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Al-Quds University

Radiation Levels from Microcell Mobile Telephony Base Stations in Bethlehem and Hebron Cities – Palestine

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Jerusalem – Palestine

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Dedication

To My Father's Soul

To My Beloved Family, Mother, Brothers, Wife, Sons, Daughters

To My Teachers

To my Friends

Declaration:

I certify that this thesis submitted for the degree of master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other University or Institution.

Signed:...

Raed Subhi Abdel Qader Ahmad

Date: 20 / 3 /2017

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First and for most, great thanks for Allah for all his blessing and for helping me to finish this wok.

My deep appreciation goes to my supervisors Dr. Adnan Lahham for his constant advice.

Abstract:

The general public through our region are concerned that exposure to Electromagnetic Radiation (EMR) from mobile telephones and their base stations could be hazardous to health, especially for the children and the peoples who live beside the base stations site. While there are guidelines on the limitation of human exposure to (EMR), little measurements have been done to evaluate compliance with the limits on exposure in the vicinity of base stations in Palestine, most of these measurements have been done for the macrocells base stations, while no measurements were done for the level of radiation from micro cells base stations. In response to public concerns, this study has been initiated at Al-Quds University.

The general objective of this study is to assess the electromagnetic radiation levels emitted from micro cells mobile base stations in Bethlehem and Hebron cites.

A database for microcells base station in Hebron and Bethlehem is supplied by the Palestine cellular communications Ltd (JAWWAL). This database includes information about 30 microcells base stations (sites, highest above ground and number of antennas). Digital maps were constructed for the sites of base stations in Bethlehem and Hebron cites.

The exposure to electromagnetic radiation levels generated due to these microcells base stations were measured and compared with the reference level advised by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Palestinian Environmental Quality Authority (EQA) standards for exposure of the general public.

This study present the radiation levels from 16 microcells mobile telephony base stations in Bethlehem and Hebron cities. Measurements of electric filed were at 200 locations around these microcells mobile base stations that belong to JAWWAL. All

measurements were conducted at a high of 1.7 m above the ground level corresponding to the head position of an average adult, over six minutes under real life conditions using selective radiation meter BK 2650 handhold spectrum analyzer. The results show that all stations are licensed by the EQA.

The result also illustrates that the maximum value for the electromagnetic radiation from microcell mobile telephony base stations was (8.51 mW/m^2) which represents (0.2%) of the reference level advised by the ICNIRP standards for exposure of the general public, but represents (4.5 %) of the reference level advised by the EQA exposure for the general public at the short stay sights only. The average of the electromagnetic radiation was (1.14 mW/m^2) which represents (0.02%) of the reference level advised by the ICNIRP, and 0.6% of the reference level advised by the EQA standards for exposure of the general public. In addition, the study shows that electromagnetic radiation levels are much lower than the exposure limit recommended by the international and Palestinian standards for the general public.

The study illustrates that there is infers relationship between the power density and the highest of the antennas, also there is a relationship between the power density and the direction of the measurement.

It has been noticed that there is a relationship between the electromagnetic radiation levels and the antenna heights at different distances for the microcells base station. The results also show that there is a relationship between the electromagnetic radiation levels and the direction with the bore sight for the antenna.

In general, exposure to EM radiation from Microcell Mobile Telephony Base Stations in Hebron and Bethlehem areas is below the recommended limits of and ICNIRP and EQA standards for exposure of the general public, so exposures that comply with the guidelines are not considered hazardous.

مستوى الإشعاع المنبعث من المحطات الميكرو خلوية
في مدينتي بيت لحم والخليل – فلسطين

إعداد: رائد صبحي عبد القادر أحمد

إشراف: د. عدنان اللحام

الملخص

لقد تزايد القلق لدى عامة الناس من احتمالات الضرر الناتج من الإشعاعات الكهرومغناطيسية المنبعثة من الهواتف النقالة ومحطاتها الخلوية وخصوصاً لدى الاطفال او من يسكنون بالقرب من هذه المحطات، ورغم وجود ارشادات ومعايير دولية ومحلية لحدود تعرض الافراد لتلك الإشعاعات الا ان عدد الدراسات التي قامت بقياس مستوى الإشعاع الناتج من محطات الهواتف الخلوية في فلسطين كانت قليلة جدا وكانت تركز فقط على دراسة المحطات الماكروخلوية في حين لم توجد حتى هذا التاريخ اي دراسة للمحطات الميكروخلوية واستجابة لاهتمام المواطنين، أجريت هذه الدراسة في جامعة القدس.

كان الهدف الرئيسي لهذه الدراسة تقييم مستوى الإشعاع المنبعث من المحطات الميكروخلوية في مدينتي بيت لحم والخليل، حيث تم بناء قاعدة بيانات خاصة بالمحطات الميكروخلوية في مدينتي الخليل وبيت لحم بناءً على معلومات تم الحصول عليها من شركة الاتصالات الخلوية الفلسطينية – جوال. وتحتوي قاعدة البيانات معلومات عن (30) محطة ميكروخلوية وقد شملت هذه المعلومات (الموقع، الارتفاع عن سطح الارض، عدد الباعثات المتصلة بالمحطات). اضافة الى ذلك تم بناء خريطة تحدد مواقع المحطات التي تم استهدافها بالقياس.

تم قياس مستوى الإشعاع المنبعث من المحطات الميكروخلوية وتم مقارنته بمجموعة من المعايير مثل سلطة جودة البيئة، منظمة الصحة العالمية والمنظمة الدولية للحماية من الاشعة غير المؤينة. تعرض هذه الدراسة نتائج قياس شدة الإشعاع المنبعث من (16) محطة مايكرو خلوية للهواتف النقالة التابعة لشركة جوال الفلسطينية في منطقتي بيت لحم والخليل، تم قياس شدة المجال الكهربائي في (200) موقع بالقرب من هذه المحطات الميكرو خلوية ثم حساب وتقدير كثافة القدرة لشدة الإشعاع المنبعث منها على ارتفاع (1.7) متر عن سطح الأرض، وهو متوسط ارتفاع رأس الإنسان البالغ، كانت مدة القياس في كل نقطة (6) دقائق باستخدام جهاز BK 2650 handhold spectrum analyzer.

أظهرت نتائج الدراسة أن جميع المحطات الميكروخلوية تلبي الشروط الفنية التي وضعت من قبل سلطة جودة البيئة والمنظمات الدولية المختصة بهذا المجال، لكن لا يوجد أي من الإشارات التحذيرية أو الإرشادية بالقرب من هذه المحطات.

