.6	-62	$0.0631*10^{-8}$	2.5	$0.1936*10^{-6}$
938.8	-98	$0.00002*10^{-8}$	2.5	$*10^{-6}$
935.4	-80	$0.001*10^{-8}$	2.5	$0.0031*10^{-6}$
938.2	-74	$0.004*10^{-8}$	2.5	$0.0122*10^{-6}$
total				

Table (B-2-20) Power density ground floor, under the tower Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
951.2	-68	$0.0016*10^{-7}$	2.5	$0.0501*10^{-6}$
948.8	-54	$0.0398*10^{-7}$	2.5	$1.251*10^{-6}$
949.4	-67	$0.002*10^{-7}$	2.5	$0.0628*10^{-6}$
1711.8	-71	$0.0008*10^{-7}$	2,5	$0.0812*10^{-6}$
949.6	-73	$0.0005*10^{-7}$	2.5	$0.0158*10^{-6}$
951.8	-73	$0.0005*10^{-7}$	2.5	$0.0158*10^{-6}$
948.6	-68	$0.0016*10^{-7}$	2.5	$0.0498*10^{-6}$
935.8	-49	$0.1259*10^{-7}$	2.5	$3.8483*10^{-6}$
938	-67	$0.002*10^{-7}$	2.5	$0.0613*10^{-6}$
935.4	-70	$0.001*10^{-7}$	2.5	$0.0305*10^{-6}$
937.6	-61	$0.0079*10^{-7}$	2.5	$0.2437*10^{-6}$
937.2	-78	$0.0002*10^{-7}$	2.5	$0.0049*10^{-6}$
938.8	-92	$0.0000063*10^{-7}$	2.5	$0.0002*10^{-6}$
938.4	-69	$0.0013*10^{-7}$	2.5	$0.0387*10^{-6}$
total				$5.75425*10^{-6}$

Table (B-2-21) Power density back courtyard with horizontal distance 18.3m Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-52	$0.0631*10^{-7}$	2.5	$1.9877*10^{-6}$
948.8	-53	$0.0501*10^{-7}$	2.5	$1.5749*10^{-6}$
1742.6	-51	$0.0794*10^{-7}$	2.5	$8.4198*10^{-6}$
1711.8	-49	$0.1259*10^{-7}$	2.5	$12.87*10^{-6}$
951.2	-58	$0.0158*10^{-7}$	2.5	$0.5006*10^{-6}$
949.4	-59	$0.0126*10^{-7}$	2.5	$0.3961*10^{-6}$
950.6	-50	$0.1*10^{-7}$	2.5	$3.1543*10^{-6}$
937.6	-51	$0.0794*10^{-7}$	2.5	$2.4375*10^{-6}$
938	-61	$0.0079*10^{-7}$	2.5	$0.244*10^{-6}$
935.6	-80	$0.0001*10^{-7}$	2.5	$0.0031*10^{-6}$
935.8	-61	$0.0079*10^{-7}$	2.5	$0.2428*10^{-6}$
936.6	-74	$0.0004*10^{-7}$	2.5	$0.0122*10^{-6}$
935.2	-73	$0.0005*10^{-7}$	2.5	$0.0153*10^{-6}$
938.4	-100	$0.000001*10^{-7}$	2.5	$0.0307*10^{-6}$
total				$3.1865*10^{-5}$

Table (B-2-22) Power density in front courtyard with horizontal distance 49m, "the stadiums" Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
951.2	-47	$0.02*10^{-9}$	2.5	$6.3016*10^{-6}$
948.8	-35	$0.3162*10^{-9}$	2.5	$99.3703*10^{-6}$
948.6	-53	$0.005*10^{-9}$	2.5	$1.5742*10^{-6}$
950	-51	$0.0079*10^{-9}$	2.5	$2.5024*10^{-6}$
949	-56	$0.0025*10^{-9}$	2.5	$0.7897*10^{-6}$
1742.6	-59	$0.0013*10^{-9}$	2.5	$1.3345*10^{-6}$
950.6	-64	$0.004*10^{-9}$	2.5	$0.1256*10^{-6}$
935.8	-36	$0.2512*10^{-9}$	2.5	$76.7845*10^{-6}$
938	-51	$0.0079*10^{-9}$	2.5	$2.4396*10^{-6}$
935.4	-69	$0.0001*10^{-9}$	2.5	$0.0385*10^{-6}$
936.4	-56	$0.0025*10^{-9}$	2.5	$0.7688*10^{-6}$
937.2	-76	$0.0025*10^{-9}$	2.5	$0.0077*10^{-6}$
938.8	-88	$0.00158*10^{-9}$	2.5	$0.0005*10^{-6}$
938.4	-62	$0.631*10^{-9}$	2.5	$0.1939*10^{-6}$
total				$1.92232*10^{-4}$

