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Al-Quds University

Assessment of Environmental Electromagnetic Radiation from Mobile Telephone Base Station Towers in the West Bank and Gaza Strip

By

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Declaration

I certify that this thesis, which is submitted for the master degree in environmental studies, is the result of my own research, except where otherwise acknowledged, and this thesis (or any part of the same) has not been submitted for a higher degree to any university or institution.

Signed:………………

(Jehad N. Abualkbash)

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Abstract

This work deals with the assessment and measurement of electromagnetic radiation levels emitted from mobile telephone base station tower located in the west bank and Gaza strip. Assessments are based on theoretical and calculations using commercially available software Telstra's RF_Map from Telstra Research Laboratories (Australia). Measurements are made using a power density meter (RF Filed Strength Meter). The base stations in the study operated by the Palestine cellular communication Ltd (Jawwal). Thirty three Base stations were studies over the West Bank and Gaza Strip. About one hundred electromagnetic field levels estimations were calculated at different locations around the investigated base stations including schools and kindergartens. Street mapping of power density field strength meter for bandwidth from (0.5 MHz – 3GHz) have also been conducted in some areas. Result are compared with the general public exposure limit of 400 $\mu W/cm^2$ recommended by International Commission of Non_ionizing Radiation Protection (ICNIRP). Levels of electromagnetic emission have been found well below recommended ICNIRP's limit for general public. The maximum electromagnetic emission from a single site was $0.413\mu W/cm^2$ and found at Hizma near Jerusalem. An average maximum level estimated from all sites was $0.113\mu W/cm^2$. This value is about 1770 times below the maximum permissible exposure recommended by ICNIRP. The maximum estimated exposure from a multi site configuration (13 base stations in the city of Ramallah) was $1.66\mu W/cm^2$. This level is 0.42% of the general public exposure limit of $400\mu W/cm^2$ which is applicable for Radiofrequency electromagnetic emission generated by mobile telephone base stations.

الملخص

تعرض هذه الدراسة نتائج تقدير مستويات الإشعاعات الكهرومغناطيسية المنبعثة من أبراج الهواتف النقالة المنتشرة في مناطق الضفة الغربية وقطاع غزة. وقد تمت هذه التقديرات على أسس نظرية وأخرى تجريبية. أما التقديرات النظرية فقد حصلنا عليها باستخدام تقنيات النمذجة الحاسوبية باستخدام برنامج (RF_Map) صمم في مختبرات شركة تلسترا و بالنسبة للقياسات فقد تمت بجهاز قياس كثافة القدرة (RF field strength) . تمت دراسة ثلاثة وثلاثون محطة تقوية في الضفة الغربية وقطاع غزة وتقدير مستويات الإشعاعات الكهرومغناطيسية في ما يقارب مئة موقع مختلف حول المحطات التي تم دراستها وقد تضمنت هذه المواقع مدارس وحضانات أطفال ومرفق عامة. جميع المحطات التي جرت دراستها تشغل من قبل شركة الاتصالات الخلوية الفلسطينية (جوال). استخدم جهاز قياس كثافة القدرة(يعمل في مدى ترددي مابين 0.5 ميجا هرتيز إلى 3 جيجا هيرتز) في قياس مستوى الإشعاع الكهرومغناطيسي في مناطق محددة توجد بها محطات تقوية. جميع النتائج تم مقارنتها مع حدود التعرض المسموح به للجمهور والذي يساوي 400 مايكرووواط /سم^2 والذي أوصت به اللجنة الدولية للوقاية من الإشعاعات غير المؤينة, وتدل جميع النتائج التي تم تقيمها على أن مستويات الإشعاعات الكهرومغناطيسية الصادرة من المحطات أقل من الحد الأعلى المسموح به للجمهور. وقد وجد أعلى مستوى للإشعاعات الكهرومغناطيسية المنبعثة من محطة واحدة وهي 0.413 مايكرووواط /سم^2 في قرية حزما القريبة من القدس. أما معدل المستويات الذي تم تقييمه من جميع المحطات فهو 0.113 مايكرواط /سم^2 وهذه القيمة اقل من حدود التعرض المسموح به من اللجنة الدولية للوقاية من الإشعاعات غير المؤينة بما يقارب 1770 مرة. وفد تم دراسة تأثير بعض المجموعات من المحطات لمعرفة مستوى الإشعاع التراكمي المنبعث من هذه المحطات مجتمعة. ففي مدينة رام الله تم دراسة مستوى الإشعاع التراكمي المنبعث من ثلاثة عشره محطة وكانت القيمة العظمى 1.66 ميكرووواط /سم^2, وهذه القيمة تشكل ما نسبته 0.42% من الحد الأعلى المسموح به للجمهور.

I Introduction

1.1 Introduction and background

The industrialization and electrification of society has resulted in the exposure of population to a complex environment of electromagnetic field. Public exposure may result from high frequency sources such as computer monitors, microwave oven, radio and TV broadcast station, radio communication equipment and society surveillance and navigation radars.

With the technology rapidly advancing, mobile telephone users and people living within close range of the mobile telephone base stations have become increasingly concerned over the potential harmful effects of electromagnetic radiation produced by these devices to their health. In many countries, over the half population already use mobile telephones and the market is still growing rapidly. In some parts of the world, they are the most reliable or only phones available. In this year (2005), there are about 2 billion mobile phone subscribers worldwide. This increased use of mobile phones has led to an increased deployment of base stations and antennae. As a reaction to this deployment, public debates and in several situations concerns about the possibility of adverse health effects due to exposure to electromagnetic radiation have also increased.

Mobile telephone base stations transmit power levels from a few watts to 100 watts or more. Directional antenna used generally is such station emits radiofrequency beams that are typically very narrow in the vertical direction, but quite broad in the horizontal direction. Evaluations of exposure levels in the vicinity of the base stations are made for several purposes; one important motivation for exposure evaluation is to measure the compliance with safety standards recommended by the International authorities.

In Palestine there are about nine hundred thousands of mobile telephone subscribers. The Palestine cellular communications Ltd (Jawwal) covers about 47% of the Palestinian cellular market.
This company operates about 300 GSM base stations distributed over the West Bank and Gaza Strip. Other base stations in the county are operated by the Israeli operators, and are located in areas that are not accessible for the Palestinians. These base stations also contribute to the total exposure of Palestinian population from electromagnetic fields.

Public interest in the West Bank and Gaza strip in the possible health issues arising from exposure to electromagnetic field has increased after the spread of mobile telephone base station tower over the county. This interest has highlighted the importance of having accessible information on levels of electromagnetic radiation in our environment.

This thesis is oriented to evaluate the radiation exposure to Palestinian population resulted from the emission of electromagnetic radiation from mobile telephone base station towers operated by Jawwal.
For the assessment of radiation levels, theoretical and experimental methods are used. Theoretical calculations of electromagnetic radiation levels are made using commercial

software RF_Map. This software is able to assess the cumulative environmental electromagnetic levels around single or multiple radio communications transmitter's sites. Measurements are conducted using a power density meters in the bandwidth from (0.5 MHz - 3 GHz).

1.2 Thesis objectives

The main goal of this work is to evaluate the radiation exposure to the Palestinian population resulted from electromagnetic radiation emitted from mobile telephone base station towers.

Specific objectives are:

1) Performing mathematical calculations to predict electromagnetic radiation levels caused by base station towers located in Palestine using advanced mathematical modeling software.
2) Performing measurements of radiofrequency power densities and comparing the measured values with calculated results.
3) Constructing contour maps of electromagnetic radiation levels for regions of interest in Palestine.
4) Comparing the obtained results of radiofrequency emission levels with recommended safety standards (public exposure limits).

II Electromagnetic radiation in the environment

2.1 Concept of electromagnetic radiation

Electric fields are created by differences in voltage: the higher the voltage, the stronger will be the resultant field. ***Magnetic fields*** are created when electric current flows: the greater the current given the stronger the magnetic field. An electric field will exist even when there is no current flowing. If current does flow, the strength of the magnetic field will vary with power consumption but the electric field strength will be constant. Electricity and magnetism are manifestations of the same thing called ***electromagnetic radiation*** as shown in figure (2.1)

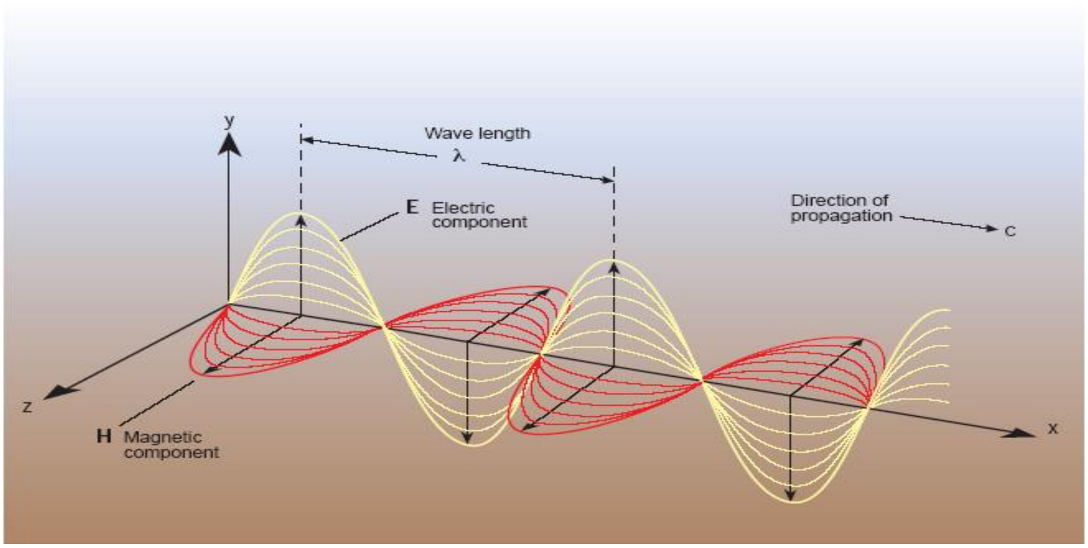


Figure (2.1): *The electromagnetic wave and its field.*

Electromagnetic Radiation results from accelerating (or decelerating) electric charge. This term of electromagnetic radiation denotes all forms of radiation which is non-ionizing radiation comprises electric and magnetic fields, thermal radiation, light and ultraviolet radiation. The term is used in the strict sense of electric and magnetic fields in the frequency range of 0 Hz to 300 gigahertz (GHz),(WHO,2000b).as shown in figure (2.2). A continuous wave has crests and troughs; the distance between two successive crests is known as the wavelength. Related to its wavelength and its speed of propagation, its frequency. (Speed = frequency multiplied by wavelength) for all waves.

$$C = f \, . \, \lambda \qquad (1)$$

Frequency measures the number of wave crests which pass a specific point in a given time. Since light always propagates through space with the same velocity, the longer the wavelength the smaller the frequency. We detect visible light of different wavelengths as colors. For instance, red light has a longer wavelength and lower frequency than blue light. Visible light is only a very small portion of the electromagnetic spectrum. Radiation with a longer wavelength than red light will be sensed by us as heat, because it is infrared radiation (WHO, 1998c). As the wavelength continues to increase, the radiation becomes first microwaves and then radio waves. On the other side of the visible spectrum, the wavelength continues to get shorter as the radiation becomes first ultraviolet, then X-rays and, finally, gamma rays. Fundamentally, all these radiations are the same transverse waves but they are distinguished because they have different wavelengths. Shorter wavelength (higher frequency) radiation carries more energy than radiation of longer wavelengths. The energy of the radiation is carried by fundamental particles known as photons. A photon is a packet of waves of one frequency and (very approximately) can be about a micrometer long if in the visible region. Photon travels at the speed of light and have no rest mass. The energy carried by a photon is known as a quantum of energy and is given by equation (2).

$$E = h \, f \qquad (2)$$

Where h is Planks constant ($6.6 \times 10^{-34} \, Joule.Sec$).

Thus blue light photons carry more energy than red light photons. Photons interact with matter via interactions with charged particles - often with the electrons which are arranged around atomic nuclei in specific energy levels. The only way the electrons can jump from their lowest permitted level to a higher one, is if they are supplied with enough energy. When a photon of the right energy collides with an electron, the electron absorbs it and jumps up to a more energetic level around the atom (at a larger radial distance from the nucleus). The atom does not stay in that excited state for long and the electron soon drops down into its original state although not necessarily in one step.

Sometimes an atom absorbs a photon that has sufficient energy for an orbital electron to be ejected from the atom altogether. This process is known as ionization. The atom thus becomes positively charged with one less negative electron than positive protons, and is known as an ion. The electron is free but may be captured by another atom (ion) that is deficient in an electron. When thinking about light interacting with matter it is often best to think of the light as massless capsules that carry energy, linear and angular momentum, but since light (visible or otherwise) can be diffracted and show interference effects, it is necessary to think of it as an electromagnetic wave. This is a concept known as wave-particle duality.

2.1.1 Electromagnetic radiation at low frequencies

Electric fields exist whenever a positive or negative electrical charge is present. They exert forces on other charges within the field. The strength of the electric field is measured in volts per meter (V/m). Any electrical wire that is charged will produce an associated electric field. This field exists even when there is no current flowing. The higher the voltage, the stronger the electric field at a given distance from the wire (WHO, 1998a).

Electric fields are strongest close to a charge or charged conductor, and their strength rapidly diminishes with distance from it. Conductors such as metal shield them very effectively. Other materials, such as building materials and trees, provide some shielding capability. Therefore, the electric fields from power lines outside the house are reduced by walls, buildings, and trees. When power lines are buried in the ground, the electric fields at the surface are hardly detectable.

Magnetic fields arise from the motion of electric charges. The strength of the magnetic field is measured in amperes per meter (A/m); more commonly in electromagnetic field research, scientists specify a related quantity, the flux density (in microtesla, μT) instead. In contrast to electric fields, a magnetic field is only produced once a device is switched on and current flows. Electric fields, magnetic fields are strongest close to their origin and rapidly decrease at greater distances from the source. Magnetic fields are not blocked by common materials such as the walls of buildings.

2.1.2 Electromagnetic fields at high frequencies

Mobile telephones, television radio transmitters and radar produce radiofrequency fields. These fields are used to transmit information over long distances and form the basis of telecommunications as well as radio and television broadcasting all over the world. Microwaves are RF fields at high frequencies in the GHz range. In microwaves ovens, we use them to quickly heat food. At radio frequencies, electric and magnetic fields are closely interrelated and we typically measure their levels as power densities in watts per square meter (W/m^2).

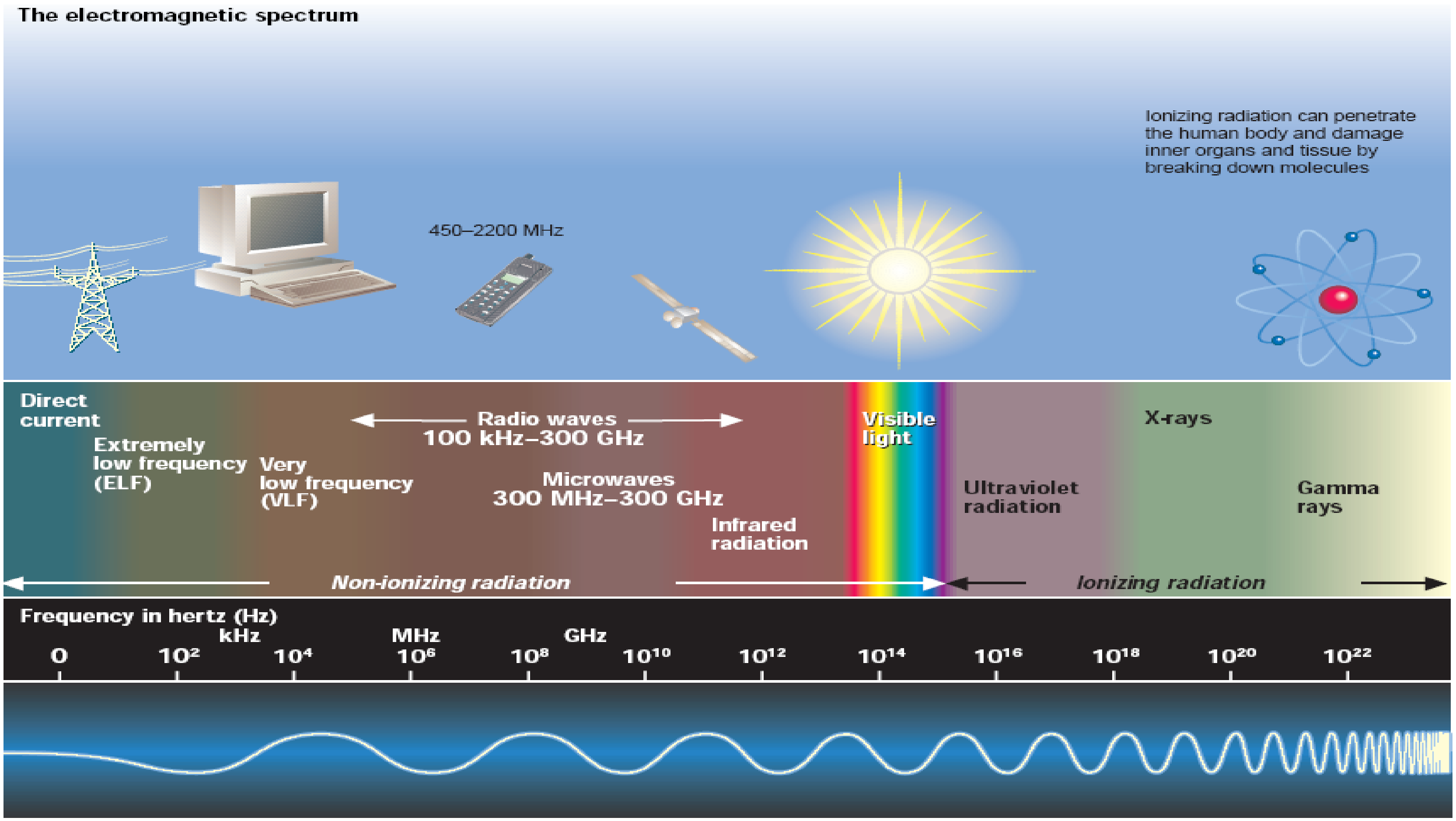


Figure (2.2): *The electromagnetic spectrum.*

2.2 Source of electromagnetic radiation

Electromagnetic energy is emitted, or given off, by all matter in our universe at varying levels. In general, the higher the inherent energy levels in the energy source, the shorter the wavelength of the energy created and the higher the frequency. This difference in energy wave characteristics allows us to classify electromagnetic energy into groups that exhibit similar wave property characteristics. In addition a distinction is made between low-frequency radiation in the range of 0 to 100 kilohertz (kHz) and high-frequency radiation in the range of 100 kHz to 300 GHz(WHO, 1999d). Table (2.1) present the two type of radiation ionizing and non-ionizing. There are other electromagnetic field sources at homes shown in table (2.2).

Table (2.1): *Electromagnetic spectrum with typical radiation sources and applications in the various frequency ranges*.

Type of Radiation		**Frequency**	**Wavelength**	**Sources**
Electromagnetic Radiation	Low Frequency	0Hz-100kHz	>3 km	Railways($16^{2/3}$Hz) Electric grid 50Hz
	High frequency radiation	100kHz-300GHz	1mm-3km	Radio and TV transmitters, radio telephony, mobile telephony, cordless telephones, microwave appliances, directional transmission, radar
	Infrared	>300GHz	780 nm-1 mm	Thermal Radiation
	Visible light		380 nm-780nm	Sun
	Ultraviolet		10 nm-380 nm	Sun, UV lamp
Ionizing Radiation	X ray and Gamma radiation		<10 nm	X ray appliances radioactivity

Table (2.2)*: Typical Electromagnetic field of household.*

Electric appliance	Colour TV	Hair dryer	Computer
Electric shaver	Washing machine	Portable radio	Electric oven
Vacuum cleaner	Microwave oven	Fluorescent light	Dishwasher

2.2.1 The non-ionizing electromagnetic Spectrum

Non-ionizing radiations (NIR) encompass the long wavelength (λ > 100 nm), low photon energy (E< 12.4 eV) portion of the electromagnetic spectrum, from 1 Hz to 3 x 10^{15} Hz. Except for the narrow visible region, NIR is unperceived by any of the human senses unless its intensity is so great that it is felt as heat. The ability of non-ionizing radiation to penetrate the human body, the sites of absorption, and the subsequent health hazards are very much wavelength (frequency) dependant. The NIR part of the electromagnetic spectrum is divided into four approximate regions(CEC, 1989):

- Static electric and magnetic fields, 0 Hz;
- Extremely low frequency (ELF) fields, > 0 Hz to 300 Hz;
- Radiofrequency (RF) and microwave (MW) radiation, 300 Hz to 300 GHz;
- Optical radiations: Infrared (IR) 760 - 106 nanometers (nm)
  Visible 400 - 760 nanometers (nm)
  Ultraviolet (UV) 100 - 400 nanometers (nm).