أظهرت النتائج أيضاً أن القيمة العظمى لشدة الإشعاع من المحطات المايكرو خلوية للهواتف النقالة كانت (8.51 ملي واط/م^2) وهذه القيمة تمثل (0.2%) من الحد الأعلى المسموح به حسب معايير اللجنة الدولية للوقاية من الإشعاعات غير المؤينة (ICNIRP) كما أنها تساوي (4.5%) من الحد الأعلى المسموح به حسب معايير سلطة جودة البيئة (EQA) للمحطات التي توفر التغطية لمناطق الحركة فقط مثل الشوارع. أما متوسط كثافة شدة الإشعاع حول المحطات الميكروخلوية فكانت (1.14 ملي واط / م^2) وهي تمثل (0.02%) من الحد الأعلى المسموح به حسب معايير اللجنة الدولية للوقاية من الإشعاعات غير المؤينة (ICNIRP)، كما أنها تساوي (0.6%) من الحد الأعلى المسموح به حسب معايير سلطة جودة البيئة (EQA). لقد أظهرت

الدراسة أن مستوى شدة الإشعاع المنبعث من المحطات الميكروخلوية أقل بكثير من الحد الأعلى المسموح به حسب المعايير الدولية والفلسطينية.

لوحظ من خلال الدراسة وجود علاقة بين مستوى الإشعاع المنبعث من المحطات الميكروخلوية وارتفاع الباعثات المرتبطة بها وهي علاقة عكسية، كما أظهرت النتائج وجود علاقة بين مستوى الإشعاع الكهرومغناطيسي المنبعث من المحطات الميكروخلوية والاتجاه.

لقد خلصت الدراسة بشكل عام إلى أن التعرض للأشعة الكهرومغناطيسية المنبعثة من المحطات الميكروخلوية للهواتف النقالة في منطقتي الخليل وبيت لحم أقل من الحد الأعلى المسموح به من قبل سلطة جودة البيئة ومنظمة الصحة العالمية واللجنة الدولية للوقاية من الإشعاعات غير المؤينة (ICNIRP). لذلك فإن التعرض لهذه الإشعاعات لا يشكل أي نوع من الخطر على سلامة الانسان في هذه المناطق.

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Symbol	Description
E	Electric Field Strength
EQA	Environmental Quality Authority
GSM	Global System for Mobile Communication
H	Magnetic Field Strength
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ITU	International Telecommunication Union
RF	Radio Frequency
WHO	World Health Organization
S	Electromagnetic Power Density
NMT	Nordic Mobile Telephony
TACS	Total Access Communication System
AMPS	Advanced Mobile Phone System
MOA	Mobile Operators Association
BCCH	Broadcast Control Channel
FCC	The United States Federal Communication Commission
TDMA	Time Division Multiple Access
EMR	Electromagnetic Radiation
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
MPE	Maximum Permissible Exposure
SAR	Specific Absorption Rate
CDMA	Code Division Multiple Access
WLAN	Wireless local area network
NTRA	National Telecom Regulatory Authority
ECC	Electronic communications committee
CEPT	European Conference of Postal and Telecommunications Administrations.

Chapter (I)

Introduction

1.1Wireless communication

Cellular wireless telephones have become ubiquitous. Over the last years, the total number of mobile-broadband subscriptions in developing countries is expected to reach 3.6 billion by end of 2016 (I T U, 2016). In some parts of the world, mobile phones are the most reliable or the only phones available (WHO, 2014).Wireless technology is based on extensive networks of base stations that connect users through radiofrequency (RF) signals. The radio waves used in mobile telephony are, like visible light and X-rays, electromagnetic waves that consist of both an electric and a magnetic component which vary periodically in time. The frequency of variation determines the wave properties and uses (Abdelati, 2005). Radio waves, which can be used for various types of communication are found in the lower part of the spectrum and classified as non-ionizing radiation (Walke, 1999).

Usually, base stations are more numerous in populated areas than in non-populated ones to serve as many users as possible while maintaining high service quality (viel, J. et al, 2009).

The early mobile telephony systems such as Nordic Mobile Telephony (NMT), Total Access Communication System (TACS), and Advanced Mobile Phone System (AMPS), use analog telephony while newer systems such as Global System for Mobile (GSM) use digital technology. GSM system operates in either the 900 MHz or 1800 MHz bands. The 900 MHz band is utilized in Palestine; only 24 channels are allocated for Jawwal Company (Palestinian Territories, 2009).

Digital systems have several advantages compared with analog systems: for example, higher user capacity, increased privacy, lowers power consumption, and better immunity to interference (John Wiley & Sons Ltd, Chichester, 1999). The GSM is adopted in Palestine by tow Companies, Jawwal and Al Watanya. The overall system is made up of a network of radio base stations, each of which covers a certain geographical area (called a cell) and which together provide coverage for a larger area.

1.2 Mobile telephone Base stations

The base stations, which continuously send and receive signals, are linked by cable or radio links to the fixed network via mobile exchanges that direct traffic and keep track of where in the network each activated mobile telephone is located (John Wiley & Sons Ltd, Chichester, 1999). The cells are grouped into clusters. The number of cells in a cluster must be determined so that the cluster can be repeated continuously within the covering area. The typical clusters contain 4, 7, 12 or 21 cells. The total number of channels per cell depends on the number of available channels and the type of cluster used.

1.3 Types of Base Stations

There are many different types of cells base stations used by operators. The cells vary in size depending on the density of mobile phone users, purpose of the site and the topography of the surrounding area rather than in terms of technical constraints such as radiated powers or antenna heights (El-Wasife, 2010).

The largest cells are known as macrocells. Smaller cells, particularly those in urban areas, can be classified as microcells or picocell. The definition of the different cell categories provided by the Mobile Operators Association are given below.

1.3.1 Macrocell base station:

provides the main coverage in a mobile network. The antennas are mounted on ground-based masts, rooftops and other existing structure. They must be positioned at a height that is not obstructed by surrounding building and terrain as shown in figure (1). Macrocell base stations have a typical power output of tens of watts. (MOA, 2003).

Figure (1): Macro cell base station

1.3.2 Microcells base station:

provide infill radio coverage and additional capacity where there are high numbers of users within microcells. The antennas for microcells are mounted at street level, typically on the external walls of existing structure, lamp posts and other street furniture as shown in figure (2). The antennas are smaller than macro cells antennas. Typically, microcells provide coverage across smaller distances than the macrocell, and are placed 300-1000 m apart as shown in figure (4). They have lower outputs than macrocells, usually a few watts. (MOA, 2003)

Figure (2): Micro cell base station

1.3.3 Picocell base station:

provides more localized coverage than a microcell. They are normally found inside buildings where coverage is poor or where there are a high number of users, such as airport terminals, train stations or shopping centers as shown in figure (3).