Table (B-2-23) Power density in east of school. with horizontal distance 60m. "out of school fence". Attasadi School

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950.6	-53	$0.005*10^{-6}$	2.5	$1.5809*10^{-6}$
651.2	-58	$0.0016*10^{-6}$	2.5	$0.5006*10^{-6}$
948.4	-68	$0.0002*10^{-6}$	2.5	$0.0498*10^{-6}$
949.6	-71	$0.0001*10^{-6}$	2.5	$0.025*10^{-6}$
948.8	-37	$0.1995*10^{-6}$	2.5	$62.6984*10^{-6}$
1746.6	-75	$0.0000316*10^{-6}$	2.5	$0.0337*10^{-6}$
949.4	-63	$0.0005*10^{-6}$	2.5	$0.1577*10^{-6}$
935.8	-48	$0.0158*10^{-6}$	2.5	$4.8448*10^{-6}$
938	-67	$0.0002*10^{-6}$	2.5	$0.0613*10^{-6}$
935.4	-69	$0.0001*10^{-6}$	2.5	$0.0385*10^{-6}$
937.6	-62	$0.0006*10^{-6}$	2.5	$0.1936*10^{-6}$
937.2	-68	$0.0002*10^{-6}$	2.5	$0.0486*10^{-6}$
938.8	-82	$0.00000631*10^{-6}$	2.5	$0.0019*10^{-6}$
938.4	-82	$0.00000631*10^{-6}$	2.5	$0.0019*10^{-6}$
total				$7.02375*10^{-5}$

Table (B-2-24), Power density in north of school, with horizontal distance 60m, "out of school fence" Attasadi school

Frequency (MHz)	Received power (dBm)	Received power (w)	Traffic& DTx factor	Exposure S (w/m^2)
950	-64	0.0398*10^{-8}	2.5	1,254*10^{-6}
951.8	-65	0.0316*10^{-8}	2.5	0.1*10^{-6}
950.6	-73	0.005*10^{-8}	2.5	0.0158*10^{-6}
949.6	-73	0.005*10^{-8}	2.5	0.0158*10^{-6}
948.8	-59	0.1259*10^{-8}	2.5	0.3956*10^{-6}
1742.6	-70	0.01*10^{-8}	2.5	0.106*10^{-6}
949.4	-56	0.2512*10^{-8}	2.5	0.7903*10^{-6}
935.8	-60	0.1*10^{-8}	2.5	0.3057*10^{-6}
938.8	-82	0.0006*10^{-8}	2.5	0.0019*10^{-6}
935.4	-81	0.0008*10^{-8}	2.5	0.0024*10^{-6}
937.6	-70	0.01*10^{-8}	2.5	0.0307*10^{-6}
937.2	-72	0.0063*10^{-8}	2.5	0.0193*10^{-6}
938.8	-86	0.0003*10^{-8}	2.5	0.0008*10^{-6}
938.4	-76	0.0025*10^{-8}	2.5	0.0077*10^{-6}
total				1,9175*10^{-6}

B-3 Power density using RF Field strength meter

This appendix presents all complete measured power at all seven locations during the period 1-4-2007 to 5-4-2007.

Table (B-3-1) Measured power density in Attasadi School

Location	Power density (µw/cm^2) at 9:00 o'clock	Power density (µw/cm^2) at 11:00 o'clock	Power density (µw/cm^2) at 1:00 o'clock
On rooftop Under tower	0.791	1.315	0.696
On rooftop South tower, 8m	20173	4.272	3.29
On rooftop North tower,8m	1.968	2.672	2.96
On rooftop East tower,8m	0.659	0.715	1.082
On rooftop West tower,8m	0.543	2.254	0.641
On rooftop East tower,5m	0.195	1.063	0.63
On rooftop East tower,10m	1.668	3.306	3.26
On rooftop East tower, 15m	2.827	3.751	3.181
On rooftop East tower,20m	3.599	3.752	1.673
Second floor under tower	0.039	0.046	0.038
First floor under tower	0.038	0.040	0.033
Ground floor under tower	0.028	0.034	0.031
North of antenna,10m	0.029	0.032	0.031
North of antenna,20m	0.098	0.101	0.147
North of antenna,30m	0.266	0.308	0.348
North of antenna,40m	0.519	0.583	0.2869
North of antenna,50m	0.147	0.156	0.169