(Ionizing radiations, with wavelengths less than 100 nm, constitute the high photon energy portion of the electromagnetic spectrum)

2.2.2 Radiation Sources and Exposures

Occupational exposures to NIR can arise from numerous man-made sources. Ultraviolet radiation (UVR) from mercury and zenon-arc lamps is used for sterilizing equipment and air. Corneal injuries and potential damage to the skin can arise from excessive exposures. Sources of intense incoherent visible light (incandescent, gas discharge, and high intensity discharge lamps, welding arcs, etc.), are too bright for unprotected eyes, and certain wavelengths may damage skin (Hoc, 1999). Natural aversions to bright light and thermal pain help to alert us to take precautions. Exposure to infrared radiation can arise from industrial, domestic, and natural heat sources. The body’s biological warning system is generally efficient, but thermal protective clothing and special eye protection are necessary for certain occupations (e.g. in the glass and steel industries). The use of lasers (coherent radiation) in research and industry is expanding and presents potential risks for eye and skin exposures when engineered protection and personal precautions are not adequate. Uses of microwave (MW) and radiofrequency (RF) radiation for heating, television and radio broadcasting, satellite communication facilities, mobile transmitters, radar, and research and development may present activity-specific occupational hazards which are usually evaluated as near field (i.e. within one wavelength), single source exposure situations. Thermal biological effects are associated with induction currents in irradiated tissues that may or may not manifest as detectable impairments. Prolonged thermal stress is known to cause hematologic and immunologic change. Shocks and burns are acute effects that may be possible in higher frequency fields (IEC, 1989). Safety measures involve engineered controls (e.g. interlocking, switching, filtering, grounding), isolating or shielding the source, wearing RF-protective clothing, and using administrative controls such as warning signs, zoning, restricting access, and limiting exposure time.

Exposures to extremely low frequency (ELF) occur primarily due to the generation, transmission and uses of electrical energy. ELF electromagnetic fields are known to cause biological (enzymatic) effects, but the implications for human health have yet to be elucidated. Occupational exposures to static magnetic fields, related to uses of magnetic resonance imaging or magnetic levitation are associated with no known irreversible health effects (Mat, 1998).

2.3 Electromagnetic field used in mobile telephone technology

The Radiofrequency wave used for radio communication is referred to as a carrier wave. The information it carries – speech, computer data, etc – has to be added to the carrier wave in some way, a process known as modulation. As show in figure (2.3), the information can be transmitted in either analogue or digital form. For example, the electrical signal from a microphone produced by speech or music is an analogue signal at frequencies up to about 15 KHz.

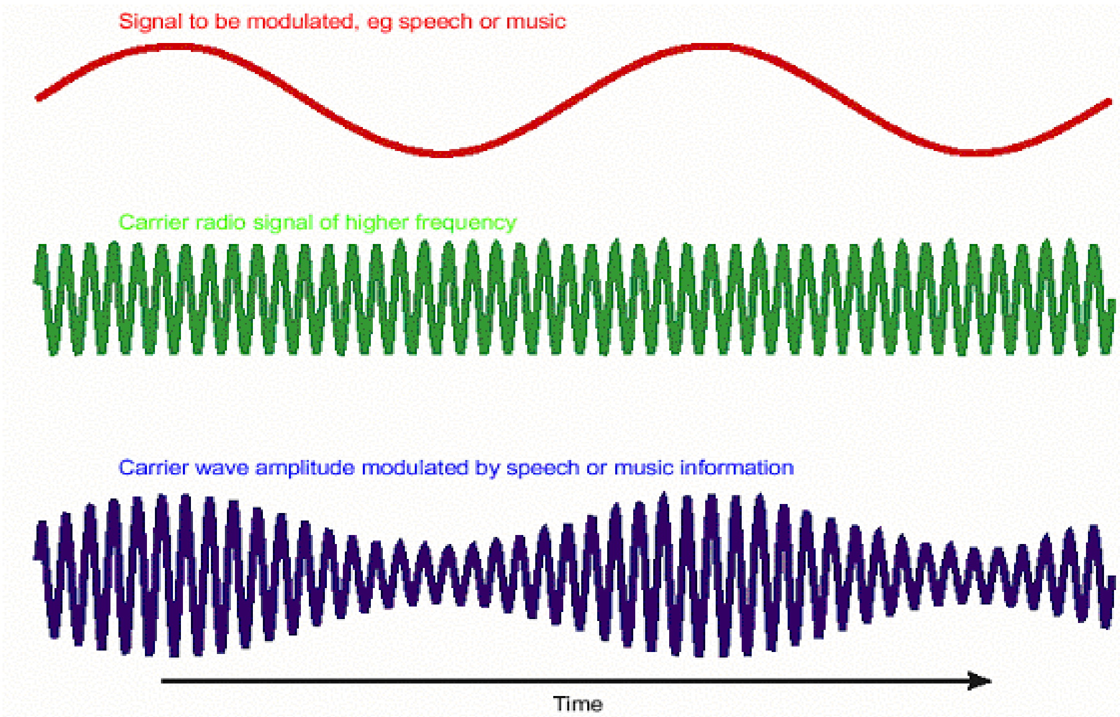


Figure (2.3) *: Radiofrequency wave used for radio communication .*

III Mobile Telephone Network

3.1 Network

The Global System Mobile (GSM) 900 network is constructed as a cellular structure. Each base station serves a limited area around it, termed a cell. A certain number of frequency bands is used within each cell. Neighboring cells cannot make use of the same frequency bands as seen in figure (3.1), because at a cell boundary there is always some overlap between the areas covered. Depending upon the size of the area covered, a cell is referred to as a Macrocell, a Microcell or a Picocell.

Macrocells cover an area with a radius of several hundred meters to ten kilometers. In heavily populated urban areas, the cell is relatively small. This is due, in particular, to the demand for capacity: because each station has a limited capacity, more base stations are needed in urban areas and the cells are smaller. Due to the limited range, the emitted power of base stations within smaller cells is correspondingly lower. Therefore, as the number of base stations increases, the total transmitted power virtually remains the same due to the relatively low capacity of base stations in small cells.

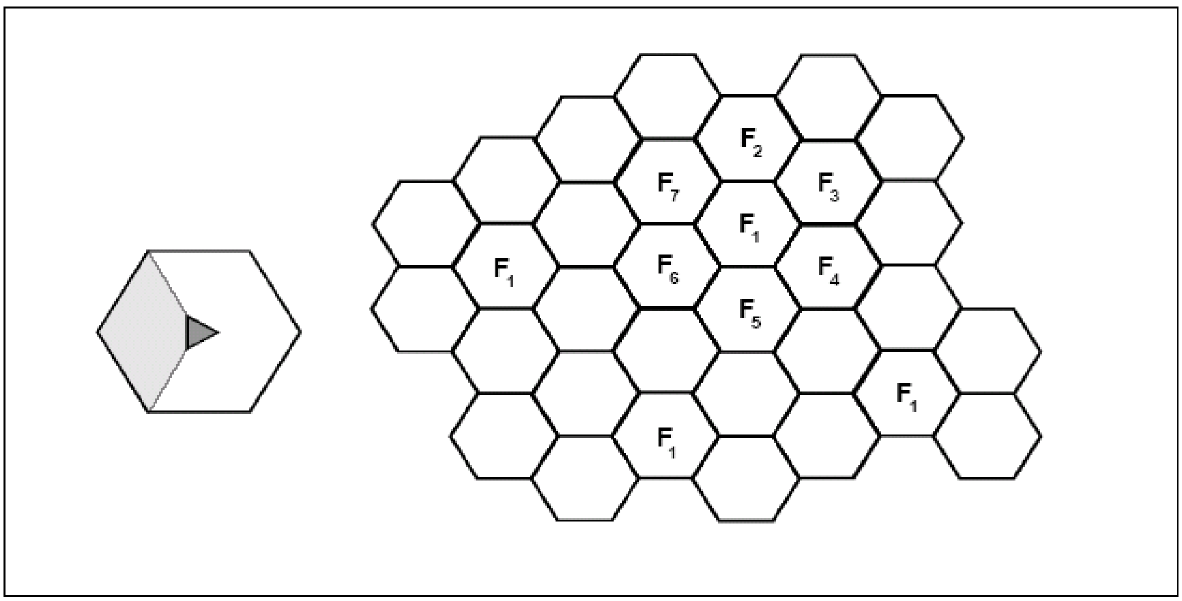


Figure (3.1): *Schematic representation of a network's cellular structure. Neighboring cells have different frequencies (F1 through F7). On the left: the position of the base station within the cell and the area covered by one antenna.*

Microcells are generally installed in places where there is a large number of people within a limited area, for example, in shopping centers and at train stations. The range of a microcell is usually not more than several hundred meters. Due to the limited area covered, the antennae are mounted relatively low and have a low power. Picocells are used inside industrial and office buildings. The antennae have a very limited range of no more than a few dozen meters and are generally mounted on the wall, close to the ceiling. They have a very low power, which is comparable to that of the base stations used in home-based portable phones. Reducing the cell size reduces the distance between base station and the mobile phone. As telephones are constructed such that they always transmit using the lowest possible power, a smaller cell size will result in the transmitted power and field strength around the phone being lower than within larger cells.

3.1.1 Providing Coverage

Transmitted signal strength falls off rapidly with distance from base stations and mobile phones, but certain minimum signal strength is required for adequate reception. The current generation of GSM base stations cannot communicate over distances greater than 35 km because the delay in receiving radio signals becomes too great. However, the decline of signal strength with distance places a practical limit on coverage of around 10 km. This means that a large number of base stations is needed to provide coverage of the whole country by all current network (ARPANSA, 1999).

3.1.2 Microwave Links

Base stations must be able to communicate with other neighboring base stations in order to relay calls between mobile phone users in two different cells and connect calls into other networks. In some cases this is achieved using cables but it is more usual for base stations to communicate via microwave links. Microwave links employ dish antennae that permit point-to-point communications.

Technical information on the powers used with microwave dishes at the sites visited during this work. The frequencies used are mostly in bands spread about 13, 23 and 38 GHz and propagation at these high frequencies is such that a line of sight path must exist between the dishes. Dish antennae produce narrow conical beams that are 1-2° wide. Typical powers are no more than a few tens of milliwatts because the power is channeled so selectively towards the receiver. The powers used by dish antennae are very much lower than those used by base station antennae so the exposures produced by signals from dish antennae will be negligible in comparison.

3.2 Principles of mobile telephone base station

Most people are familiar with the use of radio to permit wireless communication of signals between transmitting and receiving antennae. Perhaps the most familiar example is the network of very tall towers that are used to broadcast television signals to the antennae (aerials) that most houses have mounted above their roofs. Mobile phones communicate by radio signals passing to and from an antenna mounted on the phone and antennae connected to the base station. The radio link from the phone to the base station is known as the uplink and carries the speech from the mobile phone user. A separate radio link from the base station to the phone is known as the downlink and this carries the speech from the person to whom the phone user is listening. This principle is illustrated in Figure (3.2).

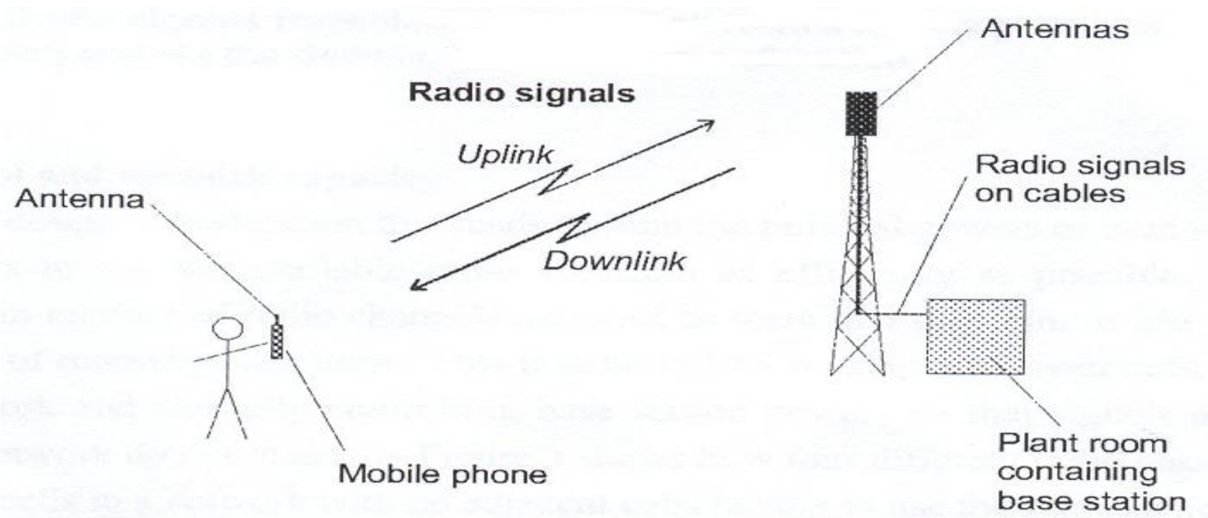


Figure (3.2): *Radio signal used for communication between mobile phone and base station.*

Antennae connected to the base station tend to be mounted high above ground level because the radio signals would be blocked by buildings if the antennae were nearer the ground. Antennae used with macrocellular base stations are generally placed between 15 and 50 m above ground level because they are designed to provide communications over distances of several kilometers. However, microcellular base stations have their antennae mounted nearer ground level as communications are only carried out over distances of a few hundred meters. These antennae tend to be mounted directly on existing structures, such as buildings, when this is convenient.

3.3 Mobile telephone base station characteristics

The arrival of second generation systems based on the digital Global System for Mobile Telecommunications (GSM) initially required more sets of antennae to be installed at existing radio sites; however, increasing usage of mobile phones quickly led to new sites being required. That the number of base station sites began to increase rapidly. Whilst some reuse of existing base station sites is anticipated, it is only when there is no further increase in the use of mobile phones that the number of base stations will stabilize.

In addition to performing simulated, the operators of the base stations have been approached in order to obtain details of radiated powers, antenna characteristics.

3.3.1 Electrical Characteristics of Mobile Telephone Base Station

Base stations contain a number of radio transmitters and each of these has the same maximum output power, $\mathbf{P_{tx}}$. The outputs from the individual transmitters are then combined and fed via cables to the base station antenna, which is mounted at the top of a mast (or other suitable structure). It therefore follows that the total power fed into the base station antenna, $\mathbf{P_{ant}}$, is given by

$$P_{ant} = NP_{tx}\, 10^{-L/10} \quad (3)$$

Where N is the number of transmitters and L is the loss (in decibels) in signal strength that occurs in the combiner and connecting cables.

The power that is fed into the base station antenna is launched into a radio wave traveling away from the tower and the strength of this radio wave decays with distance from the antenna according to the inverse square law. The power density, S, in the beam thus varies with distance, d, according to the following expression.

$$S = (NP_{tx} / 4\pi d^2)\, 10^{(G-L)/10} \quad (4)$$

The antenna gain, G is a measure of how much the antenna is able to focus the radiated power in the direction of its beam. It should also be noted that equation 4 is strictly only valid at distances greater than around 10 m from a typical sector antenna and will overestimate the power density at lesser distances (NRPB, 2000a).

3.3.2 Cell Sectors

Operators tend to divide the area about a base station into three sectors and then mount three different sets of antennae on a mast such that each set provides coverage of a 120º arc about the mast. Most base station antennae are oriented such that sector 1 is directed towards grid north, sector 2 is directed 120º East of Grid North (EGN) and sector 3 is directed 240º EGN. This gives rise to the familiar triangular configuration that is seen at the head of many of the older base station masts, as shown in Figure (3.3). In some cases omni-directional antennae are used to provide full 360º coverage.

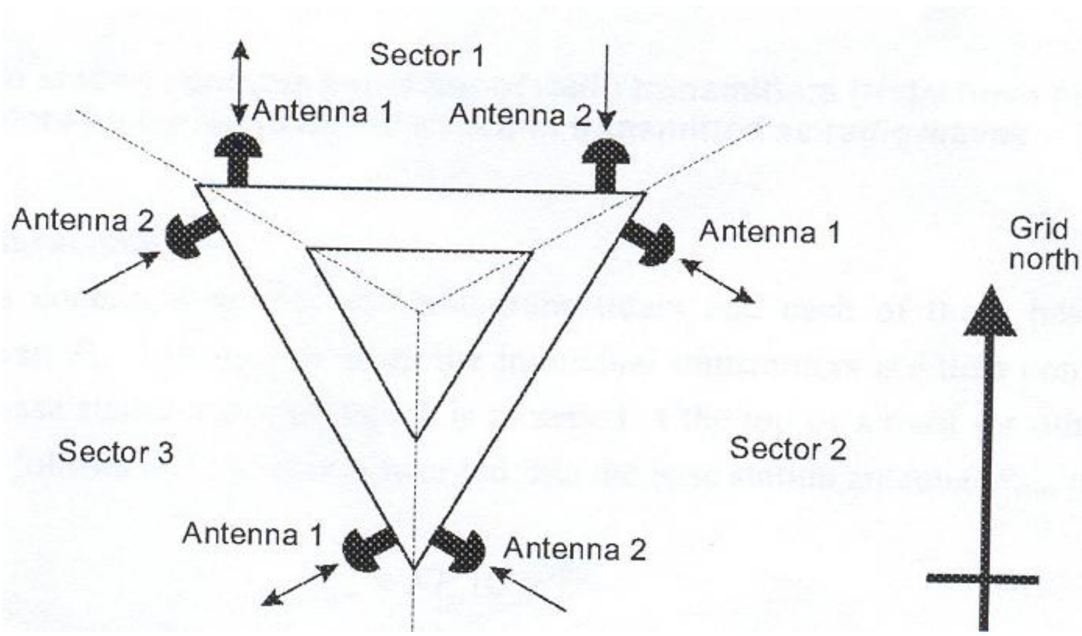


Figure (3.3): *Six antennas are arranged on some masts in order to provide coverage of cell divided in to three sectors. Arrows indicate the directions of signals to and from the antennas*

Figure (3.3) shows how a single antenna can be used to transmit signals, whereas two antennae are used to receive signals from a sector. This arrangement of diversity reception allows continuous operation even if one of the antennae experiences a reduced or faded signal. Some of the more modern antennae effectively contain two sets of receiving elements that are arranged perpendicularly to each other inside a single case. These dual polar antennae give rise to much more compact mast heads since only three are used to cover a cell.

3.3.3 Technical aspect

When discussing base stations, it is important to be clear that, in strictly engineering terms, it is the electronic equipment contained in the plant room shown in Figure (3.4) that is the base station. Nevertheless, it has become common practice to describe the complete installation, including antennae and mast, as the base station (ETSI, 1999). The features of a typical base station installation are shown in Figure (3.4).

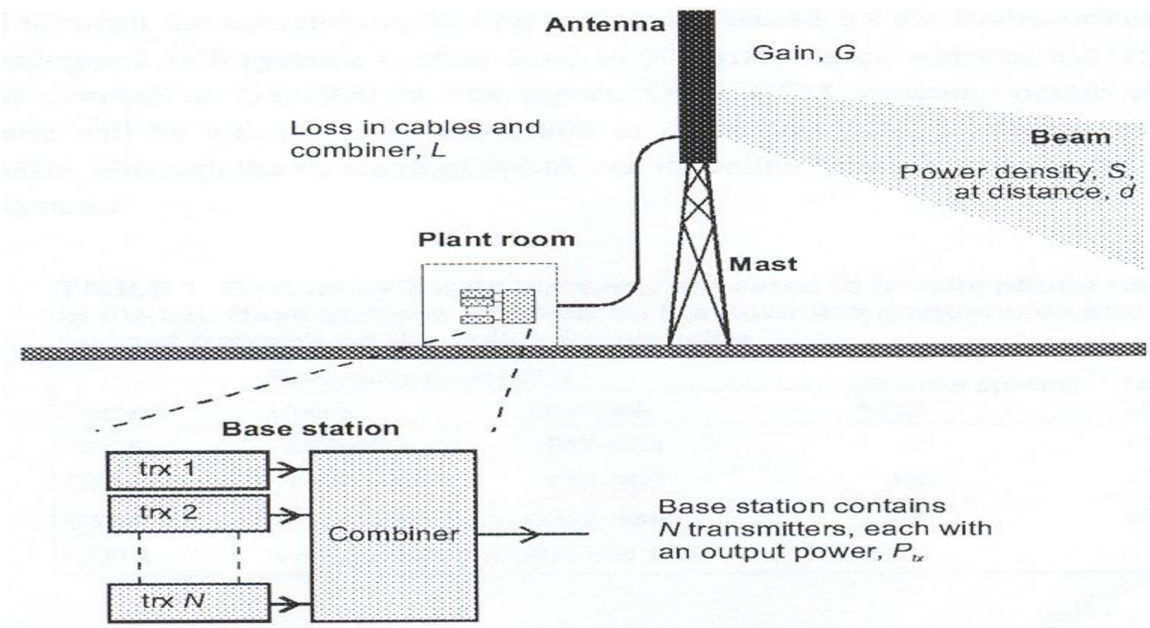


Figure (3.4): *A base station contains a number of transmitters (T_{rx}) whose outputs are combined before being fed to an antenna and transmitted as radio waves.*

3.4 Radiation emitted from mobile telephone base station antenna

3.4.1 Antenna beam shapes

The radio signals developed by base stations are fed to antennae, which produce beams that are radiated into the cell around the base station. The profile of the beams is carefully chosen by the network planners in order to produce optimal coverage of the cell, but the general principle of beam formation is illustrated in Figure (3.5).

The beams formed by antennae used with macrocellular base stations are narrow in the plane of elevation with typical widths between 6º and 10º. The beams are also tilted slightly downwards so the top edge of the main beam is approximately horizontal whereas the lower edge is directed up to 10º below horizontal. When considering the heights at which antennae tend to be mounted, this implies that the main beam from base station antennae would be expected to reach ground level typically between 50 and 300 m from the foot of a mast. The antennae used with microcellular base stations have much broader beams in the plane of elevation because they are intended to communicate over much shorter distances.