Figure (3): Pico cell base station

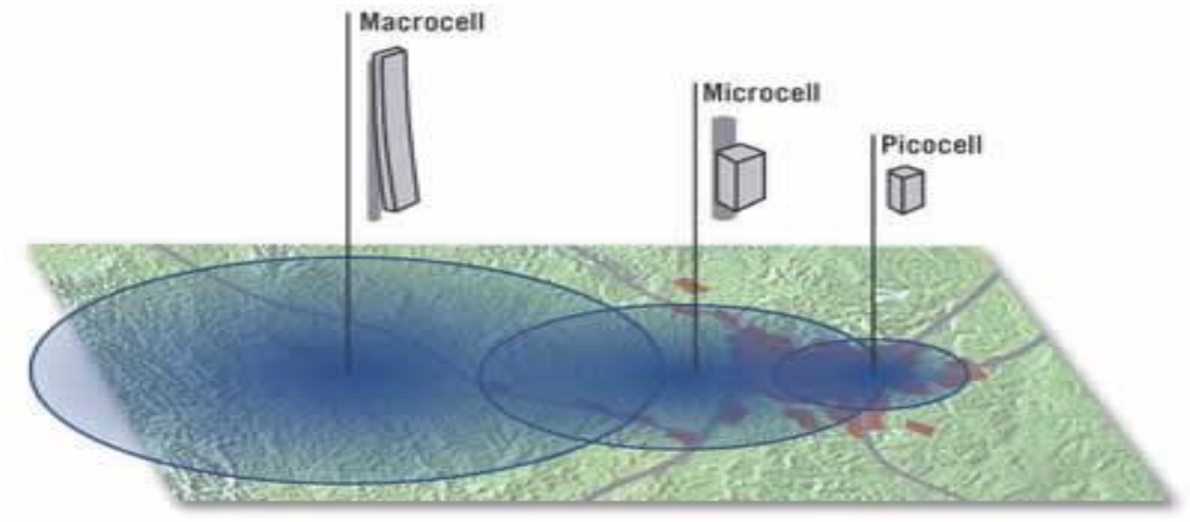


Figure (4): Coverage area of the three types of stations. (MOA, 2013)

1.4 Work principle for microcell base station:

When a mobile phone is switched on, it responds to specific control signals from nearby base stations. When it has found the nearest base station in the network to which it subscribes, it initiates a connection. The phone will then remain dormant, just occasionally updating with the network, until the user wishes to make a call or a call is received. Mobile phones use automatic power control as a means of reducing the transmitted power to the minimum possible whilst maintaining good call quality. For example, while using a phone the average power output can vary between the minimum levels of about 0.001 watt up to the maximum level which is less than 1 watt. This feature is designed to prolong battery life and possible talk time (El-Wasife, 2010).

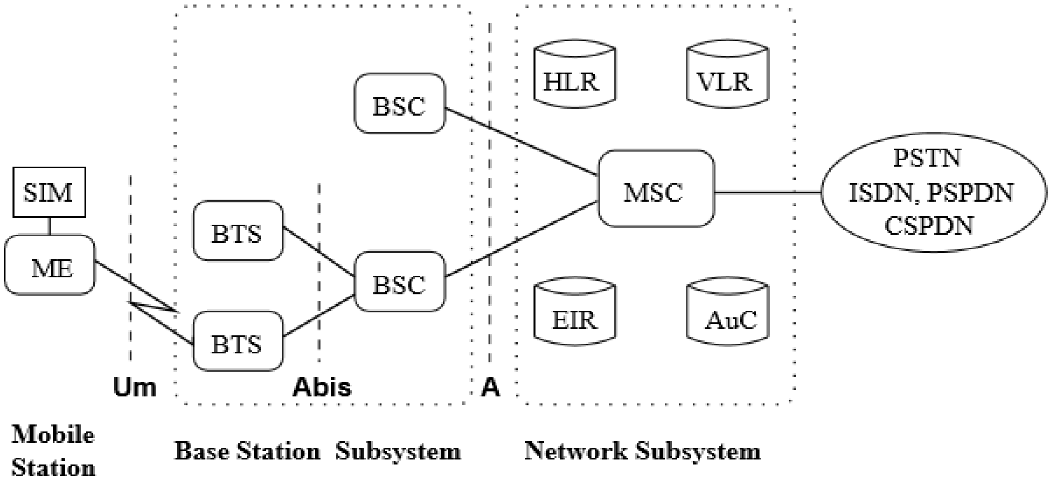
1.5 Architecture of the GSM network:

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure (5) shows the layout of a generic GSM network. The GSM network can be divided into three broad sections. The Mobile Station is carried by the subscriber. The Base Station Subsystem controls the radio link with the Mobile

Station. The Network Subsystem, the main part of which is the Mobile services Switching Center, performs the switching of calls between the mobile and other fixed or mobile network users, as well as handling mobility management. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the **Um** interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.

1.5.1 Mobile Station

The mobile station (MS) consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, allowing the user to have access to subscribed services irrespective of a specific terminal. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services. The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information. The International Mobile Equipment Identity (IMEI) and the International Mobile Subscriber Identity (IMSI) are independent, thereby allowing personal mobility. The SIM card may be protected against unauthorized use by a password or personal identity number.



SIM Subscriber Identity Module ME Mobile Equipment

BTS Base Transceiver Station MSC Mobile services Switching Center

EIR Equipment Identity Register AUC Authentication Center

BSC Base Station Controller HLR Home Location Register

VLR Visitor Location Register Abis: Automated Biometric Identification Systems

Figure (5): Architecture of a GSM network

1.5.2 Base Station Subsystem

The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). These communicate across the standardized Abis interface allowing (as in the rest of the system) operation between components made by different suppliers. The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio link protocols with the Mobile Station. In a large urban area, there will potentially be a large number of BTSs deployed, thus the requirements for a BTS are ruggedness, reliability, portability, and minimum cost. The Base Station Controller manages the radio resources for one or more BTSs. It handles radio channel setup, frequency hopping, and handovers, as described below. The BSC is the connection between the mobile station and the Mobile services Switching Center (MSC).

1.5.3 Network Subsystem

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the Public Switched Telephone Network (PSTN) or Integrated Services Digital Network (ISDNM) and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. These services are provided in conjunction with several functional entities, which together with the MSC form the Network Subsystem. The MSC provides the connection to fixed networks, such as the PSTN or ISDN. Signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7) used for trunk signaling in ISDN and widely used in current public networks.

The Home Location Register (HLR) and Visitor Location Register (VLR) together with the (MSC) provide the call routing and roaming capabilities of (GSM). The HLR is a database that contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the SS7 signaling address of the VLR associated with the mobile station. There is logically one HLR per GSM network, although it may be implemented as a distributed database.

The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although each functional entity can be implemented as an independent unit, all manufacturers of switching equipment to date implement the VLR together with the MSC, so that the geographical area controlled by the MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. Note that the MSC contains no information about particular mobile stations; this information is stored in the location registers.