Table (B-3-2) Measured power density in Atifaq Jerba School

Location	Power density (μw/cm^2) at 9:00 o'clock	Power density (μw/cm^2) at 11:00 o'clock	Power density (μw/cm^2) at 1:00 o'clock
On rooftop under tower	0.199	0.289	0.537
On rooftop north tower. 5.5m	0.443	0.446	0.536
On rooftop east tower 5.5m	0.288	0.224	0.349
On rooftop west tower.5.5m	0.359	0.437	0.443
On rooftop west tower,7.5m	0.405	0.454	0.433
On rooftop west tower9.5m	0.486	0.512	0.53
On rooftop west tower11.5m	0.370	0.378	0.504
On rooftop west tower13.5m	0.466	0.467	0.664
On rooftop west tower,20m	0.413	0.431	0.421
Under tower first floor	0.037	0.045	0.044
Under tower ground floor	0.034	0.040	0.041
North of antenna, 10m	0.076	0.077	0.074
North of antenna, 20m	0.132	0.124	0.154
North of antenna, 30m	0.081	0.095	0.108
North of antenna, 36m	0.044	0.061	0.084

Table (B-3-3) Measured power density in Ali Annaflati School

Location	Power density (μw/cm^2) at 9:00 o'clock	Power density (μw/cm^2) at 11:00 o'clock	Power density (μw/cm^2) at 1:00 o'clock
On rooftop under tower	0.18	0.334	0.556
On rooftop north of tower,6.75m	0.351	0.197	0.403
On rooftop east of tower,6.75m	0.104	0.139	0.140
On rooftop south of tower,6.75m	0.176	0.306	0.282
On rooftop west of tower, 6.75m	0.414	0.702	0.393
Second floor under tower	0.044	0.045	0.046
First floor under tower	0.040	0.041	0.040
Ground floor under tower	0.037	0.036	0.033
South of antenna,20m	0.079	0.163	0.236
South of antenna,30m	0.080	0.103	0.066
South of antenna,40m	0.064	0.117	0.071
South of antenna,50m	0.073	0.123	0.069
South of antenna,60m	0.082	0.114	0.111

Table (B-3-4) Measured power density AL Entelaka School

Location	Power density (µw/cm^2) at 9:00 o'clock	Power density (µw/cm^2) at 11:00 o'clock	Power density (µw/cm^2) at 1:00 o'clock
On rooftop under tower	0.083	0.185	0.080
On rooftop north of tower,6.5m	0.119	0.080	0.060
On rooftop east of tower, 6.5m	0.156	0.192	0.247
On rooftop south of tower, 6.5m	0.075	0.075	0.125
On rooftop south of tower,10m	0.094	0.110	0.124
On rooftop south of tower,14m	0.088	0.104	0.091
On rooftop south of tower,20m	0.089	0.072	0.094
On rooftop south of tower,26m	0.087	0.083	0.074
Second floor under tower	0.038	0.045	0.048
First floor under tower	0.036	0.041	0.043
Ground floor under tower	0.032	0.039	0.041
West of antenna.40m	0.042	0.061	0.067
West of antenna.50m	0.122	0.088	0.081
West of antenna.60m	0.067	0.064	0.083
West of antenna,70m	0.074	0.084	0.103
West of antenna,80m	0.070	0.080	0.077

Table (B-3-5) Measured power density Azzahf Al-Mostamer School

Location	Power density (μw/cm^2) at 9:00 o'clock	Power density (μw/cm^2) at 11:00 o'clock	Power density (μw/cm^2) at 1:00 o'clock
On rooftop under tower	1.947	0.620	0.623
On rooftop north tower,8m	1.644	1.787	1.949
On rooftop south tower,8m	2.628	4.237	3.306
On rooftop east tower,8m	0.959	0.842	1.29
On rooftop west tower,5	0.836	0.853	1.187
On rooftop west tower,8m	1.859	2.038	2.04
On rooftop west tower,12	4.781	4.460	4.49
On rooftop west tower,18	3.766	4.174	5.014
On rooftop west tower,25	17.181	19.476	17.011
Second floor under tower	0.037	0.046	0.042
First floor under tower	0.035	0.041	0.039
Ground floor under tower	0.032	0.039	0.037
West of antenna,40m	0.754	0.833	0.978
West of antenna,50m	1.869	2.052	2.118
West of antenna,60m	3.066	3.434	1.688
West of antenna,66m	0.805	1.023	0.698