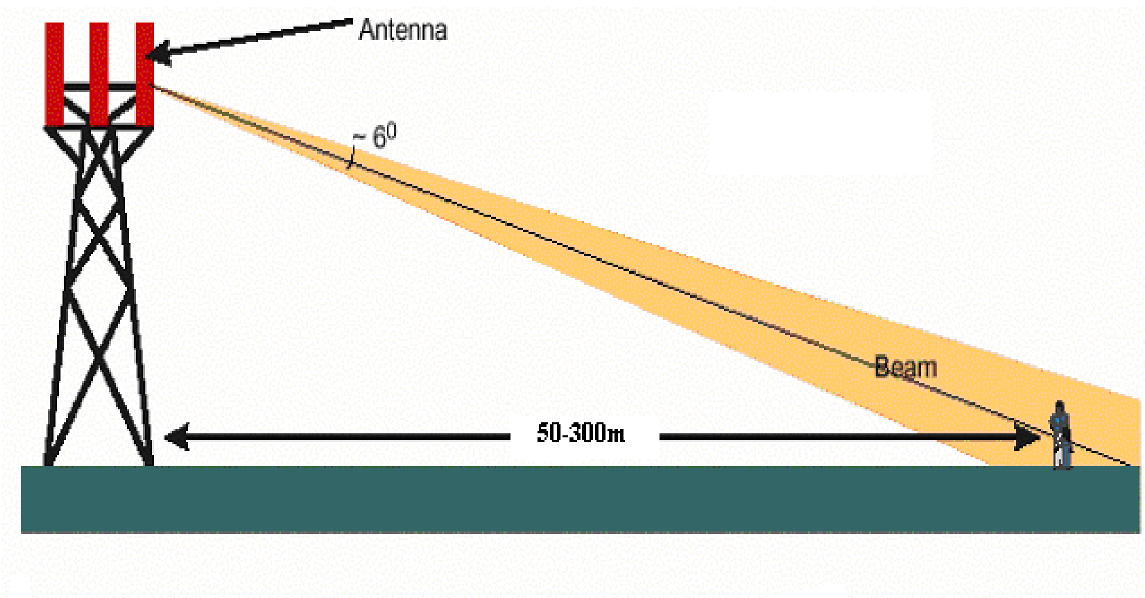


Figure (3.5): *Elevation showing the shape of the beam formed by a typical antenna used with a macrocellular base station.*

Figure (3.5) shows a simplified version of the directional properties of an antenna illustrating why much lower radio wave strengths are found at the foot of a mast than at distances of around 100 m from the mast. The beams from real antennae do not have sharply defined lower edges and some power will be directed at all angles below horizontal. Typically the power in the downwards direction is at least a hundred times weaker than in the main beam at the same distance from antennae.

3.4.2 Antenna Gain

When considering the directional properties of antennae, it is useful to refer to the antenna gain. This is a measure of how effective an antenna is at radiating power in the direction of its main beam. An isotropic antenna is an antenna that radiates equally in all directions, and if a spherical surface enclosing such an antenna is considered, the power density, S, at a radial distance, d, would be given by:

$$S = NP_{rad} / 4\pi d^2 \qquad (5)$$

Where P_{rad} is the total radiated power.

Any real antenna will employ some means to remove power from undesired radiating directions and channel it into the intended direction of the beam. This means that the power density at a distance, d, will be greater than that given by equation (5) by a factor equal to the antenna gain. Gain is normally quoted in decibels relative to an isotropic radiator in the unit dBi.

The beams from antennae used with base stations are narrow in the plane of elevation (Figure (3.5)), and this is achieved by mounting a stack of radiating elements vertically above each other inside the antenna cases. The taller the stack is in relation to the wavelength, the narrower the beam width that is achieved. Mounting reflectors around the radiating elements inside the antenna case can be used to narrow beam widths in the azimuth plane, to between 60º and 120º in order to produce sector antennae. Both of these design techniques cause antennae to radiate preferentially in a certain direction, and hence form a main beam. Typical gains for the sector antennae used with macrocellular base stations in Palestine are in the range 12-18 dBi for GSM900 systems and 16-18 dBi for GSM1800 systems. Omni- directional antennae for macrocellular base stations are much less common than sector antennae.

Microcellular base station antennae are not intended to communicate over such large distances as macrocellular base stations so their beams tend to be wider and their gains tend to be lower.

3.5 Effective Isotropic Radiated Power (EIRP)

The power density formed in the beam from a base station depends upon the radiated power and on the gain of the antenna. The product of the power radiated and the antenna gain is known as the effective isotropic radiated power (EIRP) and is usually quoted in decibels relative to a milliwatt (dBm). By convention, the EIRP is quoted in terms of the power radiated by a single transmitter and this should be taken into account when calculating total radiated power. The licenses allocated to the operators stipulate that no more than 62 dBm EIRP may be radiated (per transmitter). This arises from considerations associated with the possibility of interference with other electrical equipment in the environment, and is not related to electromagnetic field safety. Ensuring compliance with protection guidelines is a matter for the operators through their general safety obligations.

VI Safety guideline and exposure assessment

4.1 International exposure guidelines

4.1.1 Basis for guidelines

There is a consensus amongst organizations responsible for providing advice on exposure to electromagnetic fields and radiation. The consensus is as follows.

(a) Heating can occur as a consequence of exposure to electromagnetic fields at telecommunications frequencies.

(b) The established adverse effects on people's health occur at exposure levels where heating would be expected to occur.

(c) Exposures should be restricted to avoid the established effects of exposure to electromagnetic fields.

(d) There is no convincing evidence that adverse effects can occur as a result of exposure within the current protection guidelines.

4.2 International commission on non-ionizing radiation protection 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 most recent guidelines on limiting exposure to electromagnetic fields were published in April 1998 (ICNRP, 1998).

The guidelines on limiting exposure for the general public provide adequate protection and the health benefits to be obtained from further reductions in exposure have not been demonstrated.

The ICNIRP guidelines specify basic restrictions on SAR which are state that `protection against adverse health effects requires that these basic restrictions are not exceeded. The basic restrictions on SAR that apply to frequencies within the range 10 MHz to 10 GHz for occupational and public exposure are given in Table (4.1). All restrictions are to be time-averaged over a six minute period. The restrictions on localized SAR permit averaging over a 10 g mass of contiguous tissue.

Reference levels of exposure are provided for comparison with measured value of physical quantities; compliance with all reference levels will insure compliance with basic restriction. For the frequency of interns (900 MHz) reference levels are provided on power density which is 10 W/m^2 for occupational exposure and 4 W/m^2 for general public exposure (ICNIRP, 1998).

Provision is also made for 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 (ICNRP, 1998).

(a) The power density averaged over 20 cm^2 is less than the basic restriction.

(b) The power density averaged over 1 cm^2 is less than 20 times the basic restriction.

TABLE (4.1):*International commission on non-ionizing radiation protection basic restrictions on exposure to electric and magnetic fields in the frequency range 10 MHz to 10 GHz for occupational and general public exposure*.

Exposure quantity	**Occupational**	**General public**
SAR averaged over the body and over any 6 minute period	0.4 W kg^{-1}	0.08 W kg^{-1}
SAR averaged over any 10 g in the head and trunk and over any 6 minute period	10 W kg^{-1}	2 W kg^{-1}
SAR averaged over any 10 g in the limbs and over any 6 minute period	20 W kg^{-1}	4 W kg^{-1}

4.3 Evaluation of exposure

Several different approaches to evaluate the exposure of a person in the vicinity of a transmitting antenna are possible. In general, the simpler the calculation approach used, the more conservative will be the outcome and the greater the compliance distance that will result.

4.3.1 Power density calculation

If the total power fed into an antenna is known as well as the antenna gain, it is possible to calculate the power density in the main beam by assuming an inverse square law dependence upon distance at all distances from the antenna. The following equation is analogous to equation 5 in Section 3.4.2 and may be used to calculate power density, S, in this way.

$$S = (GP_{rad} / 4\pi d^2) \qquad (6)$$

where d is the distance from the antenna, P_{rad} is the total radiated power and G is the antenna gain (in linear units) (ETSI, 1999).

Reflections may increase or decrease the power density from that calculated by equation (6) if the path length traveled by a reflected wave is comparable with the direct distance to an antenna. The most likely situation where this could occur would be where a wave was reflected from the ground, as indicated in Figure (4.1). Reflections would be expected to increase the electric field strength by a factor of up to two, thus the total power density would be increased by a factor of up to four.

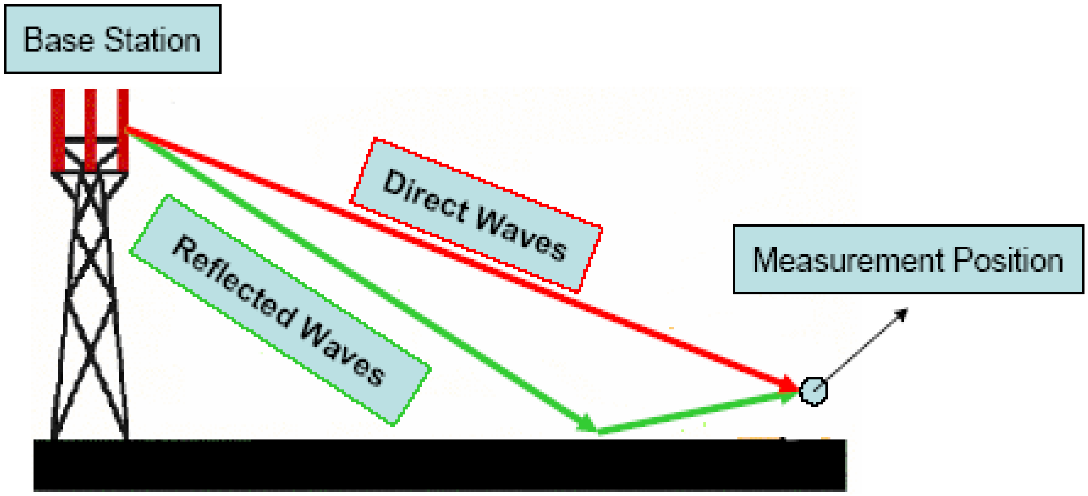


Figure (4.1) *Direct and reflected waves arriving together to increase the power density at a measurement position.*

The use of equation (6) will overestimate power density in directions other than the main beam, because the antenna gain is effectively less in these directions. It will also overestimate power density at short distances, generally within 10 m of antennae (Kuster, 1992).

If the detailed electrical structure inside an antenna is known, it becomes possible to perform a more rigorous calculation of power density than is represented by equation (6). Such a near-field calculation is able to evaluate the precise variation of power density (or field strength) at all distances and in all directions from an antenna. If field strength is measured close to an antenna, calculations accounting for the near-field character of the antenna should be in good agreement.

4.3.2 Near field and far field situations

The physics of electromagnetic emission from an antenna produces different circumstances for measurements depending on the distance r from the source. For practical purposes, this is commonly described as the existence of three zones (figure (4.2)).

At a sufficiently large distance from the source, in the so-called far-field region, the electric and magnetic field components are closely related, and it is sufficient to evaluate only one of them. This region can be expected at a distance larger than about $2D^2/\lambda$, where D is the largest dimension of the antenna, and λ is the wavelength. Considering the wavelength λ of 33 cm for 900 MHz and 17 cm for 1800 MHz, and assuming an antenna dimension D of 1.8 m suggests that this far-field zone boundary should be as far as 20 to 40 meters from a large base station antenna. (The critical value is the dimension D of the antenna. It is, however, not clear whether the value of the total panel dimension should be used, or whether a smaller size is relevant. As a result, the far-field boundary might be expected at somewhat shorter distances). As this situation can be described as radiating, it is frequently found useful to characterize the exposure in terms of the incident power density in W/m^2. Since the electric and magnetic fields have a simple relationship, then the power density can be calculated based only on measurements of the electric field, according to the formulae (Walke, 1999).

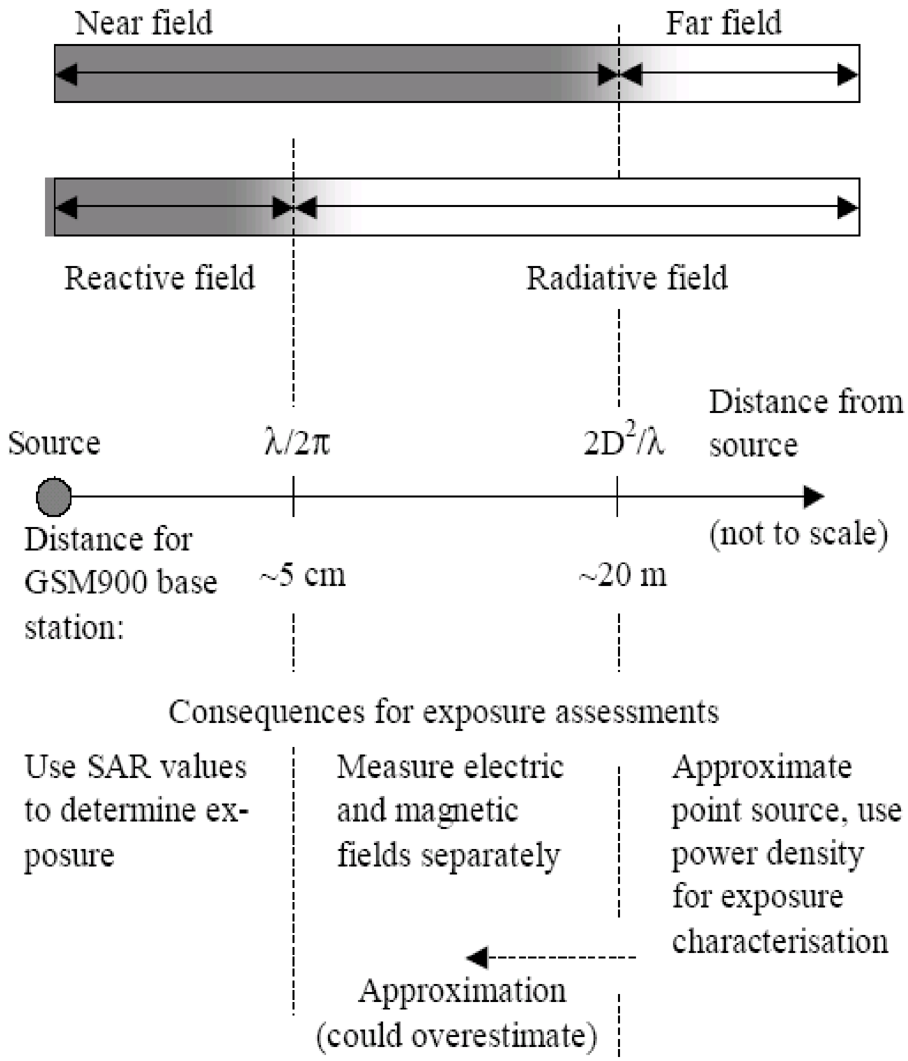


Figure (4.2): *Illustration of three zones: reactive near field, radiative near field and (radiative) far field, and its consequences for exposure assessments. D = largest dimension of source. λ = wavelength (33 cm for 900 MHz). SAR = Specific Absorption Rate.*

$$P = E^2/377 \qquad (7)$$

Where E is the electric field in V/m and P is the power density in W/m^2 and 377 is free space impedance. In this far field region, the source can be approximated as a point, suggesting that the power density for an isotropic antenna, and in the absence of any interfering objects, will decrease as $1/r^2$. As already indicated, the actual decrease may be even faster due to objects interfering with the path. In the close vicinity of base stations, measurements and calculations are more difficult because of the so-called near field conditions. In the radiative near field, the relationships between the electric and the magnetic fields are much more complex, and separate evaluation of them should be performed. Measuring the electric fields and using the far-field assumptions in this zone would often lead to overestimating the exposure. Calculations by the (Mann et. al., 2000) has indicated that using the far-field approximation (above) at e.g. 10 m from a large base station antenna would overestimate the exposure by a few percent, while at 1 m the overestimate would be some 10-20 times. In the reactive near field, at distances somewhat smaller than one wavelength, there is a dynamic energy interaction between the source and the human body. As a consequence, the external field strengths are not good indicators of the actual exposure, and other methods of evaluations must be used – primarily the determination of the exposure directly into SAR levels (SAR = Specific Absorption Rate). From a practical point of view, beyond a distance of about 10 meters from the base station antenna, far-field-based calculations are suitable for determining and surveying the exposures. This is especially true for compliance evaluation, where a limited overestimate would normally not be crucial (Mátay, 2001).

4.3.3 Direct SAR evaluation

The most rigorous approach to calculating the variation of the exposure produced by an antenna as a function of distance is to account fully for the electromagnetic coupling between the antenna and an exposed person. This approach should be accurate for exposure at all distances and will generally give the shortest compliance distances. The approach is similar to that used for assessing the exposures produced by mobile phone handsets and can be used for microcellular base stations which radiate similar power levels (Mátay, 2001).

A computer model of an antenna and of the human body can be used for analysis of energy deposition in the body using a computer code implementing Maxwell's equations. An alternative approach is to carry out SAR evaluation through measurement by producing a physical model of the human body and placing this in the field of the real antenna. Small field probes can be implanted inside the physical model and, if sufficiently sensitive for the powers transmitted, these can be used to measure the SAR that is produced.

4.4 Factors affecting the exposure

Many factors influence the RF exposure an individual may receive, whether environmental or occupational. These factors include:

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

In the case of environmental exposures, many of these factors (such as relative location with respect to the antenna, presence of other structures, and time spent in that location) may be nearly constant. For workers, these factors may be much more variable, leading to greater fluctuations in exposure intensity (Dolk, 1997).

There are two basic types of RF signals, continuous wave (CW) and pulsed. Continuous wave signals are those which are constantly transmitted whenever the transmitter is on, although the amplitude or total power transmitted may change. In contrast, pulsed signals are emitted in bursts while the transmitter is on. These bursts, or pulses, are usually transmitted at regular intervals, in very rapid succession, with a momentary break in the transmission between pulses.

The time intervals involved in pulsed transmission are very short, typically a few millions of a second or a microsecond. The pulse may be described by its maximum strength (the peak power or power density), the pulse width, and the pulse repetition rate. In the case of wireless telecommunications, the pulse pattern is used as an essential part of the information transmission, and the pulse parameters can be very complex. For the purposes of measuring exposure, the average power or power density is normally used to describe pulsed RF radiation as well as continuous wave RF radiation (Mann et.al, 2000). In the case of RF fields from wireless telecommunications, this approach for measuring exposures should be subject to review on a frequent basis, because laboratory reports exist of biological effects that are dependent on the particular modulation of the RF field exposure.

Wireless communications antennae come in many types. Often cellular telephone base station towers have multiple antennae that transmit the signals in certain directions. Each area or sector around that tower may be subject to different RF field power intensities. Some systems use antennae that look like long rods, or whips, that are more omni-directional in their transmissions and, therefore, would present a different exposure profile than the more directional antennae.

It is also important to note that cellular telephone antennae do not transmit the same irradiated power on a continuous basis. This system has channels that are automatically turned on and off as the demand for the number of phone calls to be handled by a given base station fluctuates. A single base station may have 20 to 50 channels, with a power output usually expressed as the number of watts irradiated power per channel. The total power transmitted by a given antenna at a particular time would depend on the power output per channel and the number of channels transmitting (Mátay, 2001). The maximum output possible for a given base station would be the total number of channels multiplied by the power per channel, although the base station would not usually have all channels activated at one time. An estimate of the maximum field strength might be obtained by making exposure measurements at that time of day when the base station is likely to be operating closest to capacity. One of the critical factors in evaluating exposure is the relative location of the person with respect to both the antenna and the resulting RF field, in particular, ascertaining whether the area in question is within the near field zone of the antenna or the far field zone.

V Methodology

5.1 RF-Map Program Overview

The RF-Map program is a software tool for the assessment of cumulative environmental electromagnetic emission (EME) levels around single or multiple radio communications transmitter sites. This includes cellular mobile telephone base stations. The program gives users a significant competitive edge through time saving in calculating the EME levels. The program is ideal for network operators, EME assessment contractors, and authorities managing environmental emission levels. It allows a pre-cautionary approach to be used in RF site development and operation. The RF-Map survey area consists of a grid comprising more than 22,000 calculation points for each antenna system selected in the fine resolution mode. RF-Map itself has no limit to the number of transmitter sites and antenna systems that can be modeled, provided the antenna data is available. The advanced map-imaging feature allows real-time assessments to be overlaid on drawings or street maps.

5.2 RF-Map program calculation formula and system parameter

RF-Map program can either calculate the power density for a single transmitter and antenna system, or the cumulative power density from multiple transmitters and antenna systems at multiple sites. RF-Map uses either a direct path or 2-ray propagation path, and is capable of further expansion to include other propagation models.

The main objective of RF-Map is calculation of maximum EME levels in the local environment from radio communications sites in accordance with this Thesis methodology. EME estimations deliberately do not include possible radio signal attenuation due to buildings and the general environment; however RF-Map has the capability to specify an enhancement or attenuation factor. Environmental EME assessments using RF-Map will be therefore conservative when there is attenuation from the local environment. This is the preferred to providing the community with a worst-case analysis in a timely manner. Feedback from local councils and planning authorities suggests that a conservative approach is best with the actual levels always guaranteed to be lower than predicted. Detailed environmental attenuation factors can be included or simulated in RF-Map.

5.2.1 RF_Map Program formula

The field calculations of power density in W/m^2 are carried out using standard far-field formula (equation 6)

(EME level) $\mathbf{S = PG/4\pi d^2}$

S = power density (W/m^2).