The other two registers are used for authentication and security purposes. The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where each mobile station is identified by its International Mobile Equipment Identity IMEI. An IMEI is marked as invalid if it has been reported stolen or is not type approved. The Authentication Center (AuC) is a protected database that stores a copy of the secret key stored in each subscribers SIM card, which is used for authentication of the subscriber, as well as encryption over the radio channel

1.5.4 Multiple access and channel structure

The GSM system operates in either the 900 MHz or 1800 MHz band. The 900 MHz band is utilized in Palestine by Palestine cellular company (Jawwal). This band is divided into two regions: The uplink band (890 MHz to 915 MHz) which is used by the mobile phones and the downlink band (935 MHz to 960 MHz) which is used by base stations. Each link band is divided into 200 KHz channels, thereby, providing 124 channels for communications and one needed for technical reasons. Out of the 124 channels, only 24 are allocated for Jawwal Company, while the rest are reserved for other networks. The signals transmitted by Jawwal base stations are within the frequency band 955.2 MHz to 960 MHz while the signals transmitted by Jawwal mobile phones are within the frequency band 910.2 MHz to 915 MHz.

The microcells base station transmitted one radio signal q uasi-continuously and this known as the Broadcast Control Channel (BCCH) carrier because it carries important signaling information that is used to set up calls. The BCCH carrier can also serve up to seven mobile phone calls simultaneously, so it may give sufficient capacity for base station in a lightly loaded area. Where there is the potential need for more than seven phone calls at the same time, a base station can be configured to transmit extra carriers (non-BCCH) carriers, each allowing the base station to provide a further eight mobile phone calls (Mann et al, 2000).

GSM base station use Time Division Multiple Access (TDMA) within each radio carrier so base station communicates with any given mobile phone by sending out 217 frames of information every second. Each frame is divided into eight timeslots of 0.58 ms duration and each timeslot is used for the downlink to a particular mobile phone. The BCCH carrier is transmitted at full power in all eight timeslots, even when no calls are being handled, whereas the non- BCCH carriers (if available) are only transmitted when calls are present.

1.6 Problem Statement

Study of the EM radiation levels from microcell mobile telephony base station is one of the most important topics for many reasons:

First of all the dramatic increase in mobile phone usage in recent years especially with the falling cost, causes the rapid growth in the number of mobile phone subscribers. Consequently, mobile phone base stations have become a common sight at the cities. **Secondly**, very limited information is available on the exposure of general public to RF radiation emitted from microcells base station in residential areas, because most of studies and researches focus on macro cells base station.

Finally, most of peoples still believe that there is a strong relationship between the mobile base station and the dangerous health effects such as cancer, so they refused to have those stations around the neighborhood, or even closer to their surroundings. Based on this assumption we will study EM radiation levels emitted from the microcells base stations and compare it with the exposure limits recommended by Palestinian Protocol, International Commission on Non Ionizing Radiation Protection (ICNIRP), World Health Organization (WHO) to figure out rightness of such belief.

1.7 Objectives

The present study aims to:

1. Measure the level of radiation emitted by microcells mobile base stations in Bethlehem and Hebron cites**.**
2. Compare the radiation measurements with Palestinian Protocol and (WHO), (ICNIRP) standard for human exposure to EM radiation.
3. Determine the relationship between the heights of mobile phone base stations and the level of radiation.
4. Determine the relationship between the direction with the boresight of the antenna of the base stations and the level of radiation.

1.8 Hypotheses

Taking into consideration, the set objectives, questions and variables of the study, the following hypotheses were proposed:

1. There are no statistically significant differences at $\alpha \leq 0.05$ in the power density scores of the sampled population by base station.
2. There are no statistically significant correlation at $\alpha \leq 0.05$ between the high of antenna and the power density scores of the sampled population.
3. There are no statistically significant differences at $\alpha \leq 0.05$ in the power density scores of the sampled population by angle (direction) with the bore sight.

1.9 Literature review

1) Cooper, T G et al. (2004).

Twenty GSM base stations in the UK were selected at random from a group of 3000 that had low antenna height and radiated low power, in accordance with the accepted characteristics of microcell and picocell base stations. A compliance distance in terms of the reference level advised by ICNIRP for exposure of the general public was determined for the antenna of each of the selected base stations, based on technical information provided by the network operators. Under conservative assumptions, the minimum height at which the reference level could potentially be exceeded at any of the sites is 2.4 m above ground level.

On the basis of the results of the measurements and calculations carried out for the twenty selected microcell base stations, members of the public would not be exposed in excess of the ICNIRP guidelines whilst standing on the ground at any of the sites. Exposures were generally in the range 0.002-2% of the ICNIRP general public reference level, and the greatest exposure quotient near any of the base stations was 8.6%. Exposures close to microcell base stations were found to be generally greater than those close to macrocell base stations. Exposures that comply with the guidelines are not considered hazardous.

2) Mann, S M et al. (2000). Spectral measurements were obtained over the 30 MHz to 2.9 GHz range at 73 of the locations so that total exposure to radio signals could be assessed. The geometric mean total exposure arising from all radio signals at the locations considered was 2 millionths of the NRPB investigation level, or 18 millionths of the lower ICNIRP public reference level; however, the data varied over several decades. The maximum exposure at any location was 230 millionths (0.023%) of the

NRPB investigation level, or 1800 millionths (0.18%) of the ICNIRP reference level. The exposures are therefore well within guidelines and not considered hazardous.

3) Koprivica, M. Petric, N. Neskovic, A. Neskovic. Statistical Analysis of Electromagnetic Radiation Measurements in the Vicinity of Indoor Microcell GSM/UMTS Base Stations in Serbia.

In order to determine the level of radiofrequency radiation generated by base stations of Global System for Mobile Communications and Universal Mobile Telecommunication System, extensive electromagnetic field strength measurements were carried out in the vicinity of 664 base station locations, which were classified into 3 categories: indoor, masts and locations with installations on buildings. Although microcell base stations with antennas installed indoors typically emit less

power than the outdoor macrocell base stations, the fact that people can be found very close to the antennas requires the exposure originating from these base stations to be carefully considered. Measurement results showed that the maximum recorded value of electric field strength has exceeded International Commission on Non-Ionizing Radiation Protection reference levels at 7% of indoor base station locations. At the same time this percentage was much lower in the case of masts

and installations on buildings (0% and 2.5%, respectively).

4) Khatib, M. (2014): Evaluation of Electromagnetic Radiation Safety from Wireless Transmission Systems in Tulkarm City – Palestine. Palestine Technical University – Kadoorie, Palestine (International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 10, April 2014

Electromagnetic fields of all frequencies represent one of the most common and fastest growing environmental influences, about which anxiety and speculation are spreading. There is a general concern on the possible hazardous health effects of exposure to these radiations. This paper aims to measure radiofrequency radiation levels from different wireless systems at the same time and to compare the results with the recommended limits by the International Commission on Non-Ionizing Radiation Protection (INCRIP) and the World Health Organization (WHO), and to develop a radiation scale for the city of Tulkarm to determine the dangerous places (if found) and give recommendation to the society. After taking 150 readings from all over Tulkarm city in the frequency range 100 KHz to 3GHz, all the readings were below1.6uw/cm2, which are below the limits of radiations recommended. Most of the readings in tested area (62% of the area) were below 0.1uw/cm2, which are > 4500 time less than the maximum allowed level (450uw/cm2), which is equivalent to less than 0.022% of that level.