Appendix C: technical data for base stations

Appendix (C-1): powers from sector antennas

Transmitter details and power radiated from sector antennas at the sites considered in this research summarized in Table (C-1-1).

site	system	Sector number	EIRP (dBm)	Number of transmitters
Ibn Haitham School	GSM900(Almadar)	3	47	18
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	-	57	-
Attasadi School	GSM900(Almadar)	3	47	18
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	3	57	24
Atifaq Jerba School	GSM900(Almadar)	3	47	18
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	3	57	24
Ali Annaffati School	GSM900(Almadar)	3	47	10
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	-	57	-
AL Entelaka School	GSM900(Almadar)	3	47	12
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	-	-	-
Shohadaabomelyana School	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	3	57	24
Azzahf Al-Mostamer School	GSM900(Almadar)	3	47	12
	GSM900(libyana)	3	57	12
	AGSM1800(libyana)	3	57	24

Appendix (C-2) beam characteristics of sector antennas

Data giving the beam widths and elevational downward tilt below horizontal were made available for some of the sites. The available data are given in Table (C-2-1).

School	system	Sector number	Antenna direction (°)			Antenna tilt (°)			Antenna height (°)		
			S1	S2	S3	S1	S2	S3	S1	S2	S3
Ibn Haitham	GSM900	3	0	120	240	8	8	8	25	25	25
	AGSM1800	-	-	-	-	-	-	-	-	-	-
Attasadi	GSM900	3	0	120	240	5	5	5	21.5	21.5	21.5
	AGSM1800	3	0	120	240	4	4	4	24	24	24
Atifaq Jerba	GSM900	3	0	120	240	6	6	6	22	22	22
	AGSM1800	3	0	120	240	4	4	4	26.2	26.2	26.2
Ali Annaffati	GSM900	3	330	120	240	4	4	4	22.5	22.5	22.5
	AGSM1800	-	-	-	-	-	-	-	-	-	-
AL Entelaka	GSM900	3	0	120	240	8	8	8	19.5	19.5	19.5
	GSM1800	3	-	-	-	-	-	-	-	-	-
Shohadaabo melyana	GSM900	3	0	120	240	6	6	6	25	25	25
	GSM1800	3	0	120	240	8	8	8	31	31	31
Azzahf Al-Mostamer	GSM900	3	0	120	240	5	5	5	23	23	23
	GSM1800	3	0	120	240	8	8	8	28.3	28.3	28.3

Appendix D: Matlab programs

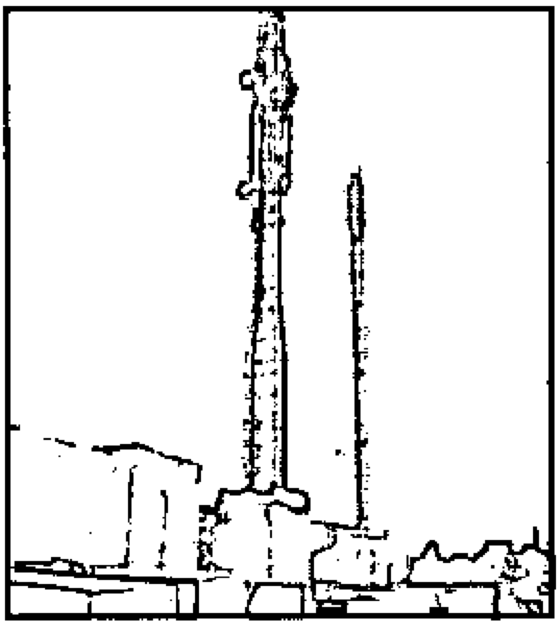
1- %program to calculate the power density

```
%from SAGEM meter
clear
clc
f=input('input frequency');
prdbm=input('input power dbm');
lampda=(3*10^8)./f./1000000;
a=(lampda.^2)/(4*pi);
prw=.001*10.^(prdbm/10);
s=prw./a
sf=2.50*s
```