G = Antenna power gain.

P = Antenna power.

D = Distance to antenna.

The program uses either a direct ray path or a 2-ray propagation path. If the two ray model is used, calculation then assumes flat ground. The program calculates the correct ground reflection for vertical, horizontal or slant polarization. In this thesis we use the two models; direct and two ray path.

5.2.2 Near-field calculations

In the near-field of an antenna, which is generally very close to an antenna, the gain is reduced, and this reduction should be taken into account when conducting EME assessments, RF-Map incorporates near-field correction values derived from published Uniform Line Source and Tapered Circular Aperture curves. The correction values are applicable to cellular and other well characterized antennae that have a known type of aperture. The gain reduces in the near-field because the finite sizes of the aperture no longer focus all the radiated energy from each part of the antenna in-phase at the point of observation. The near field and antenna aperture correction applied in RF-Map allow for the accurate calculation of EME levels the close to antennae and antenna arrays.

5.3 Electromagnetic radiation hazards assessments

The RF-Map antenna near field correction algorithm enables the assessment of radiation hazard EME zones close to antennae and structures. Plan and elevation radiation hazard assessments are possible using RF-Map. The radiation hazard exposure limits and colors scheme are user settable. This radiation hazard assessment plots the maximum cumulative EME level at roof level. The red and yellow zones show the Occupational and General public exposure limits and boundaries. An elevation view for each antenna array is also available. This environment assessment demonstrates the maximum cumulative EME level surrounding the building at ground level is approximately 0.2% of the permitted standard.

5.4 Data Collection

This involves collection of all the relevant information on each functional base-station site. This data, includes site addresses, map coordinates and technical parameters as required for field calculations; namely: antenna mounting configuration, number of sectors, antenna type for each sector, height of each antenna sector above ground, mechanical tilt at each sector, direction (azimuth) of main lobe at each sector as given in table (5.l), number of carriers for each sector and power output. Antenna manufacturers supply beam patterns, which are required for field computation. All technical data and site parameter are provided by the Palestine cellular communication. Ltd. (Jawwal) specific import for each base station is provided in appendix.

5.4.1 Antennae database

A database of all types of antennae used by the Palestine cellular communications Ltd. is established in a form which is acceptable for the RF-Map program. The database contains mechanical tilt, bearing, aperture size and other technical data.

Table (5.2) shows the antennae type, gain and frequency ranges operated by Jawwal.

Table (5.1): *Typical data used by RF_Map program showing the Power of transmitters antennae, type of antennae, and tilt, azimuth of antennae in(Abu_Dies, Bethany and Hizma) towns*

Area	**Antenna Type**	**Height**	**Azimuth**	**Tilt**	**Transmitters Power (Watt)**
Abu_Dies	K 739160	24	20	4	300
	K 739160	24	150	0	
	K 739160	21	250	8	
Bethany	K 739624	22	40	5	270
	K 739160	22	140	0	
	K 739160	22	260	0	
Hizma	K 739160	17	30	0	300
	K 739160	17	120	0	
	K 738819	17	240	0	

Table (5.2): G*ain and frequency rang for the antennae operated by Jawwal.*

Katherine Antennae Type No	Gain (dBi)	Frequency Rang (MHz)
K 730619	2*18	806-960
K 739635	2*15.5	806-960
K 739635	2*17	880-960
K 739160	2*17	806-960
K 739624	2*17.5	806-960
K 739632	2*14.5	806-960
K 738819	2*15	806-960
K 739623	2*16.5	806-960
K 7216.02	2*12	806-960 just use in Gaza
K 739620	2*12.5	880-960

5.4.2 Maps of the investigated sites

The program can import bit map images and merge them with both the RF_Map design and plot pages. All maps used in this study are aerial photo maps converted to bit map format (except one street map in Gaza city). Maps were a limiting factor in our study since many of them are not available because it's very expensive or are available with a resolution which dose not fit to the program.

5.5 Power density meter

Technically a "power density" meter, the RF Field Strength Meter, manufacture by (ALFALAP Company) detects the electric field of radio and microwaves (RF) from 0.5 MHz to 3 GHz, and expresses the field strength as power density from 0.001 to 2000 μW/ cm^2. The instrument is an extremely sensitive RF and microwave radiation detector which can accurately measure RF background even in rural areas 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.

VI Results and Discussion

Thirty three base stations are investigated in this work (29 base stations in the West Bank and 4 base stations in Gaza Strip). Figure (6) illustrates the locations and number of the investigated sites over the West Bank.

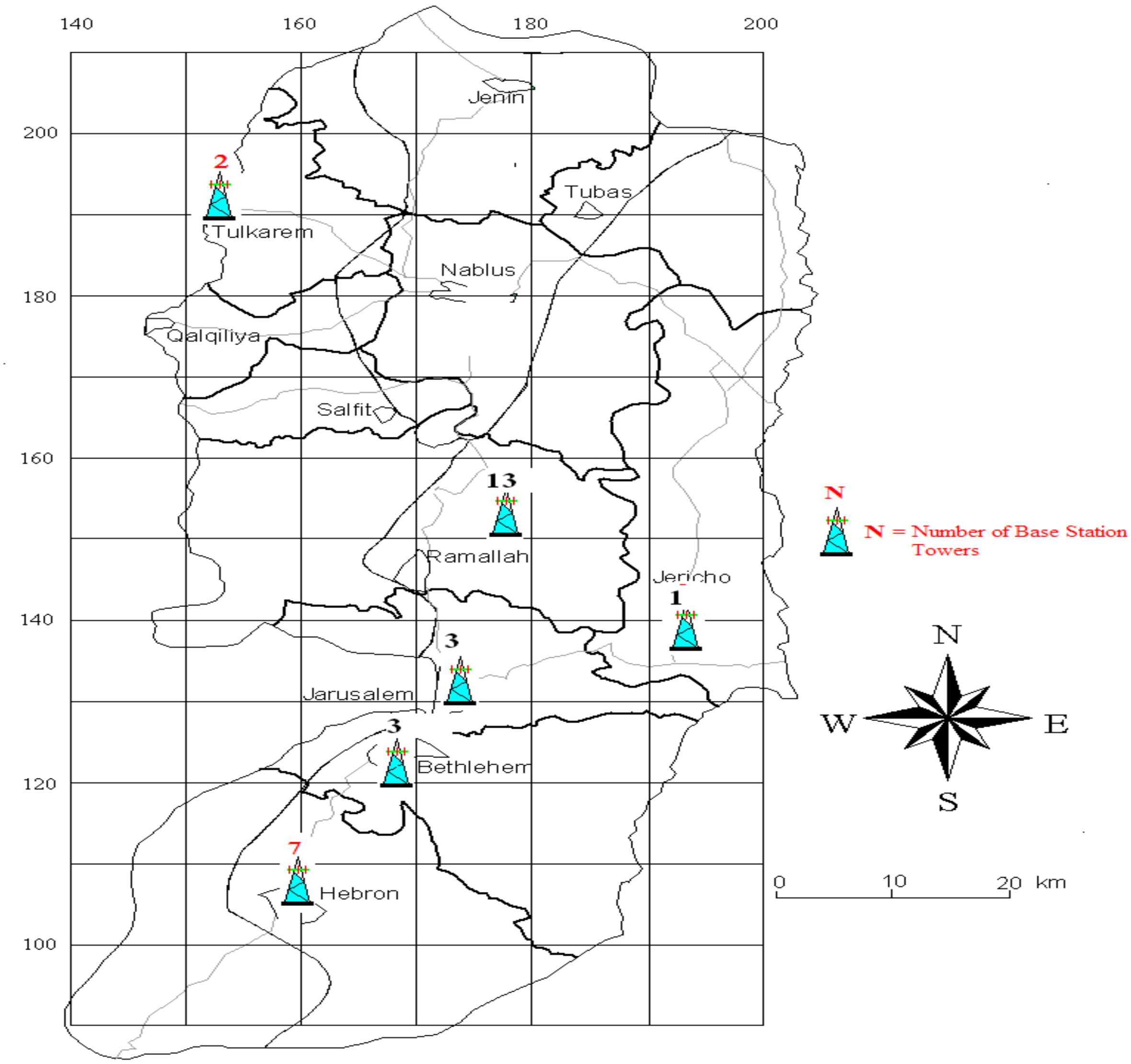


Figure (6): *Investigated base station towers in the West Bank.*

6.1 Base stations in the Gaza strip

In this study we have investigated four base stations out of forty in Gaza strip that are operated by Jawwal Company in order to estimate the electromagnetic radiation. Two models of electromagnetic radiation assessment are used:

6.1.1 Direct ray path model for single site

This model of exposure evaluation considers only the direct beam from the antenna (reflected beam is not taken into consideration).

Figure (6.1) presents the electromagnetic radiation levels emitted from the base station at Al Nourien building. This site contains three antenna panels mounted separately. The maximum power density from this base station is 0.026μW/cm^2. This value is about 15384 times below the ICNIRP's limit for general public which is 400μW/cm^2.

6.1.2 Two ray path model for single site

This type of evaluation considers the direct ray and reflected wave of the beam that comes out from the antenna and evaluated the power density around the base station. Therefore, the evaluation can be made of the reliability of field estimates in comparison to ICNIRP limit, where the electromagnetic field is relatively unperturbed. In this investigation we consider that the ground has a conductivity = 0.01 Ωm^{-1} and dielectric constant = 7, these values depends on the type of soil in the studying area and the type of building which is different from one location to another.

The same base station of Al Nourien "as shown in figure (6.2)" has been investigated using the two ray path model (reflected beam is taken into account for power density calculations).

The resulted maximum density is 0.044μW/cm^2 (9090 times below the ICNIRP's limit). This result indicates that by using the two ray path model, it doubles the power resulted density (i.e. the reflected beam from the ground has the same effect on the exposure as the direct beam emitted from the antenna).

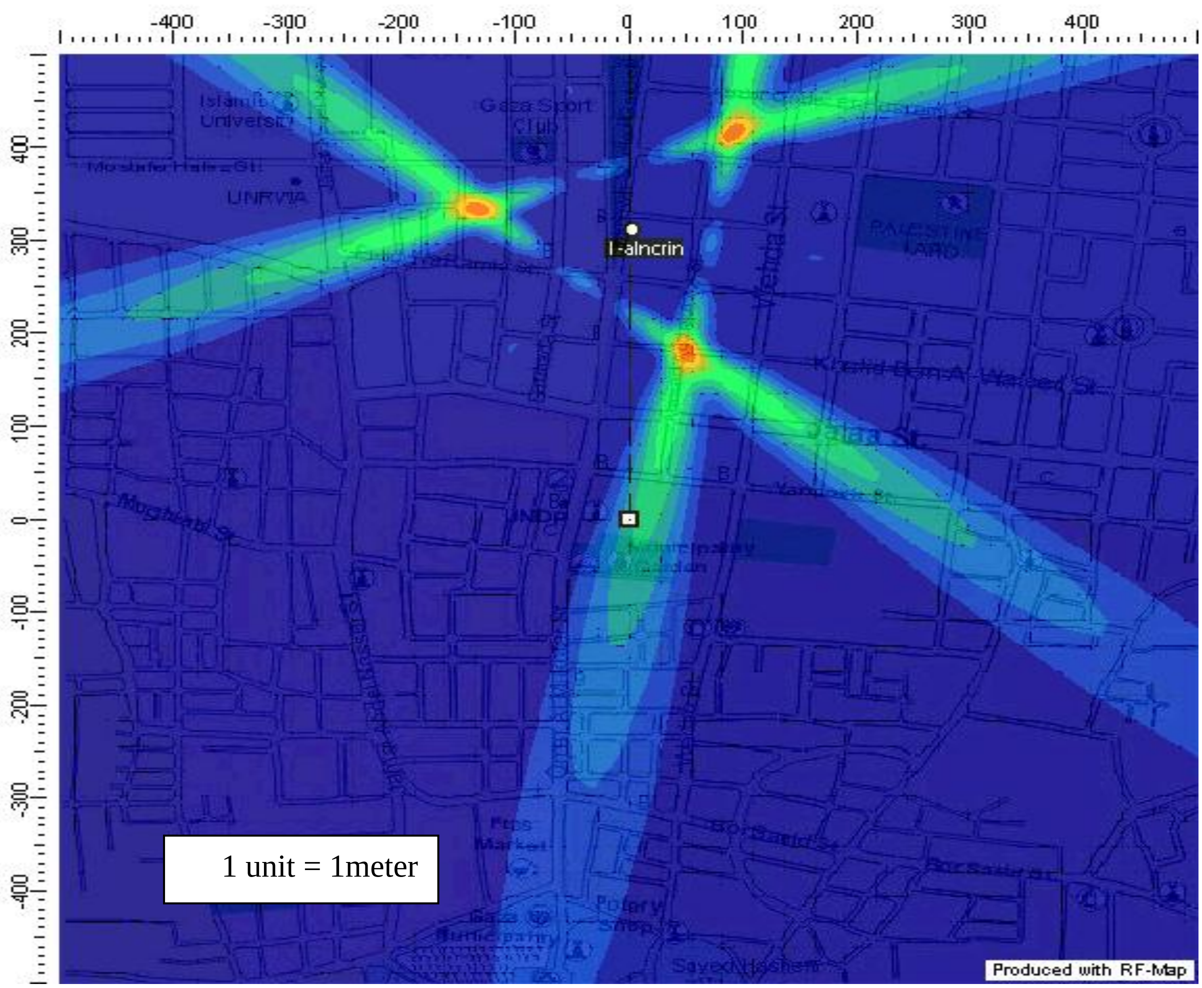


Figure (6.1): *Electromagnetic radiation levels estimated from the base station in Alnourien - Gaza, using direct ray model (street map overlay).*

Colour	Value [µW/cm²]
	2.599E-2
	2.339E-2 to 2.599E-2
	2.079E-2 to 2.339E-2
	1.820E-2 to 2.079E-2
	1.560E-2 to 1.820E-2
	1.300E-2 to 1.560E-2
	1.040E-2 to 1.300E-2
	7.799E-3 to 1.040E-2
	5.200E-3 to 7.799E-3
	2.600E-3 to 5.200E-3
	1.296E-6 to 2.600E-3

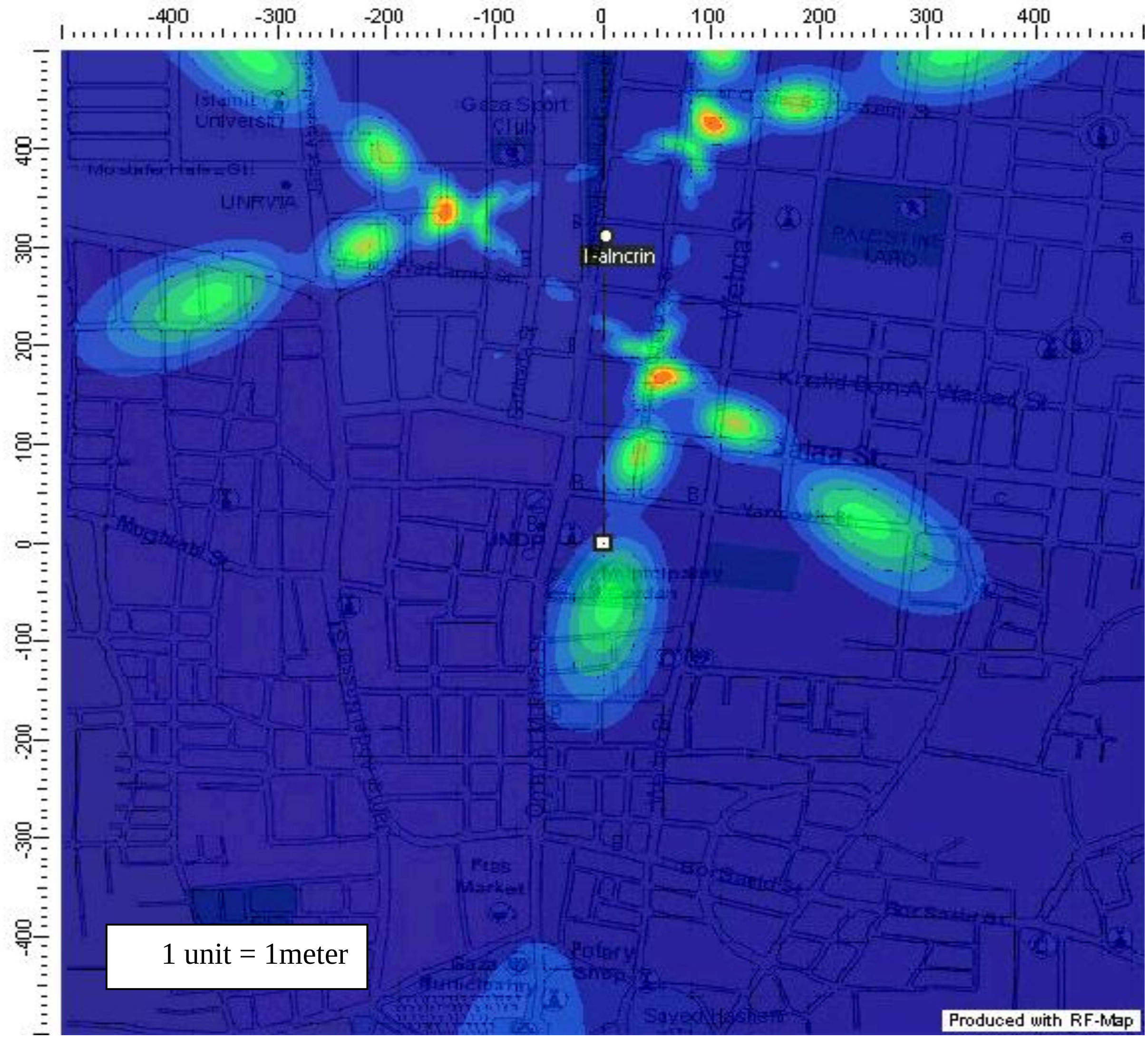
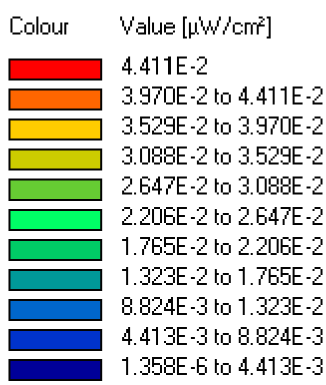


Figure (6.2): *Electromagnetic radiation levels estimated from the base station of Alnourien building-Gaza, using two ray path model (street map overlay).*



6.1.3 Two ray path model for multi sites

Figure (6.3) presents the results of the assessment of multi sites configuration (4 base stations in Gaza city). The maximum cumulative power density is 0.085µW/cm^2 which is mounted at the street of Port Said. Table (6.1) presents the results of power density estimations resulted from this configuration for various locations in Gaza city.

Table (6.1) *Electromagnetic radiation levels resulted from cumulative emissions of 4base stations in Gaza city estimated at various locations in the city.*

Location Name	Power Density level (µW/ cm^2)	Times below the ICNIRP Public exposure 400µW/cm^2
Port said Street	0.085	4705
Islamic University	0.052	7692
Gaza Municipality	0.063	6349
Municipality Garden	0.062	6451
UNDP (Gaza)	0.044	9090
Khaled Ben Alwaleed Street	0.036	11111
Palestine Yard	0.053	7547
Gaza sport Club	0.046	8695
UNRWA (Gaza)	0.036	11111
Jalaa Street	0.029	13793

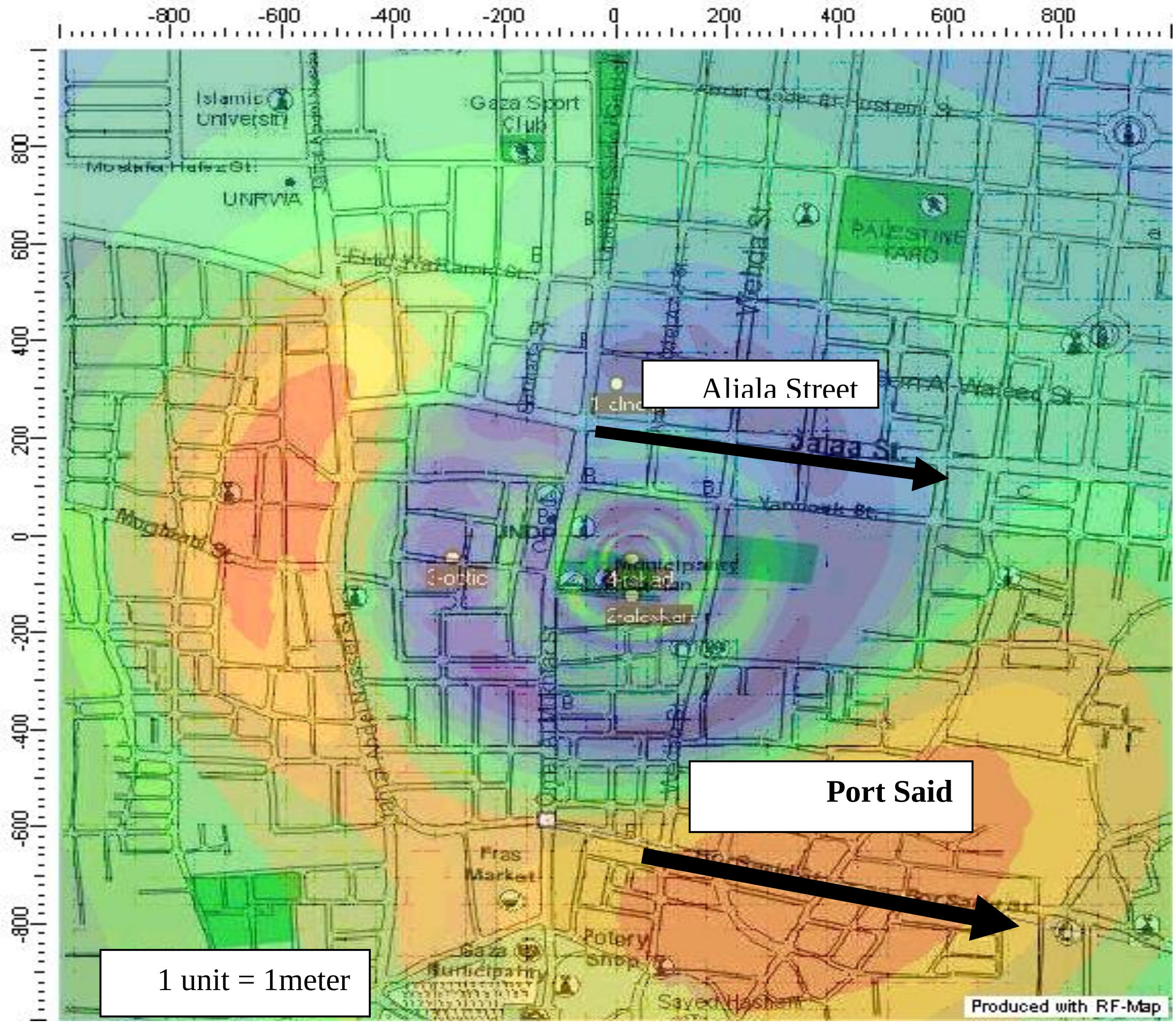
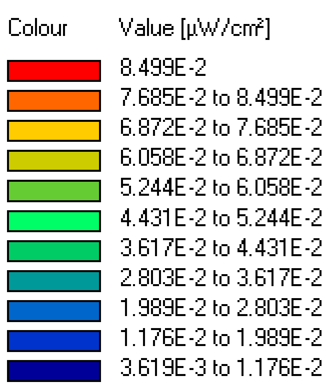


Figure (6.3): *Electromagnetic radiation levels from four base stations in Gaza city (street map).*



6.2 Base stations in the West Bank

Twenty nine base stations are investigated in the West Bank. Results are summarized as follows:

6.2.1 Single sites - West Bank

Single site calculations are done in Duhashe Camp, Biet Sahour, Jericho, and towns of (Abu_Dies, Bethany and Hizma). Results are summarized in Figures (6.4-6.9).