5) Lahham, A, Hammash, A (2011):This work presents the results of exposure levels to radio frequency (RF) emission from different sources in the environment of the West Bank—Palestine. These RF emitters include FM and TV broadcasting stations and mobile phone base stations. Power densities were measured at 65 locations distributed over the West Bank area. These locations include mainly centers of the major cities. Also a 24 h activity level was investigated for a mobile phone base station to determine the maximum activity level for this kind of RF emitters. All measurements were conducted at a height of 1.7 m above ground level using hand held Narda SRM 3000 spectrum analyzer with isotropic antenna capable of collecting RF signals in the frequency band from 75 MHz to 3 GHz. The average value of power density resulted from FM radio broadcasting in all investigated locations was 0.148 $\mu W\ cm^{-2}$, from TV

broadcasting was 0.007 μW cm^{-2} and from mobile phone base station was 0.089 μW cm^{-2}. The maximum total exposure evaluated at any location was 3.86 μW cm^{-2}. The corresponding exposure quotient calculated for this site was 0.02. This value is well below unity indicating compliance with the International Commission on non-ionizing Radiation protection guidelines. Contributions from all relevant RF sources to the total exposure were evaluated and found to be ∼62 % from FM radio, 3 % for TV broadcasting and 35 % from mobile phone base stations. The average total exposure from all investigated RF sources was 0.37 μW cm^{-2}.

6)Yassin et al., (2010): has levels of exposure to electromagnetic fields from mobile phones base-stations in Khartoum - Khartoum Nort. The measurements for the field strength and the power density were taken in some selected locations with special focus on busy streets, squares and other public places such as bus stations, student hostels and hospitals during February 2008. Measurements were carried using the reliable and most advanced monitoring device (Spectran HF 4040). Measured Power density was found to lie between a minimum value of $4.9 \times 10{-}7$ W/m^2 and a maximum of 0.025 W/m^2 and which is quite small compared to the international standard limits like those adopted by The International Commission on Non- Ionizing Radiation Protection (ICNIRP) which is 4.5W/m^2 for the public and 22.5W/m^2 for those professionals involved in telecommunications industry. Since strict adherence to national safety standards will protect everyone in the population, further research is recommended on the subject along with setting of Sudanese standards to cover different aspects of the issue namely local climatic conditions, quality & specifications of base-stations and total exposure. It is worth mentioning that other countries have their own standards and specifications in the field.

7) Abdelati, (2005): has studied Electromagnetic radiation from mobile phone base stations at Gaza, It aims to highlight relevant international work and develop computer tools which simplify estimating and measuring EMF levels in our city. The implemented software package stores the base stations parameters and coordinates in a data base and then generates tables and maps that illustrate EMF levels estimated theoretically. Moreover, it can communicate with a measuring device and store actual measurements in the database so that it is used to generate maps and tables. It is found that real measurements are consistent with Theoretical ones and they are much lower than the exposure limit recommended by the international health organizations.

Chapter (II)

Assessment of the electromagnetic radiation

2.1 Electromagnetic radiation:

An electromagnetic wave consists of two components - electric and magnetic field as shown in figure (6). The electric field results from the force of voltage, the higher the voltage, the stronger will be the resultant electric field, and the magnetic field results from the flow of current, the greater the current, the stronger the magnetic field.

Electromagnetic radiation may be considered as a series of waves of energy composed of oscillating electric and magnetic fields that travel through space with the speed of light (Irwin, 2002).

Electric field is perpendicular to magnetic field and both are perpendicular to the direction of the propagation of the electromagnetic wave as represented in figure (6).

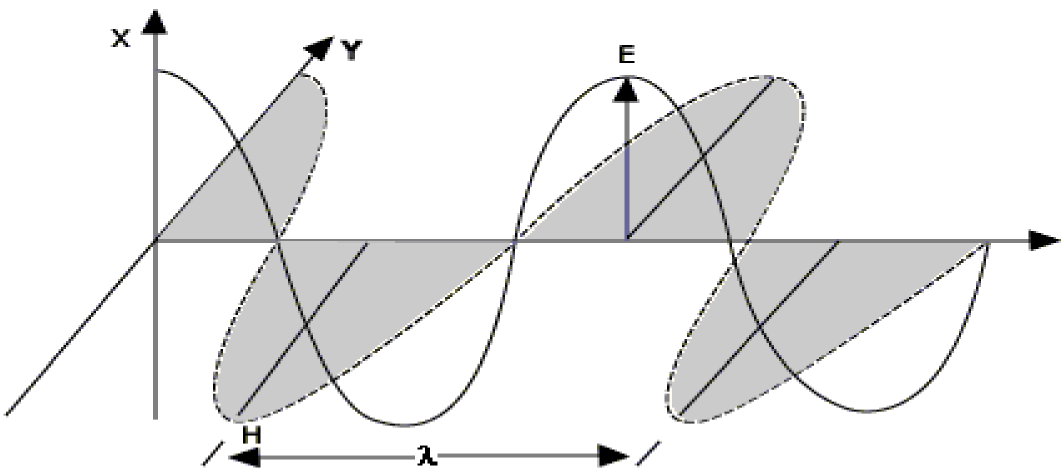


Figure (6): Two components of the electromagnetic wave.

2.2 Types of the electromagnetic radiation

In general Electromagnetic radiation can be classified into two main types according to the frequency ionizing and non-ionizing radiation (Ministry of communication- India, 2012).

2.2.1 Ionizing Radiation

Ionizing radiation is capable of stripping electrons from atoms and breaking chemical bonds, creating highly reactive ions (atoms or molecules that have an electric charge. Radioactive materials, those that contain atoms that have unstable nuclei, occur naturally and emit ionizing radiation in a process known as radioactive decay.

The most common types of ionizing radiation are alpha particles(α), beta particles(β), gamma rays(γ), and $X - rays$. The particles and rays cannot be seen, heard, tasted, smelled, or felt, which is why ionizing radiation remained undiscovered until the late 1800 even though many ordinary materials emit small amounts.

Natural sources include the soil, water, air, food, and building materials. Man-made devices such as $X - rays$ machines also produce ionizing radiation. Potential sources include nuclear accidents involving medical or industrial nuclear material or terrorist actions involving nuclear devices (USUHS, 2014).

The electromagnetic spectrum that represents the ionizing and nonionizing radiation is illustrated in figure (7).

2.2.2 Non-Ionizing Radiation

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight. Global positioning systems (GPS), cellular telephones, television stations, FM and AM radio, baby monitors, cordless phones, garage-door openers, and ham radios use non-ionizing radiation. Other forms include the earth's magnetic field, as well as magnetic field exposure from proximity to transmission lines, household wiring and electric appliances.