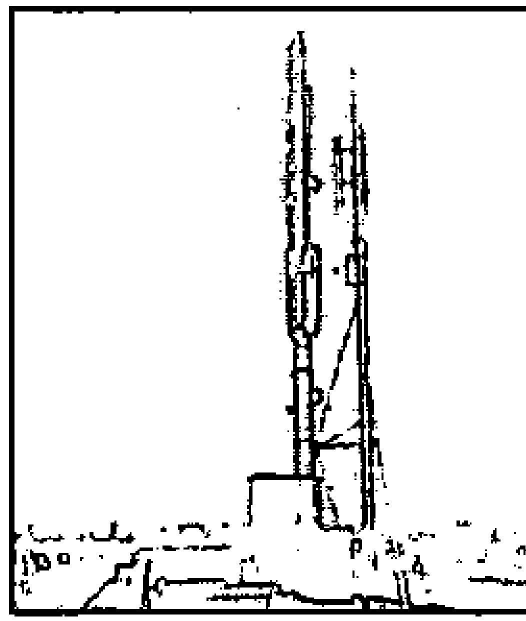
2- %program to calculate electric and magnetic fields

```
clear
clc
s=input('power density');
e1=(s*2*120*pi/100);
e=(e1).^0.5;
h1=(s*2/120/pi/100);
h=(h1).^0.5;
```