Calculations are performed at survey high of 1.5 meter. Figures (6.4-6.9) show the locations of the JMPBSs and the power densities in the area around the sites. Table (6.2) presents a comparison between the evaluated maximum power densities around the JMPBSs and ICNIRP gaudlines limit. Tables (6.3 – 6.6) summarize the resulted of power density in various locations in selected sites. In this investigation the surface ground constants are: conductivity 0.034 Ωm^{-1} (Shane, 2000) and dielectric Constant = 8.2 (Barnes, 1999). From the figures shown, we see that the values of power densities evaluation in the West Bank are grater than those in Gaza which means that the system of network in Gaza is different and it uses the microcell system which uses a lot of base stations with low powers, while in West Bank the operator uses macrocell system which depends on one base station to cover much extended area and this type of system needs a very high power and Gain of antennae.

Also we can see that the antenna is directed towards the crowded areas like universities, as in Abu_Deis. Figure (6.7) shows that the maximum location of exposure is found in Al_quds University Campus. Figure (6.11) shows that the maximum exposure in the University of Polytechnic Palestine/ Hebron.

Figure (6.10) shows the maximum power densities of all single sites in the West Bank and Gaza, and how these values are under the international commission on non-ionizing radiation protection limit. Also it shows the differences of electromagnetic radiation emission levels used between single base stations. These differences in the emission levels are due to the Gain of the antenna and the power radiated from it, also the mechanical tilt of the antennae.

In some cases, antennae are directed to crowded streets, like Port Said street (Gaza) figure (6.3).

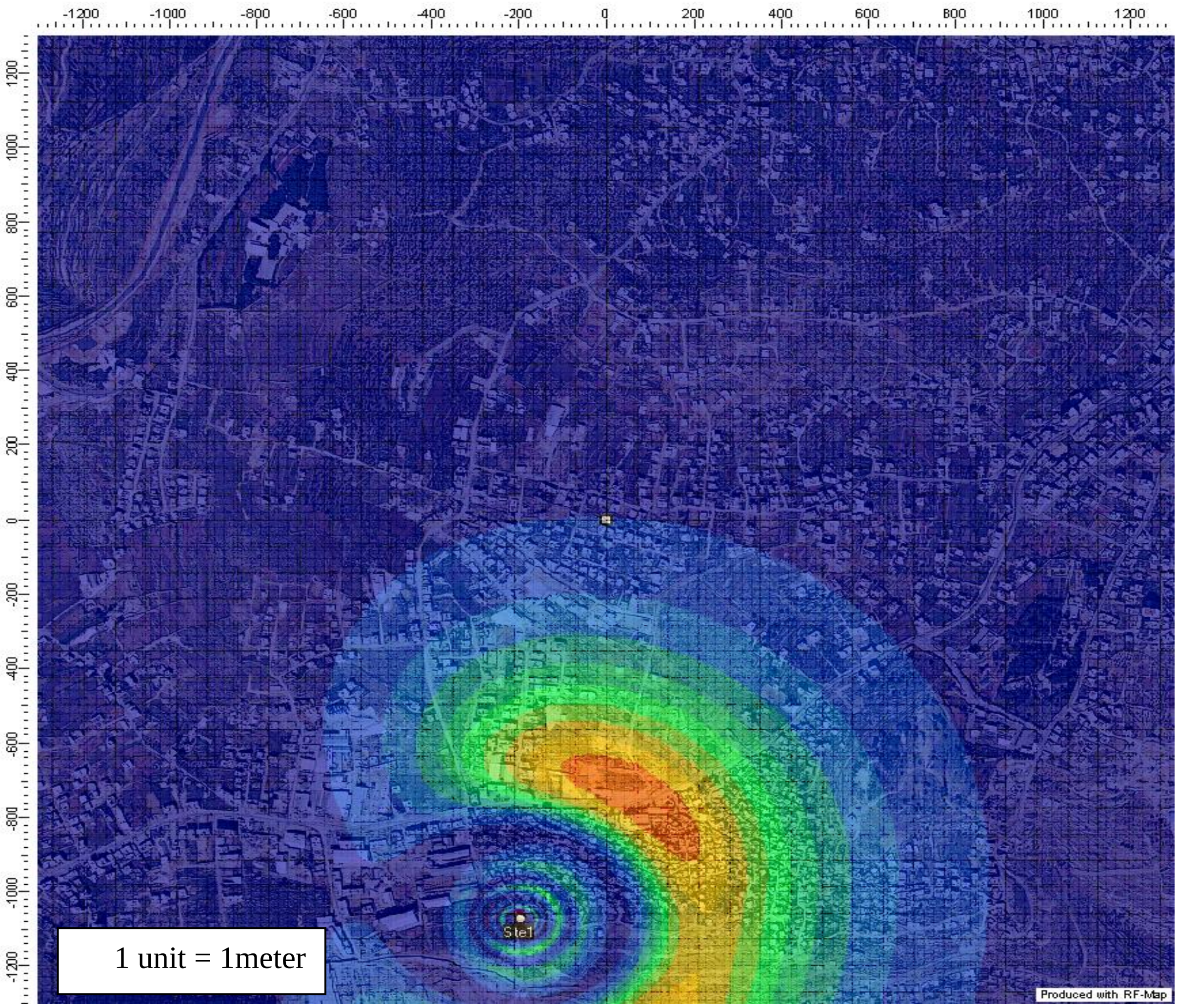
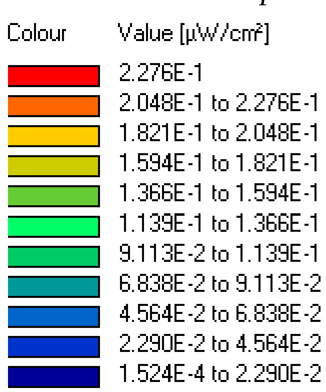


Figure (6.4): *Electromagnetic radiation levels estimated from the base station in Duhashe Camp-Bethlehem, using 2ray path model (aerial map).*



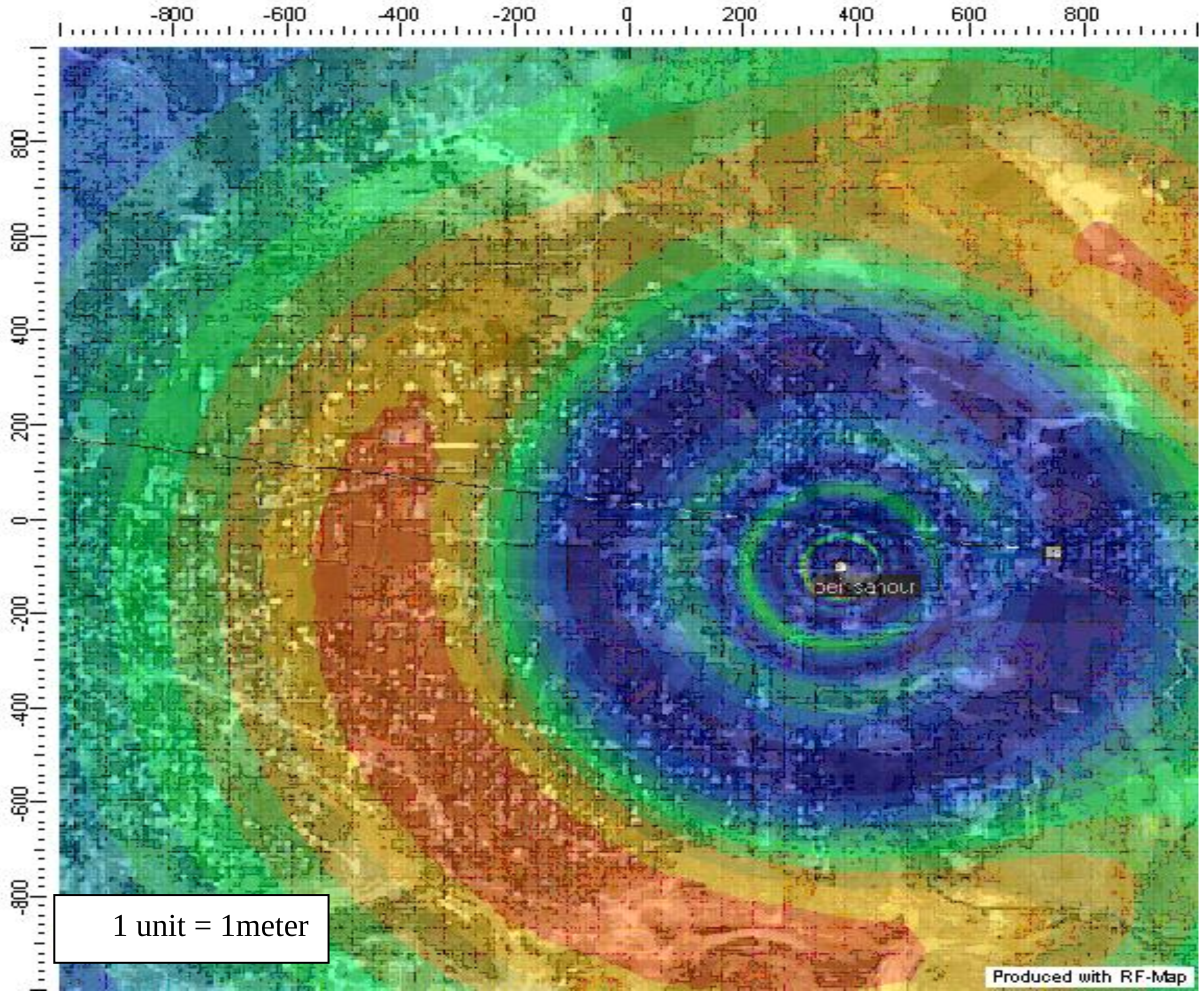
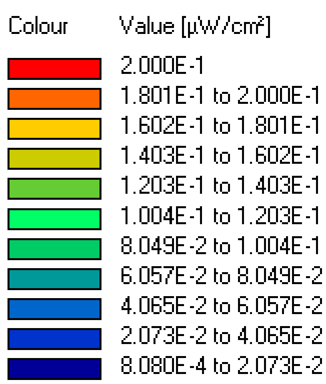


Figure (6.5): *Electromagnetic radiation levels estimated from the base station in Biet Sahour, using 2ray path model (aerial map).*



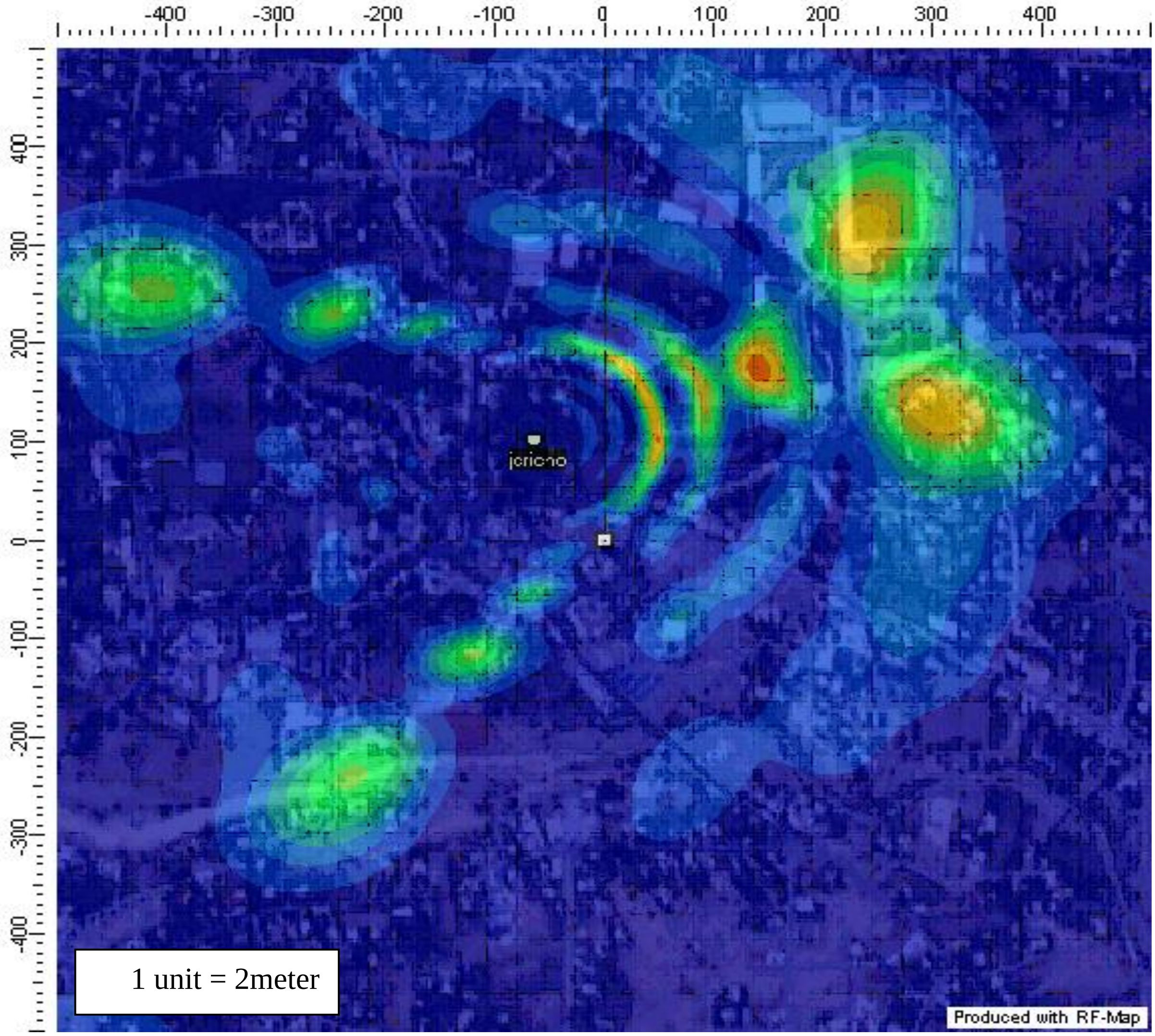


Figure (6.6): *Electromagnetic radiation levels estimated from the base station in Jericho, using 2ray path model (aerial map).*

Colour	Value [µW/cm²]
	2.005E-2
	1.805E-2 to 2.005E-2
	1.604E-2 to 1.805E-2
	1.404E-2 to 1.604E-2
	1.203E-2 to 1.404E-2
	1.003E-2 to 1.203E-2
	8.022E-3 to 1.003E-2
	6.017E-3 to 8.022E-3
	4.011E-3 to 6.017E-3
	2.006E-3 to 4.011E-3
	6.153E-7 to 2.006E-3

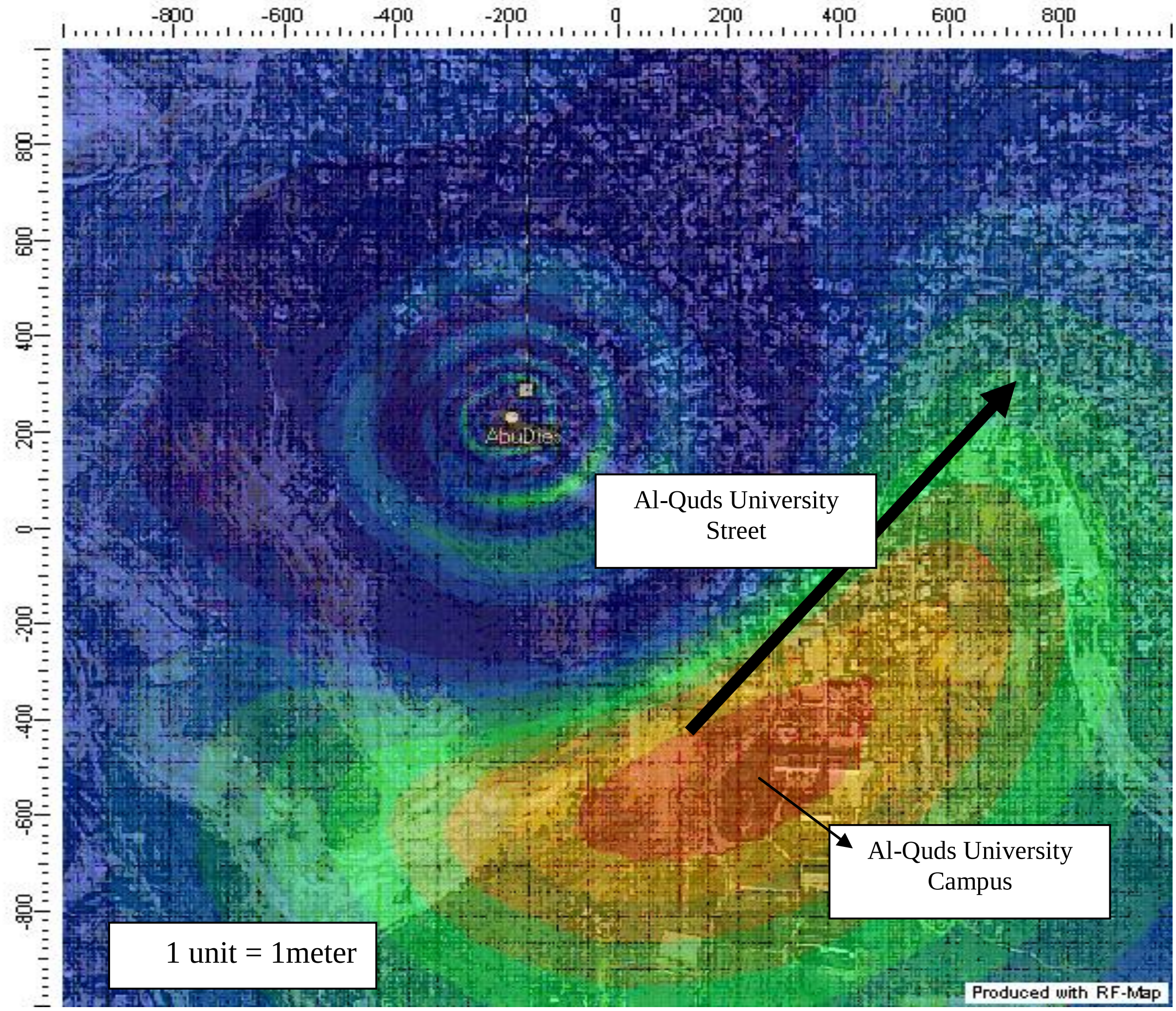
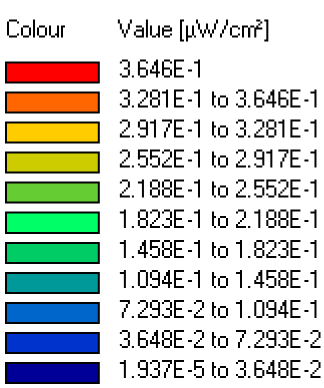


Figure (6.7): *Electromagnetic radiation levels estimated from the base station in Abu_Dies-Jerusalem, using 2ray path model (aerial map).*