These are defined as extremely low-frequency waves (USUHS, 2014). The lower part of the frequency spectrum is considered Non-ionizing (Fluor Corporation, 2005).

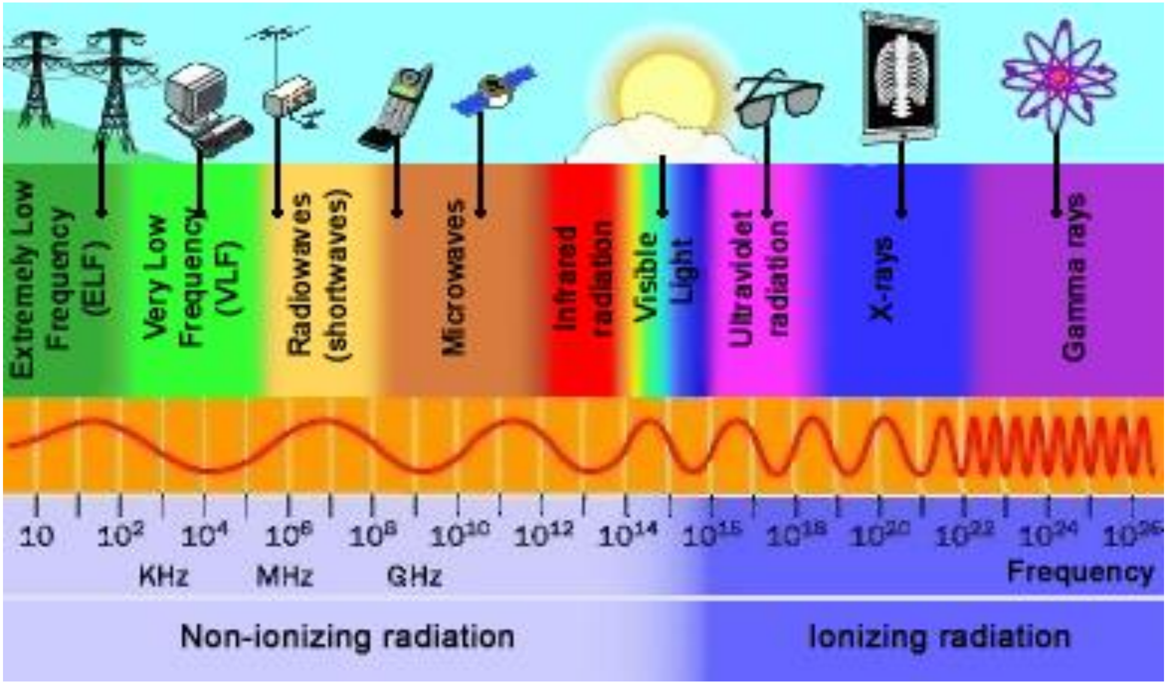


Figure (7): Electromagnetic spectrum (Fluor Corporation, 2005).

2.2.2.1 Radiofrequency radiation:

Radiofrequency radiation is part of the non – ionizing electromagnetic radiation; probably the most important use for RF radiation is in providing telecommunications services. Radio and television broadcasting, cellular telephones, radio communications for police and fire departments, amateur radio, microwave point-to-point links, and satellite communications are just a few of the many telecommunications applications. Microwave ovens are a good example of a no communication use of RF radiation.

People are exposed to RF radiation in many ways. The primary natural source of radiofrequency fields is the sun. Manmade sources are the main source of RF radiation exposure (WHO, 2008). Wireless communications sources have increased greatly in recent years and there is continuing change in the frequencies used and variety of application. However, the most prevalent and rapidly growing exposure is related to the increasing use of mobile telephones base station.

2.3 Beam Shapes and Directions from antenna:

The antenna used in base station is either of the Omni or sectored type as shown in figure (8). Omni antennas transmitting a signal over a large area in all directions or receiving signals in all directions in the horizontal plane as shown in figure (9). While sector antennas effectively only radiate in a specified direction in a horizontal sector as shown in figure (10). In addition to this horizontal directionality, the antenna lobe will also have a strong vertical directionality, with a fairly narrow beam, which is often tilted slightly downward as shown in figure (10), (Kitchen, 2001).

A tri-sectored site has antennas mounted in an equilateral triangle pattern to illuminate three different cells. The effect of sectorisation increase the re-use of frequencies, since it reduce interference. Most base station in high traffic density areas such as cities are of the sector type. The exposure behind a sector antenna could be 300 times weaker than in the main lobe (Ramsdale and Wiener, 1999).