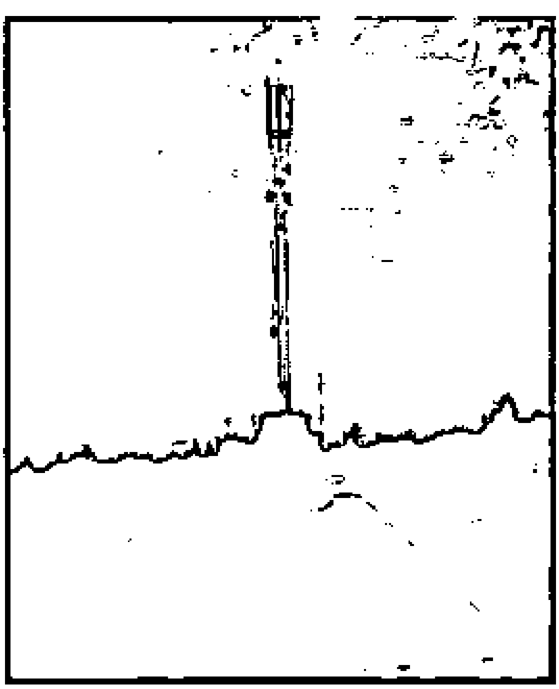
Appendix E: Pictures



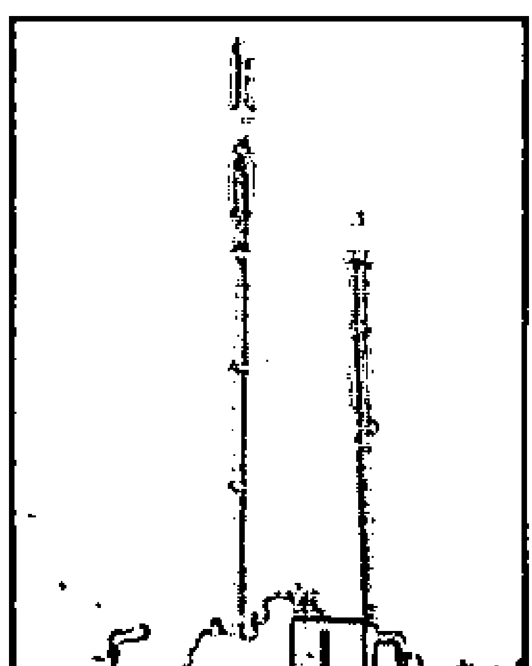
Shohadaabomelyana School



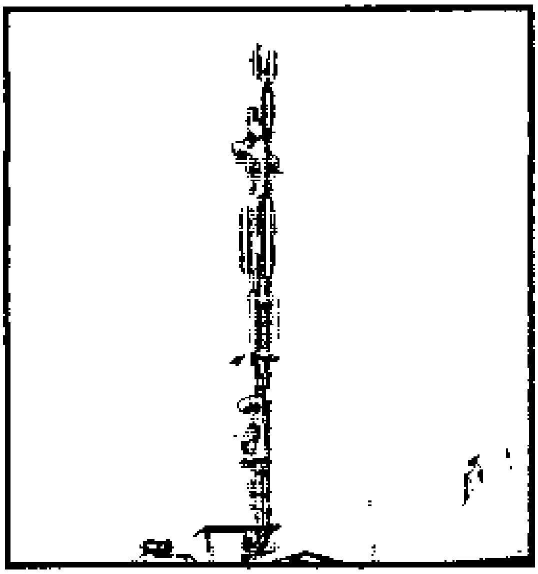
Atifaq Jerba School



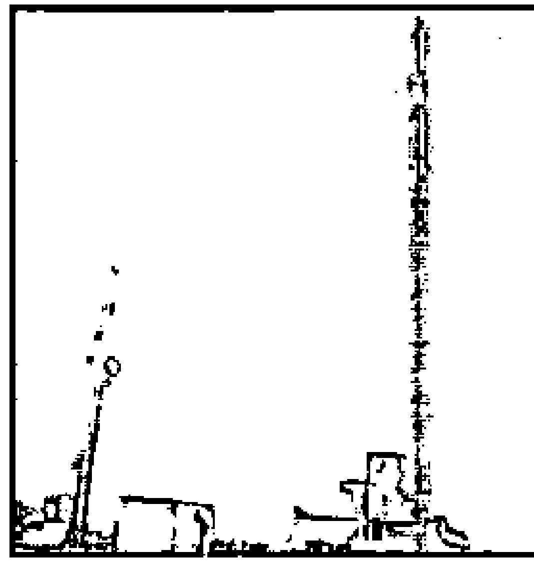
Ibn Haitham School



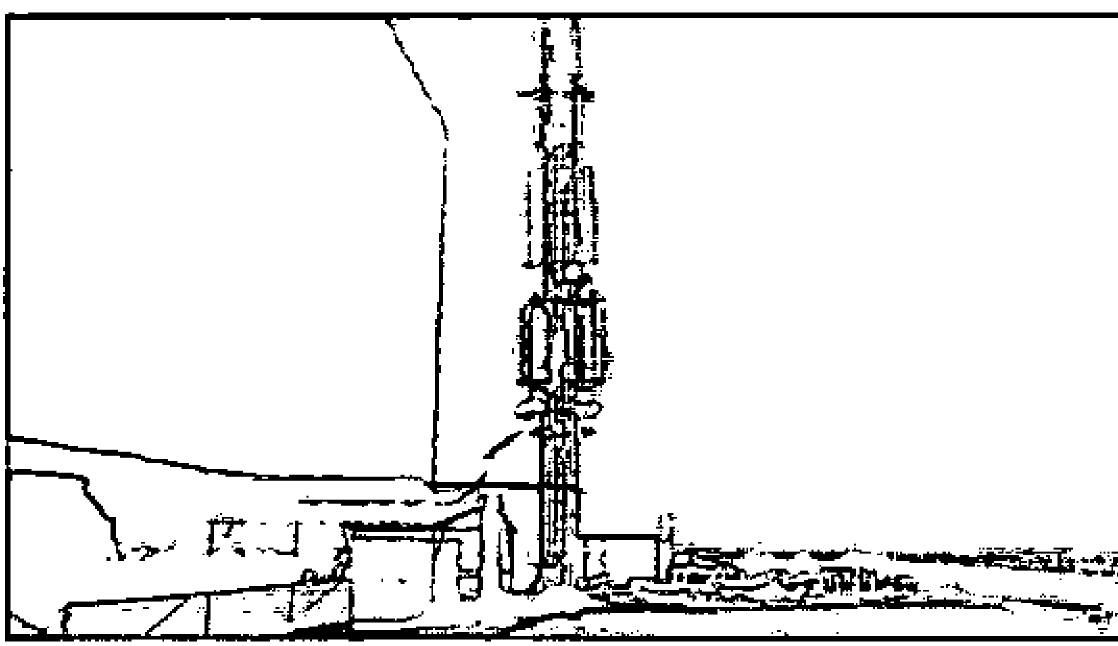
Ali Annaffati School



Azzahf Al-Mostamer School



AL Entelaka School



Attasadi School