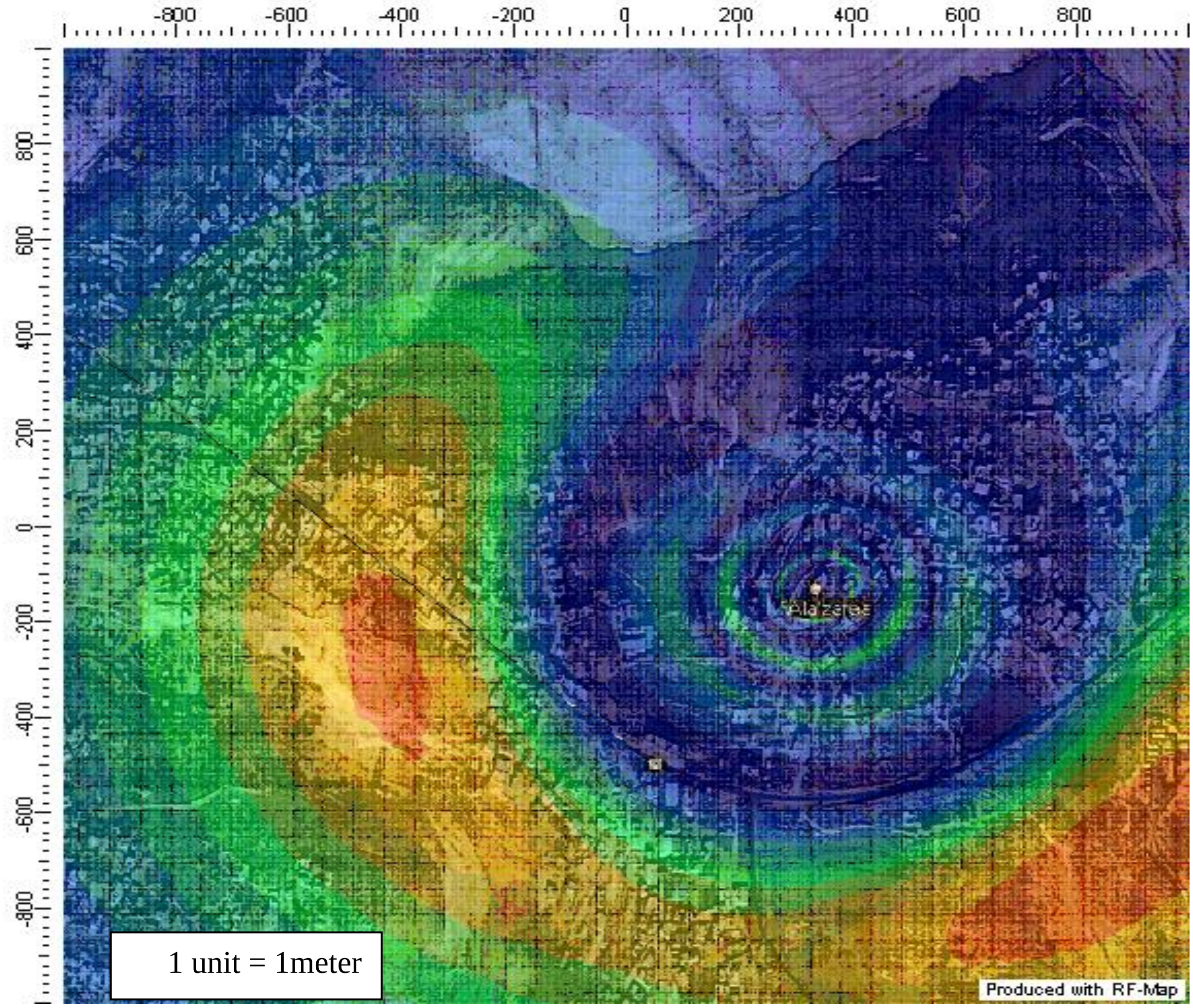
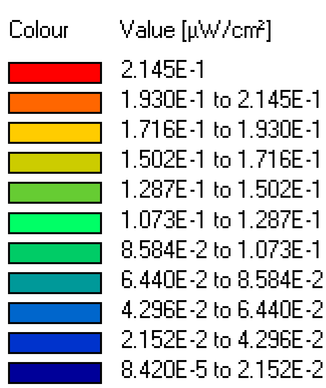


Figure (6.8): *Electromagnetic radiation levels estimated from the base station in Bethany-Jerusalem, using 2ray path model (aerial map).*



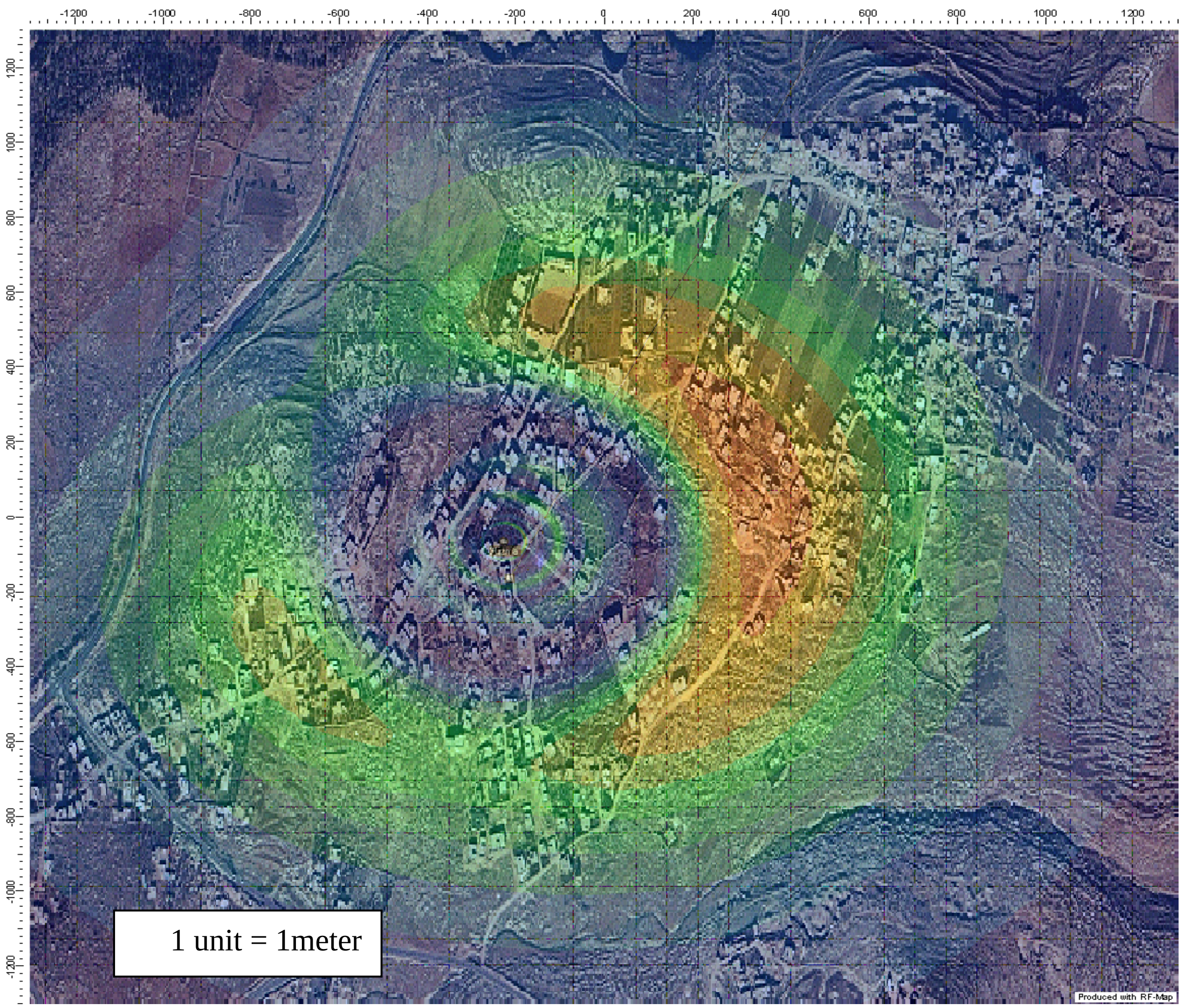


Figure (6.9): *Electromagnetic radiation levels estimated from the base station in Hizma town, using 2ray path model (aerial map).*

Colour	Value [µW/cm²]
	4.136E-1
	3.723E-1 to 4.136E-1
	3.310E-1 to 3.723E-1
	2.898E-1 to 3.310E-1
	2.485E-1 to 2.898E-1
	2.072E-1 to 2.485E-1
	1.660E-1 to 2.072E-1
	1.247E-1 to 1.660E-1
	8.342E-2 to 1.247E-1
	4.215E-2 to 8.342E-2
	8.782E-4 to 4.215E-2

Table (6.2): *Maximum power densities estimated, using tow ray path model for single base stations in selected sites in Palestine.*

Site Name	Maximum Power Density (µW/ cm^2)	Times below the ICNIRP Public exposure limit of 400µW/cm^2
Alnourien Building /Gaza	0.044	9070
Optima Hospital /Gaza	0.029	1420
Eien Sarah/Hebron	0.108	3696
Municipality/Hebron	0.074	5442
Rass Aljwra/Hebron	0.042	9478
Duhashe Camp/Bethlehem	0.023	17542
Nativity Church/Bethlehem	0.083	4830
Bethlehem Hotel/Bethlehem	0.059	6094
Biet Sahour	0.020	20000
Jericho	0.020	20000
Abu_Dies/Jerusalem	0.365	1096
Bethany/Jerusalem	0.215	1860
Hizma	0.414	966

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Table (6.3): *Electromagnetic radiation levels from the base station in Abu_Dies estimated at various locations around the site.*

Location Name	Power density level (µW/ cm^2)	Times below the ICNIRP Public exposure limit 400µW/cm^2
Alquds University	0.364	1098
Arab Institute	0.320	1250
Abu Dies Secondary School / Boys	0.302	1324
Abu Dies Club	0.119	3360
Abu Dies Secondary School / Girls	0.180	2222

Table (6.4): *Electromagnetic radiation levels resulted from the base station in Bethany estimated at various locations in the town.*

Location Name	power density level ($\mu W/ cm^2$)	Times below the ICNIRP Public exposure limit $400\mu W/cm^2$
Project Area	0.215	1860
Kedar junction Area	0.016	25000
Al_masea Hall	0.106	3772
Bessan Building	0.073	5749
Health Directorate / Bethany	0.054	7392
Awqaf Department	0.129	3100
Churches (Bethany)	0.091	4394

Table (6.5): *Electromagnetic radiation levels resulted from a base station in Jericho city estimated at various locations in the city.*

Location Name	power density level ($\mu W/ cm^2$)	Times below the ICNIRP Public exposure limit $400\mu W/cm^2$
Spin Garden	0.020	20000
Jericho Secondary School	0.008	50000
Fatima Alzhra´ School	0.015	26666
Al_Bohtory School	0.009	44444
Health Directorate / Jericho	0.015	26666
Tarsanta School / Jericho	0.016	25000
AL_Rahibat School	0.018	22222
Jericho Center Area	0.013	30769
Children Center	0.019	21052
Jericho Sport Stadium	0.014	28571

Table (6.6): *Electromagnetic radiation levels from the base station in Hizma town estimated at various locations in the town.*

Location Name	power density level (µW/ cm^2)	Times below the ICNIRP Public exposure limit 400µW/cm^2
Hizma Center	0.414	966
Hizma Secondary School / Boys	0.161	2484
Hizma Secondary School / Girls	0.173	2312
Hizma Mosque	0.036	11111
Shuhda´ Hizma School	0.382	1047

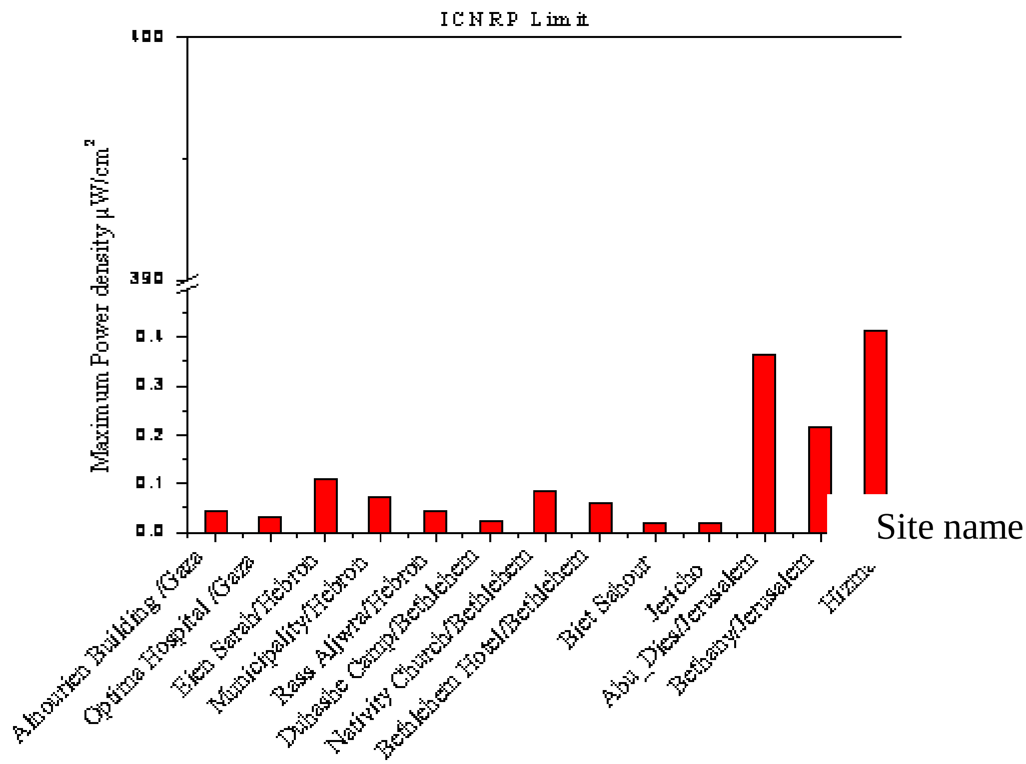

Figure (6.10): *The maximum power density estimated from single base stations in selected sites.*

6.2.2 Multi sites in the West Bank

Multi sites calculations are done in the following cities: Hebron (7 base stations), Bethlehem (3 base stations), Ramallah (13 base stations) and Tulkarm (2 base stations). Results are as follows: the maximum cumulative power density from 7 base stations in Hebron is 0.216µW/ cm^2 and about 1848 times below the ICNIRP limit. Figure (6.11) and table (6.7) summarizes the evaluation of power densities at various locations in Hebron city

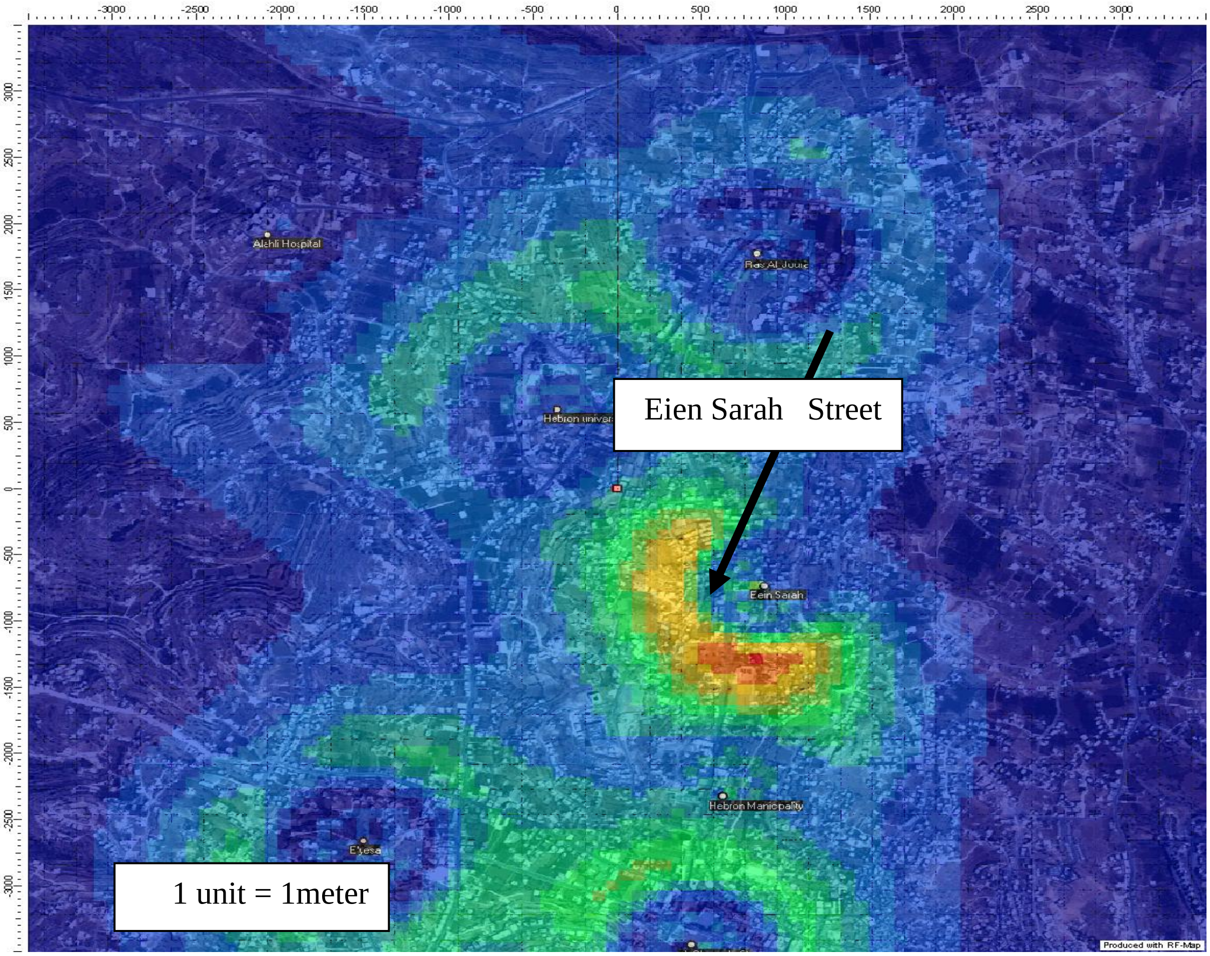

Figure (6.11): *Cumulative electromagnetic radiation levels estimated from seven base stations in the City of Hebron (aerial map).*

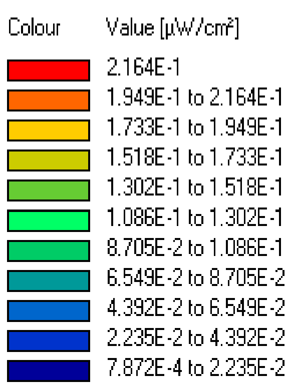

Table (6.7): *Electromagnetic radiation levels resulted from cumulative emissions of 7 base stations in Hebron city estimated at various locations in the city.*

Location Name	Power Density level (µW/ cm^2)	Times below the ICNIRP Public exposure limit 400µW/cm^2
Palestine Polytechnic University	0.216	1848
Al_Hussien Ben Ali sport Stadium	0.123	3244
Eien Sarah Street	0.087	4596
Union School	0.067	5942
Ibn Rushed School	0.087	4597
Abu_Diah School	0.048	8332
Wedad Nasser Al_Dean School	0.069	5797
Khadejah Abdeen School	0.026	15324
Hebron University	0.027	14814
Guards Mosque	0.041	9756
Coca Cola Store Area	0.023	17391
Al_Slam Glasses Factory	0.020	20000
Al_Mhjar Well Junction Area	0.023	17391
Rass Al_Jwra Area	0.039	10230
Al_Ahly Hospital	0.009	44444
Al_Miezan Hospital	0.046	8694
Queen A´lia Hospital	0.082	4878
Al_Hussien Ben Ali School	0.118	3392

Figure (6.12) and table (6.8) present the results of power densities estimation in Bethlehem..