Omni antenna

sector antenna

Figure (8): Omni and sector antennas

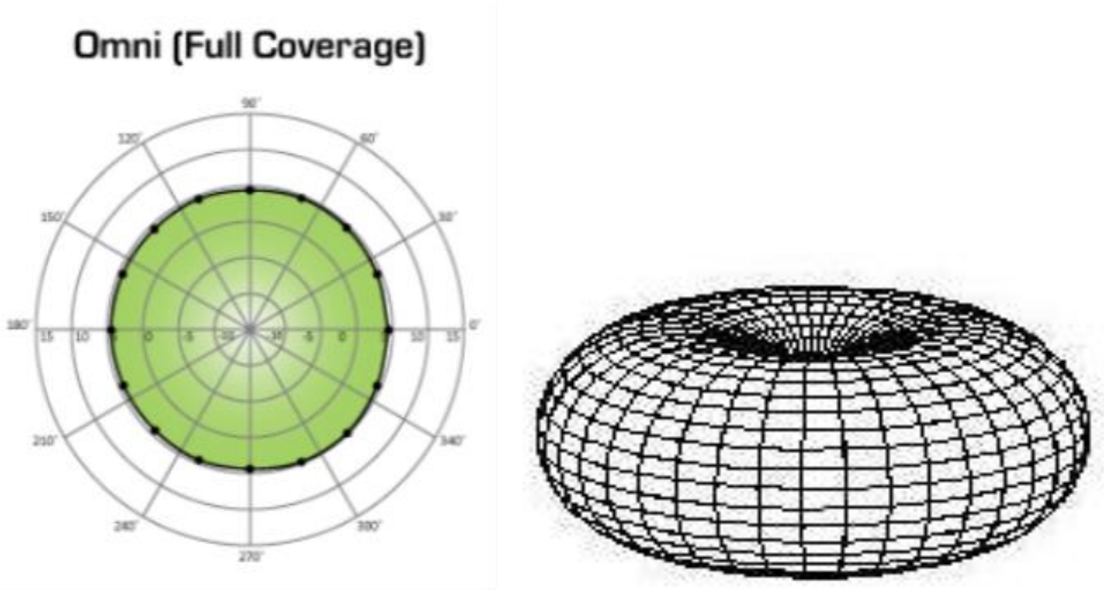


Figure (9): Direction of main radiation from Omni antenna

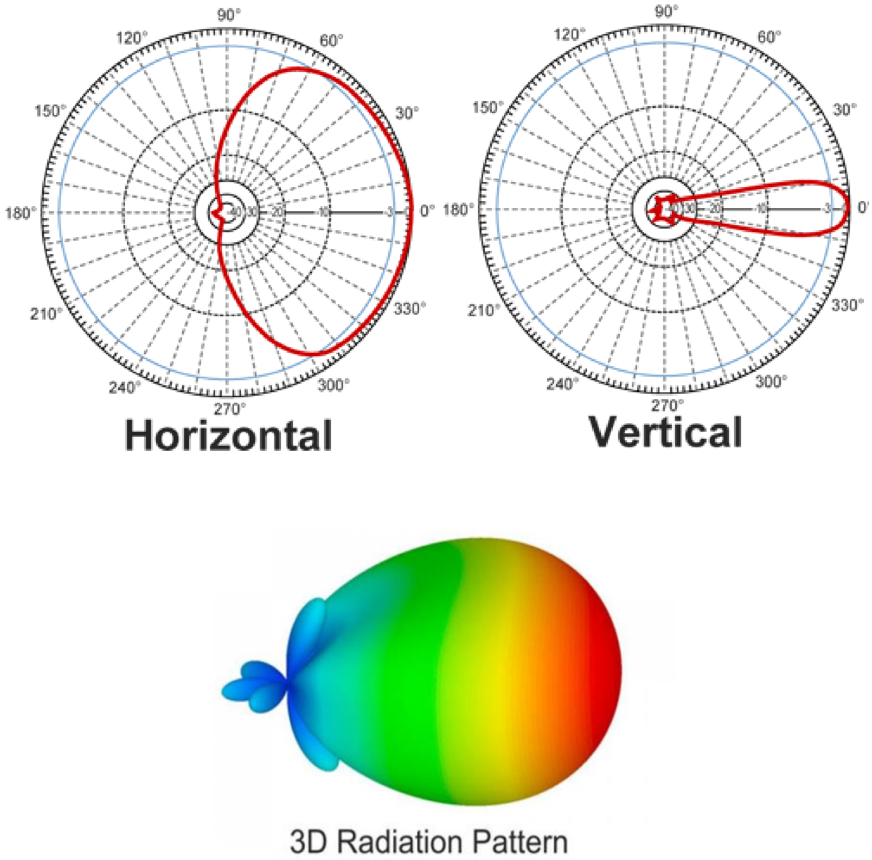


Figure (10): Horizontal and vertical direction of main radiation from sector antenna

The power from antennas used with microcell base stations is radiated in conical fan-shaped beams, which are essentially directed towards the horizon with a slight downward tilt. This is illustrated in figure (11) below and it causes the radio wave strengths below the antennas and at the base of masts to be very much lower than directly in front of the antennas at a similar distance (MOA, 2013).

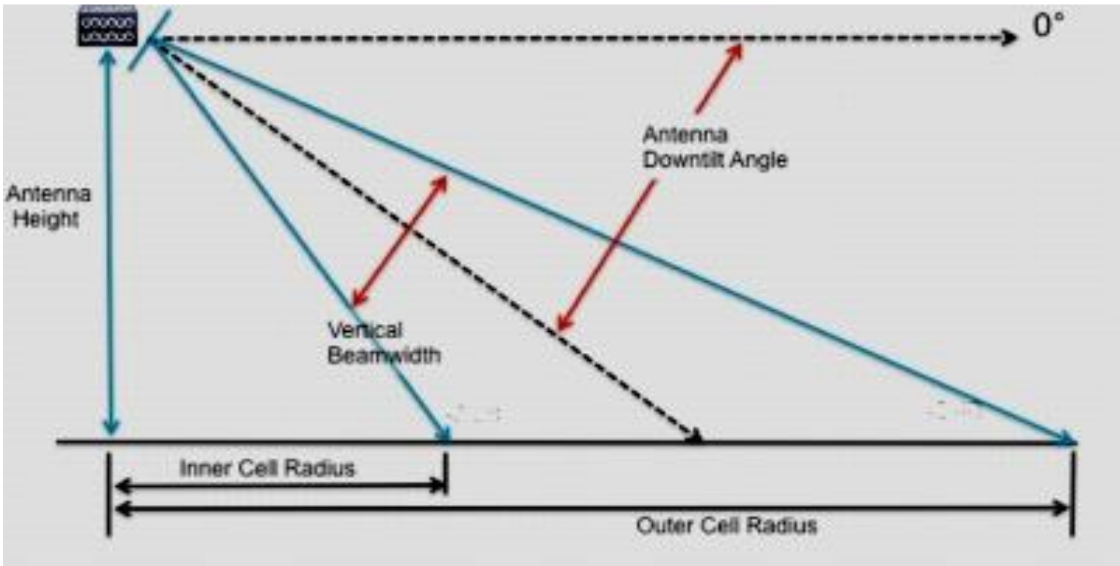


Figure (11): Beam shape and direction (MOA, 2013)

2.4 Guidelines for Exposure to Electromagnetic Radio waves:

To control the amount of Electromagnetic energy emitted from mobile base stations and hence reduce its consequences on human health, guidelines, practices and recommendations have been initiated by government agencies and international organizations.

The most known guidelines are those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998) and the Institute of Electrical and Electronics Engineers (IEEE, 2005). The standard established by ICNIRP as shown in table (1) is adopted mainly in West Europe while The IEEE standard for EM radiation exposure, called "Maximum Permissible Exposure" (MPE), as shown in table (2) is adopted mainly in the United States and also in some other countries.

Table (1): ICNIRP reference levels for occupational and general public exposure to EMF in the frequency range from 10MHz to 300GHz.

	Frequency	EF strength (V/m)	M F Strength (A/m)	Power density (W/m^2)
Occupational	10-400 MHz	61	0.16	10
	400-2000 MHz	$3\ f^{1/2}$	$0.008f^{1/2}$	f/40
	2-300 G Hz	137	0.36	50
General public	10 -400 MHz	28	0.073	2
	400-2000 MHz	**$1.375\ f^{1/2}$**	**$0.0037f^{1/2}$**	**f/200**
	2-300 GHz	61	0.16	10

f is the frequency in MHz

The variation of the levels specified for radiation levels as function of frequency is shown in figure (12). The ICNIRP reference level for exposure of the general public is five times below the occupational reference level.