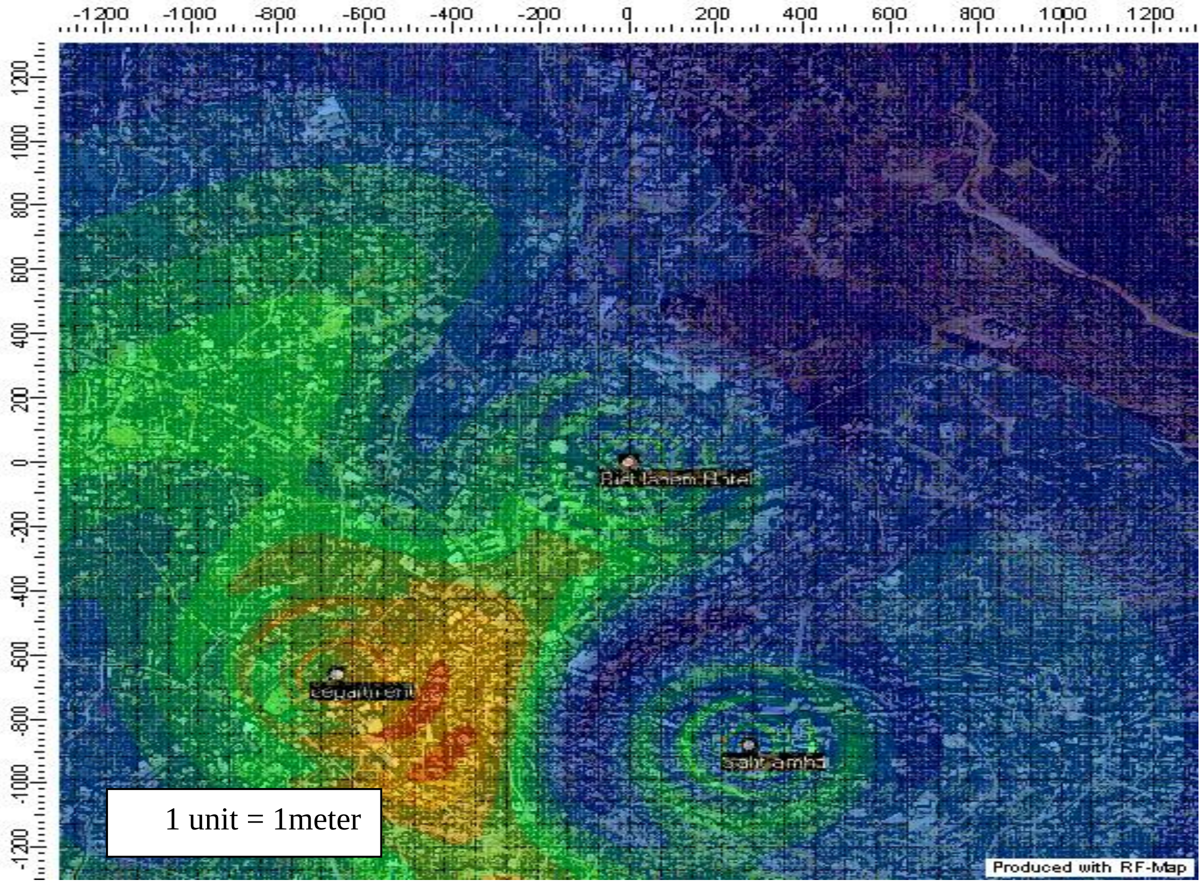

Figure (6.12): *Cumulative electromagnetic radiation levels estimated from three base stations in the city of Bethlehem (aerial map).*

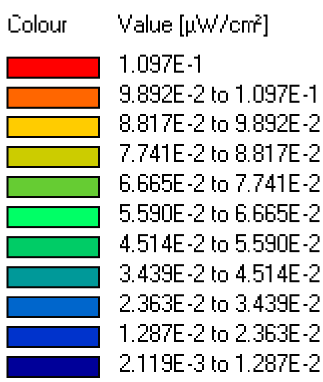

Table (6.8): *Electromagnetic radiation levels resulted from cumulative emissions of 3 base stations in Bethlehem city estimated at various locations in the city.*

Location Name	Power density level (μW/ cm^2)	Times below the ICNIRP Public exposure limit 400μW/cm^2
Al_Mukata΄a / Bethlehem	0.110	3636
Iskander Alkhory School	0.059	6779
France Hospital	0.061	6556
Bethlehem University	0.058	6884
Alquds Open University /Bethlehem	0.035	11428
Bethlehem Secondary School	0.039	10256
Aidah Camp Area	0.044	9090
Bethlehem Hotel	0.035	11428
Tarasntah School (Mar Yousf)	0.028	14285
Nativity Churches	0.057	7017
Al_Sua΄ody School	0.028	14285
Al_Cinema Area	0.076	5263
Rahil Tomb	0.026	15384
Swede School	0.083	4819
Al_Dibs Hospital	0.074	5405
Al_Akhaa΄ School	0.0320	6250
Al_Hussien Hospital	0.051	7843

Figure (6.13) shows the results of the evaluation of cumulative power density resulted from the emissions of 13 base stations. The maximum power density was found at (Al_Balua΄) and is 1.66μW/cm^2 this value is the highest one found in this work. In cooperation with ICNIRP's limit, it is 240 times below.

Table (6.9) summarized the resulted of power density in various locations in Ramallah city.

In city of Tulkarm, there are two base stations operated by Jawwal. The maximum cumulative power density resulted from these base stations is 0.143μW/cm^2 and found at the Western Part of the city. Figure (6.14) and table (6.10) summarizes the results of power densities in various locations in the Tulkarm city.

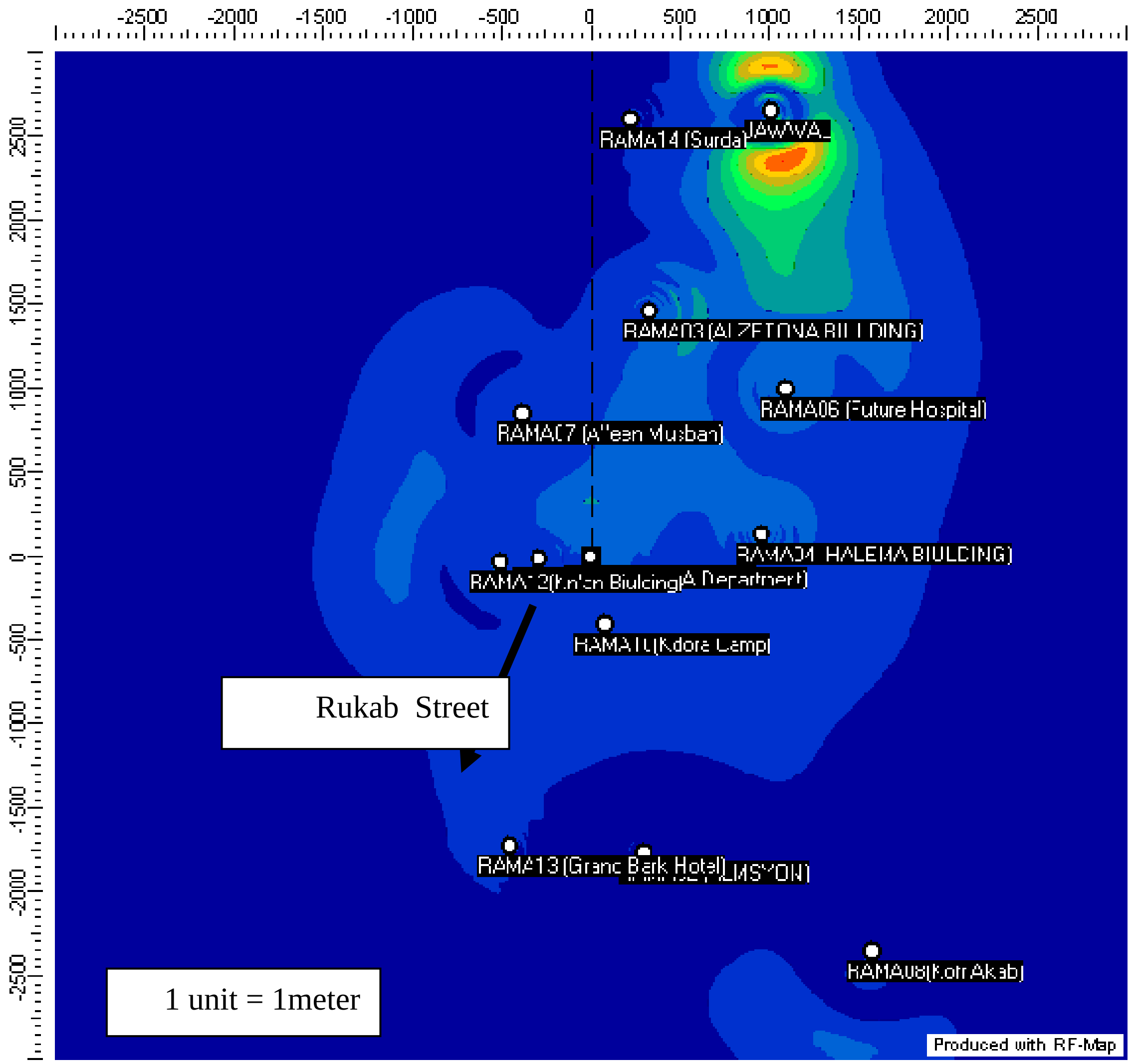

Figure (6.13): *Cumulative electromagnetic radiation levels estimated from thirteen base stations in Ramallah City (plan view).*

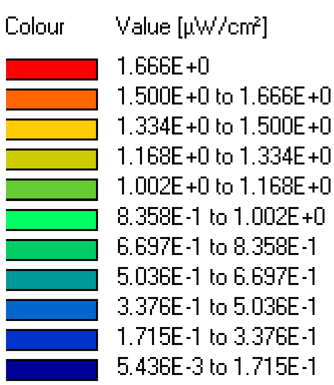

Table (6.9): *Electromagnetic radiation levels resulted from cumulative emissions of 13 base stations in Ramallah estimated at various locations in the city.*

Location Name	P.D level ($\mu W/ cm^2$)	Times below the ICNIRP Public exposure limit of $400\mu W/cm^2$
Jawwal Company Area (Al_Balua´)	1.666	240
Albirah Tourist Hotel	0.139	2877
Cinema Alksaba	0.286	1400
Ramallah Hospital	0.238	1680
Alshiekh Zayed Hospital	0.235	1702
Dwar Al_Saa´a Area	0.264	1515
Cinema Alwaleed	0.416	961
Dwar Al_Manarah Area	0.333	1201
Arab Care Hospital	0.452	884
Friends School	0.362	1104
Albirah Sport Stadium	0.311	1286
Mukhmas Shopping Center	0.463	863
Al_Mukata´a / Ramallah	0.415	963
Best Eastern Hotel	0.152	2631
Alquds Open University/ Ramallah	0.234	1709
Khaled Surgery Hospital	0.170	2352
Alquds Education TV	0.097	4123

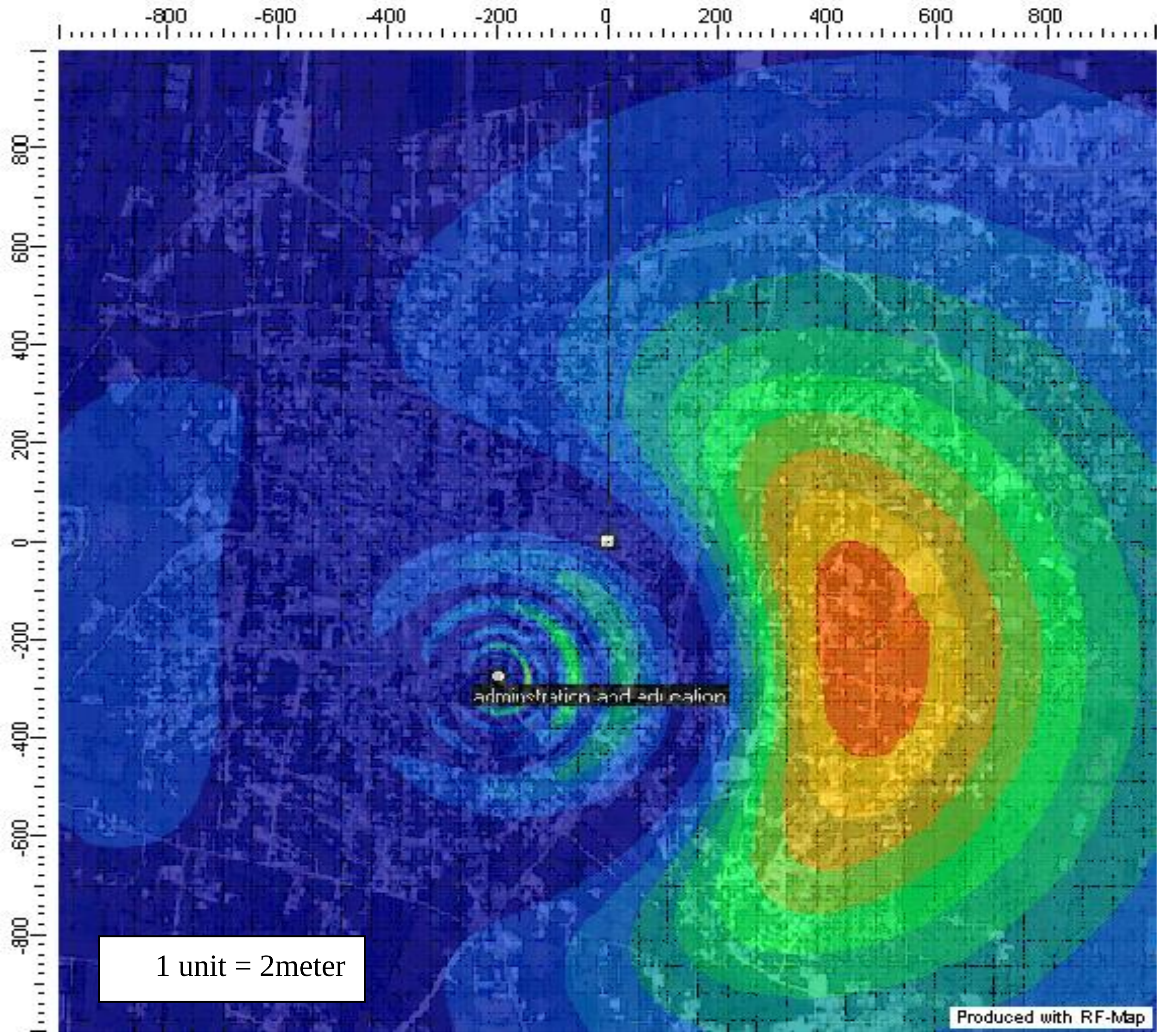

Figure (6.14) *Cumulative electromagnetic radiation levels Estimated from two Base Stations in Tulkarm City (aerial map).*

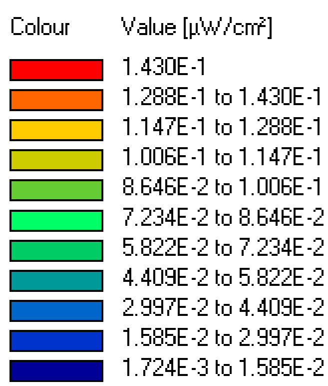

Table (6.10): *Electromagnetic radiation levels resulted from cumulative emissions of 2 base stations in Tulkarm city estimated at various locations in the city.*

Location Name	Power Density level (µW/ cm^2)	Times below the ICNIRP Public exposure 400µW/cm^2
Western Part	0.143	2796
Al_Adawea Secondary School	0.010	40000
Alslam School	0.054	7407
Arab Bank	0.024	16460
Alquds Open University / Tulkerm	0.019	21274
Al_Shweky Sport Stadium	0.034	11764
Al_Mukata´a /Tulkerm	0.004	100000
Al_Fadeliah School	0.038	10526
Khaled Ben Alwaled School	0.038	10526
Palestine technique College (Al_khdory)	0.016	25000
Thabit Thabit Hospital	0.019	21052

Figure (6.15) shows the maximum exposure resulted from all investigated multi sites and how they are related to ICNIRP limit.

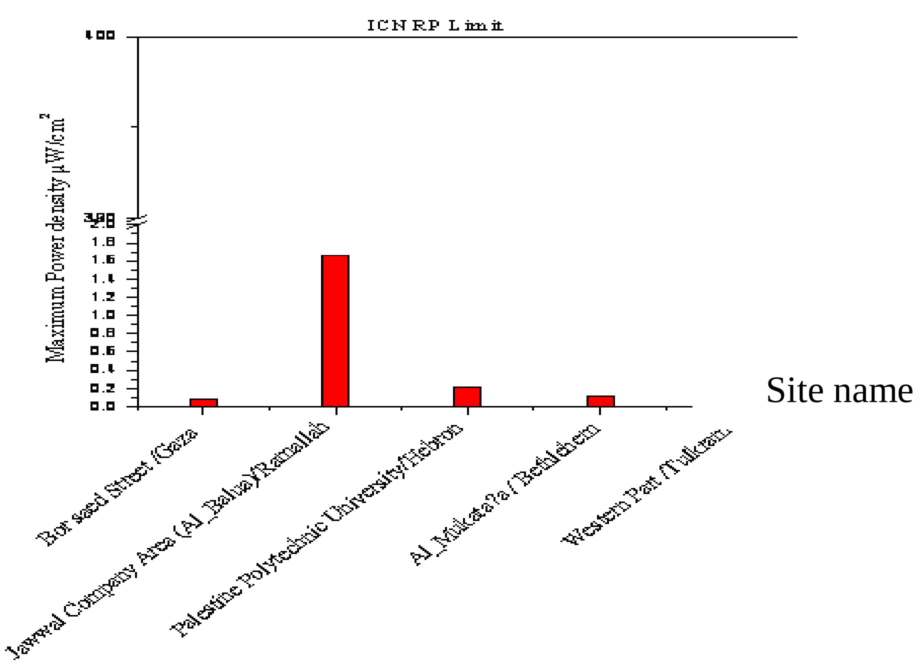

Figure (6.15): *The maximum power density estimated from multi base stations in selected sites: Hebron (7 base stations), Ramallah (13 base stations), Gaza (4 base stations), Bethlehem (3 base stations) and Tulkarm (2 base stations).*

These results of multi-site investigations have shown that even cumulative emissions from more than one site are well below the internationally recommended levels.

6.3 Street mapping of power density in the West Bank

Street mapping of power density is made over some areas in the West Bank. Figure (6.16) shows a comparison between power densities calculated along three streets in Abu_Dies, Ramallah, and Hebron. From this figure we can see that the power density along Al_Quds University Street (from one base station) has higher values, this is because the type of the particular base stations. It is a macrocell base station used to cover a large area. The power density at Rukab street/Ramallah estimated from 13 base stations which has the main contribution is from the macrocell type base station at Dwar Al_Manarah. The power density in Eien Sarah Street is estimated from 7 base stations using microcell systems are shown in the following figure.

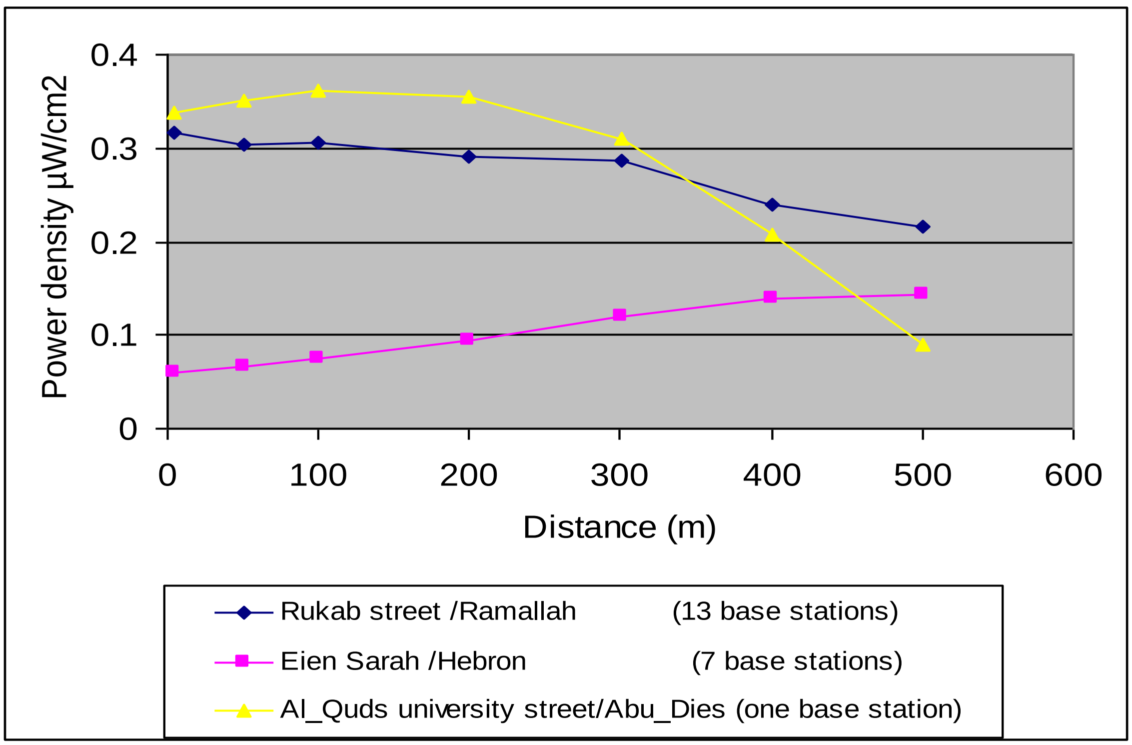

Figure (6.16): *Power densities estimated along three streets in West Bank.*

6.3.1 Street mapping of power density in Gaza

Street mapping of power density is made over some areas in the Gaza Strip. Figure (6.3) shows a street map survey along two of the most crowded streets in Gaza city. Port Said Street (as shown in figure (6.17)) is within the maximum electromagnetic radiation level. Aljala Street is out of the maximum of electromagnetic radiation level. The power density in Port Said street is clearly higher than that in aljala street.

The reason might be attributes the fact that port said street lies in the region where the power density of the contributions from the base stations are maximum.

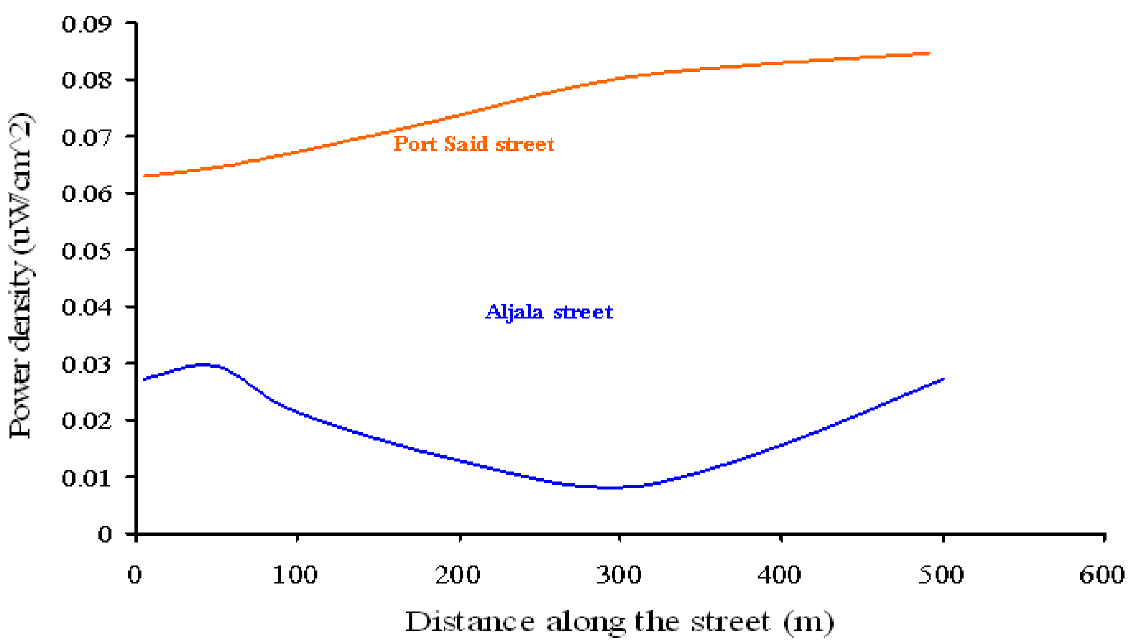

Figure (6.17): *Electromagnetic radiation levels resulted from four base stations, estimated along two crowded streets in Gaza city (survey high 1.5 m).*

6.3.2 Evaluation of power density in vertical direction

A vertical scan has been done over the position of the maximum electromagnetic radiation level resulted from the emission of 7 base stations. The results are shown in figure (6.18). The maximum power density is found at a height of 10cm over the ground.

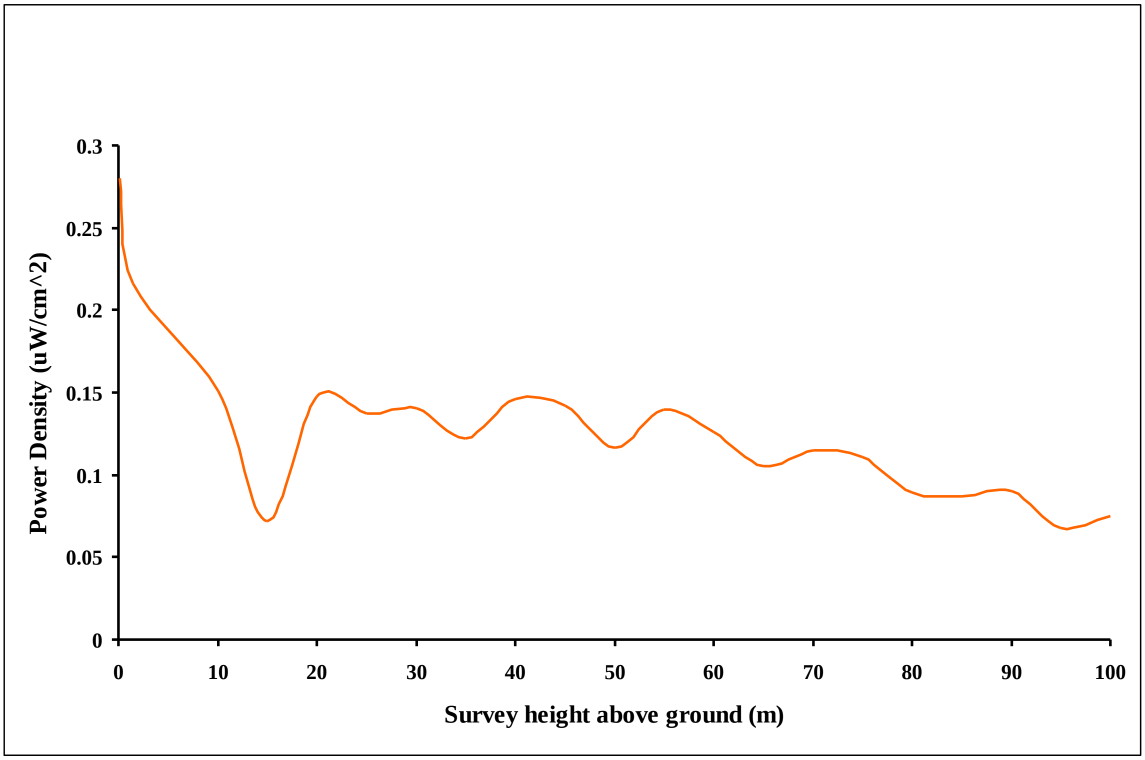

Figure (6.18): *Vertical survey over the location of maximum electromagnetic radiation level estimated from 7 base stations in Hebron.*

6.4 Measurement of power density using the RF Field Strength Meter

Measurements of the total power densities in the bandwidth from 0.5 MHz to 3 GHz have been conducted using RF field strength meter. This is done in an attempt to approximately evaluate the contribution of some base stations to the total exposure received by the people from all electromagnetic radiation sources in the bandwidth mentioned above.

Measurements were performed at Al-Quds University Street and at Rukab Street in Ramallah are shown in figure (6.19 and figure (6.20). Figures (6.19) and (6.20) show a comparison between the measured total power density along these streets and the calculated power densities along the same streets resulted from the nearby base stations. Measurements of Figures (6.19) and (6.20) (are based on 26 November 2005)! are taken after 3 minutes of RF field strength meter detects the radiofrequency in every point.

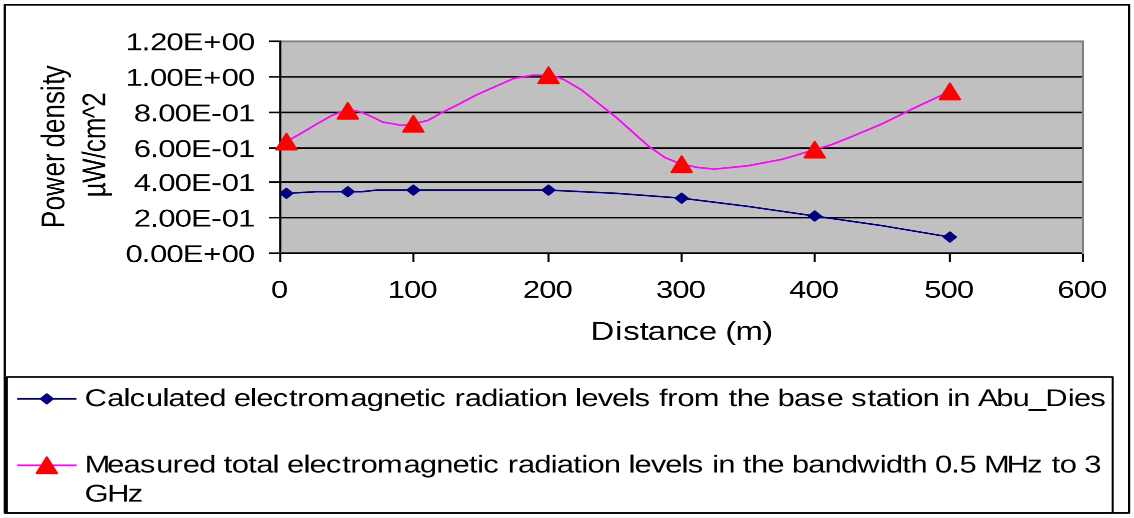

Figure (6.19): *Comparison between electromagnetic radiations levels resulted from the base station in Abu_Dies calculated along the main street (Al-Quds University) and measured total electromagnetic radiation in the bandwidth (0.5 MHz to 3 GHz).*

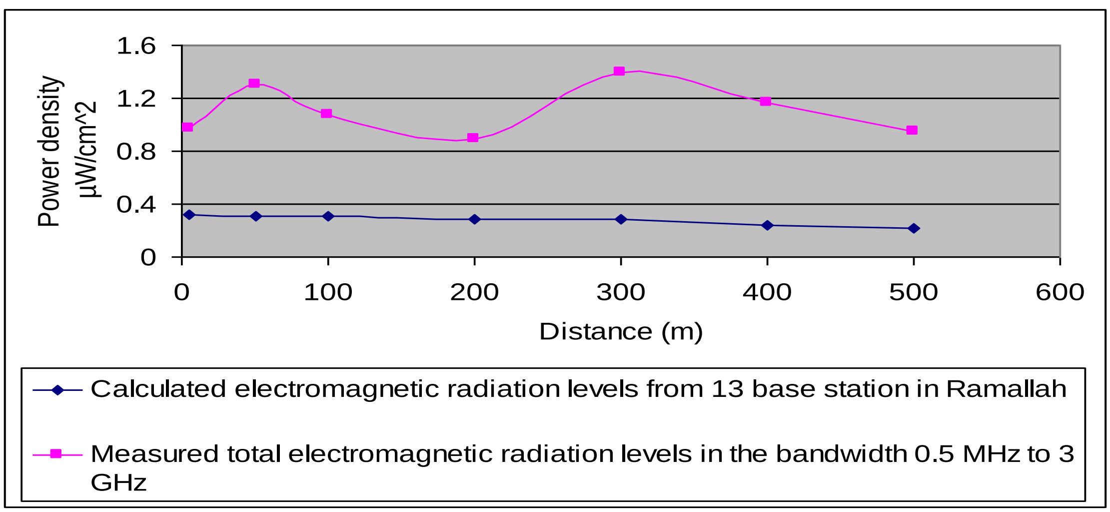

Figure (6.20): *Comparison between electromagnetic radiation levels resulted from 13 base stations in Ramallah city calculated along the main street (Rukab) and measured total electromagnetic radiation in the bandwidth (0.5 MHz to 3 GHz).*

6.5 Conclusions

A lot of progress has been done in this work, and we can conclude it as:

- The mobile phone Base Stations of Palestine cellular communications. Ltd (Jawwal) complies with the International Commission for Non-Ionizing Radiation Protection (ICNIRP) guidelines by large margins.

- The highest level of the power density estimated in this work in the West Bank is 1.66μW/cm^2. This level is more than 240 times below the ICNIRP maximum public exposure.

- The highest level of the power density estimated in the Gaza city is 0.085μW/cm^2. This value is 4705 times below the ICNIRP maximum permitted public exposure.

- As the ICNIRP guidelines are designed to provide for the full protection of everyone from the known adverse health effect at the maximum permitted public exposure values, and then when considering the very much lower estimated values, no harm should be expected to result to anyone living around Jawwal base stations or nearby to these sites.

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Appendix

Typical data used by RF_Map program showing the Power of antennae, type of antennae, tilt and azimuth of antennae for the investigated base stations in this work.

(1) Hebron City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
0	20	22	K 738819	270	عيصى
0	140	22	K 738819		
0	250	22	K 739624		
0	60	17	K 738819	150	تفوح
0	180	17	K 739624		
0	270	17	K 739624		
0	20	25	K 738819	270	راس الجوره
0	140	25	K 738819		
0	250	25	K 739622		
0	10	23	K 739635	300	مقسم جنوب الخليل
3	150	23	K 739624		
0	260	23	K 739624		
0	40	26	K 739622	180	جامعة الخليل
0	170	26	K 739632		
0	300	26	K 739635		
0	20	25	K 739622	180	بلدية الخليل
4	200	25	K 739632		
0	31	45	K 739624	150	المستشفى الأهلي
0	180	36	K 739635		
4	300	36	K 739635		

(2) Bethlehem City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
5	40	18	K 739160	180	ساحة المهد
5	150	18	K 739160		
0	280	20	K 739160		
6	40	30	K 739160	180	مقسم بيت لحم
0	160	30	K 739160		
0	290	30	K 739160		
5	40	24	K 739160	180	فندق بيت لحم
4	160	24	K 739160		
0	290	24	K 739160		
0	40	23	K 739624	180	الدهيشة
0	160	23	K 739624		
6	275	23	K 739624		
0	40	23	K 739624	150	بيت ساحور
4	180	23	K 739624		
2	280	23	K 739624		

(3) Jericho City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
6	70	30	K 738819	180	مقسم اريحا
6	190	30	K 738819		
0	310	30	K 738819		

(4) Ramallah City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
0	0	8	K 730619	300	مبنى الجوال
0	160	10	K 739622		
0	30	28	K 739635	180	المناره
0	140	28	K 739635		
7	280	28	K 739622		
0	30	28	K 739635	150	المصيون
0	140	28	K 739635		
0	280	28	K 739622		
0	70	25	K 739160	180	عمارة الزيتونة
3	130	25	K 739635		
4	340	25	K 739624		
3	80	20	K 738819	270	البيرة - عمارة حليمة القرعان
3	200	20	K 739635		
5	320	20	K 739635		
7	90	33	K 738819	240	مقسم رام الله
3	160	33	K 739635		
6	300	27	K 739635		
0	50	20	K 739635	270	مستشفى المستقبل
0	180	20	K 739635		
-2	300	20	K 739635		
0	150	17	K 739632	240	عين مصباح
0	280	18	K 739635		
7	340	19	K 739632	240	كفر عقب
0	190	19	K 739622		
7	340	19	K 739632	270	بطن الهوى
0	190	19	K 739622		
7	20	22	K 739635	180	مخيم قدورة
10	130	25	K 739632		
0	40	19	K 739620	240	عمارة كنعان
4	190	17	K 739632		
0	270	17	K 739632		
6	10	25	K 739622	150	فندق جراند برك – المصيون
7	120	25	K 739635		

(5) Tulkarem City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
4	0	19	K 739624	180	مكتب التربية و التعليم
0	90	19	K 739624		
6	170	19	K 739624		
0	40	25	K 739624	180	مقسم طولكرم
0	160	25	K 739624		
6	280	25	K 739624		

(6) Gaza City

Tilt	Azimuth	Height	*Antenna Type	Transmitters Power (Watt)	Area
40	40	6	K 739635	150	برج دو النورين، خلف سرايا غزة
160	40	6	K 739635		
280	40	4	K 739635		
40	30	4	K 739635	150	مقابل وزارة الاسكان، عمارة كساب
160	30	0	K 739635		
280	30	4	K 739623		
40	32	2	K 739635	120	شارع مستشفى العيون، برج وشاح
160	32	6	K 739635		
280	32	4	K 739635		
40	15	0	K 739632	120	غزة
160	15	0	K 739635		
280	15	0	K 739632		

(*) These antennae are manufactured by Katherine Company.

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Definitions

Antenna Gain: The increase in power transmitted by a directional antenna when compared to a reference antenna, which is usually an ideal isotropic antenna. Gain is a ratio of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength or the same power density at the same distance. Gain may be expressed in decibels (dB) or as a pure number.

Antenna: A device for radiating radiofrequency energy.

Averaging Time: The appropriate time period over which exposure is averaged for purposes of determining compliance with the exposure limits.

Contact Current: Current flowing between an energized, isolated, conductive (metal) object and ground through an electrical circuit representing the equivalent impedance of the human body.

Decibel (dB): Ten times the logarithm to the base ten of the ratio of two power levels …. $dB=10\ log_{10} P_1/P_2$).

EIRP (Effective Isotropically Radiated Power): This term applies to directional antennas. The power that would have to be transmitted by an isotropic antenna to produce the same power density at any given point along the directional antenna's axis. EIRP is the gain of a transmitting antenna multiplied by the net power delivered to the antenna from the connected transmitter.

Electric Field Strength: The force (E) on a stationary unit positive charge at a point in an electric field, measured in volt per meter (V/m).

Electric Field: The region surrounding an electric charge, in which the magnitude and direction of the force on a hypothetical test charge, is defined at any point.

Electromagnetic Radiation: The propagation of time-varying electric and magnetic fields through space at the velocity of light. For the purposes of this document, the frequency range of interest lies between 0 Hz and 300 GHz.

ELF (Extremely Low Frequency): Frequency below 300 Hz.

EMF: Electric, magnetic and electromagnetic fields.

Employer: Any person, firm, organization, or other legal entity having the overall responsibility for any work carried out in connection with the utilization of a source of electromagnetic radiation, such as a RF device.

ERP (Effective Radiated Power): The product of the power supplied to an antenna and its gain relative to a half wave dipole in a given direction.

Exposure: Exposure occurs when a person is subjected to electric, magnetic or electromagnetic fields, or contact or induced currents other than those originating from physiological processes in the body and other natural phenomena.

Far-Field Region: The space beyond an imaginary boundary, extending to infinity, around an antenna marking the beginning where the angular field distribution is essentially independent of the distance from the antenna. In this region the field has a predominantly plane wave character.

Field Strength: The magnitude of the electric or magnetic field, normally a root-mean-square (rms) value.

Frequency: The number of sinusoidal cycles made by electromagnetic waves in one second, expressed in terms of Hertz (Hz). 1 kHz = 1000 Hz, 1 MHz = 1000 kHz, 1 GHz = 1000 MHz

General Public Exposure: All exposure to EMF experienced by members of the general public excluding occupational exposure and exposure during medical procedures.

General Public: All persons other than those designated as RF workers.

ICNIRP: International Commission on Non-Ionizing Radiation Protection.

Induced Current: Current induced in a human body exposed to electromagnetic fields.

Isotropic Antenna: An antenna capable of radiating or receiving equally well in all directions, and equally responsive to all polarizations of electric and/or magnetic fields. In the case of transmitting coherent electromagnetic waves, an isotropic antenna does not exist physically, but represents a convenient reference antenna for expressing directional properties of an actual transmitting antenna.

Isotropic: Having the same properties in all directions.

JMPBSs: Jawwal Mobile Phone Base Stations.

Leakage Radiation: Any unintended or accidental radiation emitted by a RF device outside its external surface.

Magnetic Field Strength: An axial vector quantity (H) which specifies a magnetic field at any point in space, and is expressed in ampere per meter (A/m).

Magnetic Field: A region of space surrounding a moving charge (e.g. in a conductor) being defined at any point by the force that would be experienced by another hypothetical moving charge.

Magnetic Flux Density: A vector field quantity (B) that results in a force that acts on a moving charge or charges, and is expressed in tesla (T). The magnetic field strength and the magnetic flux density are related by a constant of proportionality called the *magnetic permeability* of value $4\pi \times 10^{-7}$, such that $\mathbf{B} = 4\pi \times 10^{-7}\,\mathbf{H}$. A magnetic field strength of 1 A/m is equivalent to a magnetic flux density of 1.257 µT. In describing a magnetic field for protection purposes, only one of the quantities B or H needs to be specified.

MBSFIP : Mobile Base Station Field Intensity Plotter software.

Microwave: For the purposes of this document, this applies to the portion of the electromagnetic spectrum which has a frequency range between 300 MHz and 300 GHz.

Multiple-Transmitter Environment: A situation where more than one transmitter contributes a significant exposure to RF radiation at the location being examined, even from RF transmitters not on the same site.

Near-Field Region: A region in the field of an antenna, located near the antenna, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point. The near-field region is further subdivided into the *reactive* near-field region, which is closest to the antenna and contains most or nearly all of the stored energy associated with the field of the antenna, and the *radiating* near-field region. If the antenna has a maximum overall dimension that is not large compared with the wavelength, the radiating near-field region may not exist. For most antennas, the outer boundary of the reactive near-field region is commonly taken to exist at a distance of one-half wavelength from the antenna surface.

Non-thermal Effect: Any effect of electromagnetic energy absorption not associated with or dependent upon the production of heat or a measurable rise in temperature.

Occupational Exposure: The exposure of workers to time varying electric, magnetic and electromagnetic fields as a direct and necessary requirement of their work.

Power Density: The rate of flow of electromagnetic energy per unit surface area, usually expressed in W/m^2 or mW/cm^2 or $\mu W/cm^2$.

Radiating Near-Field: That region of the field, which extends between the reactive near-field region and the far-field region, wherein radiation fields predominate and the angular field distribution is dependent upon distance from the antenna.

Radiofrequency (RF): For the purposes of this document, this applies to the portion of the electromagnetic spectrum, which has a frequency range between 300 Hz and 300 GHz.

Reactive Near-Field: That region of the field immediately surrounding the antenna wherein the reactive field predominates.

RF Device: For the purposes of this document, this includes any fixed machine, equipment or installation, which generates RF energy.

RF Facility: One or more radiofrequency transmitters owned, controlled or maintained by the same operator. In the case where a RF site has multiple RF transmitters, each operator is considered to have a separate facility at that same site.

RF Site: A fixed structure or area where RF facilities are placed.

RF Survey: The process of carrying out measurements using suitable equipment to perform any evaluation of the RF field strengths, induced and contact currents, in any accessible area on and around a RF site.

RF Transmitter: The RF device, which is used to generate and transmit radiofrequency electromagnetic radiation.

RF Worker: An employee who is exposed to RF radiation as a direct and necessary requirement of his/her work.

Scattering: The process that causes waves incident on discontinuities or boundaries of media to be changed in direction, frequency, phase or polarization.

Specific Absorption (SA): The radiofrequency energy absorbed per unit mass of body tissue, expressed in joule per kilogram (J/kg). Specific absorption is the time integral of specific absorption rate.

Specific Absorption Rate (SAR): The rate of radiofrequency energy absorbed per unit mass of body tissue, expressed in units of watts per kilogram (W/kg).

Transmitter Duty Cycle: For the purposes of this document, this is a measure of the temporal transmission characteristic of an intermittently transmitting RF transmitter, e.g. paging or mobile phone base stations) obtained by dividing the average transmission duration by the average period for transmissions. A duty factor of 1.0 corresponds to continuous operation.