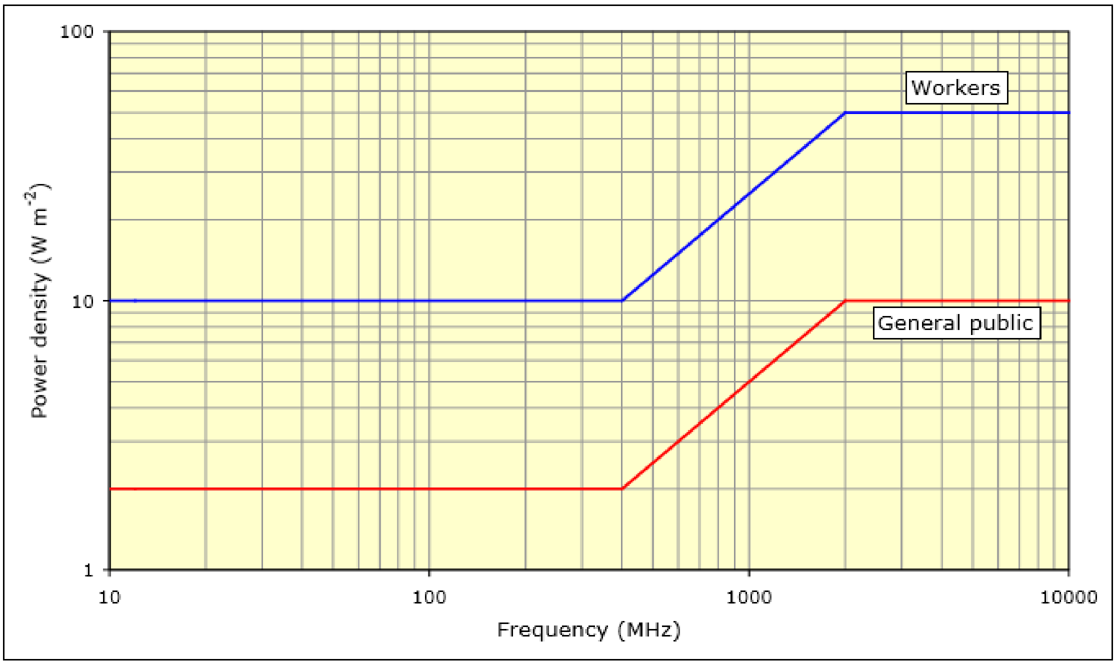


Figure (12): Variation of the ICNIRP reference levels of E M radiation levels as a function of frequency

Table 2: IEEE reference levels for occupational and general public exposure to EM radiation in the frequency range from 300 - 3000MHz.

	Frequency (MHz)	Power density (mW/cm^2)
Occupational	300 - 3000	*f*/300
General public	300 - 3000	*f*/1500

The reference levels of the Belgian exposure to EM radiation in the frequency range from 10MHz to 10GHz summarizes by Table (3).

Table 3: Belgian standard for exposure to EM radiation

Frequency	Power density (W/m2)	Electric Field (V/m)
10 MHz – 400 MHz	0.5	13.7
400 MHz – 2 GHz	f/800	$0.686\ f^{1/2}$
2 GHz – 10 GHz	2.5	30.7

The reference levels of the Palestinian exposure to EM radiation in the frequency range from 400- 2000 MHz established by Palestinian Environmental Quality Authority "Ministerial Decree No. (1) for the year 2009, on the granting of environmental approval for the establishment and operation of Cell broadcast that issued by the President of the Environmental Quality Authority" summarizes by Table (4)

Table (4): Palestinian Standard for RF radiation Exposure

	Time of Stay	Frequency (MHz)	Power Density (W/m^2)
General Public	Prelonged Stay	400 - 2000	(1/250)*(f/200)
	Short Stay		(1/25)*(f/200)
Occupational	Prelonged Stay		(1/250)*(f/40)
	Short Stay		(1/25)*(f/40)

Such organizations set guidelines which restrict the amount of electromagnetic energy dissipated in the human body. These limits are provided for both general public and personnel working on site (occupational) limits. The occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. By contrast, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals.

In many cases, members of the public are unaware of their exposure to EMR. Moreover, individual members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underlie the adoption of more stringent exposure restrictions for the public than for the occupationally exposed population.

Due to the fact that the environment for workers can somewhat be controlled, occupational exposure limit is generally higher than non-occupational (public) exposure limit in all international protection standards.

2.5 General statement on safety factors

There is insufficient information on the biological and health effects of EMR exposure of human populations and experimental animals to provide a rigorous
basis for establishing safety factors over the whole frequency range and for all frequency modulations. In addition, some of the uncertainty regarding the appropriate safety factor derives from a lack of knowledge regarding the appropriate dosimetry. The following general variables were considered in the development of safety factors for high-frequency fields:

1. Effects of EM radiation exposure under severe environmental conditions such as high temperature and high activity levels.
2. The potentially higher thermal sensitivity in certain population groups, such as the frail and/or elderly, infants and young children, and people with diseases or taking medications that compromise thermal tolerance.

The following additional factors were taken into account in deriving reference levels for high-frequency fields:

1. Differences in absorption of electromagnetic energy by individuals of different sizes and different orientations relative to the field.
2. **2.** Reflection, focusing, and scattering of the incident field, which can result in enhanced localized absorption of high-frequency energy. (Repacholi 1998)

2.6 Basic restrictions and reference levels

Restrictions on the effects of exposure are based on established health effects and are termed basic restrictions.

Depending on frequency, the physical quantities that used to specify the basic restrictions on exposure to EMF are current density, Specific Absorption Rate (SAR), and power density. Protection against adverse health effects requires that these basic restrictions are not exceeded. Reference levels of exposure are provided for comparison with measured values of physical quantities; compliance with all reference levels given in these guidelines will ensure compliance with basic restrictions. If measured values are higher than reference levels, it does not necessarily follow that the basic restrictions have been exceeded, but a more detailed analysis is necessary to assess compliance with the basic restrictions.

Different scientific bases were used in the development of basic exposure restrictions for various frequency ranges:

1. Between 1 Hz and 10 MHz, basic restrictions are provided on current density to prevent effects on nervous system functions.
2. Between 100 kHz and 10 GHz, basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating; in the 100 kHz–10 MHz range, restrictions are provided on both current density and SAR.
3. Between 10 and 300 GHz, basic restrictions are provided on power density to prevent excessive heating in tissue at or near the body surface.

Currently existing standards and guidelines (e.g. ICNIRP, IEEE C95.1) take a rate at which RF electromagnetic energy is absorbed in the body, i.e. Specific Absorption Rate (SAR) as a dosimetric quantity. For a pulsed environment an absorbed energy density (Specific Absorption - SA) is applied only for special kinds of exposure: it is either an exposure to a single pulse or when there are less than five pulses with a pulse-repetition period of less than 100ms. (IEEE C95.1, 1991), or to pulses of duration less than 30 ms. If the unit SAR is to be applied, measurement results have to be averaged over 6 minutes. In practice, it is impossible to perform direct measurements of SAR. Therefore, recommended measurement practice introduced exposure levels in terms of unperturbed electric and magnetic field strength in the near field and power density in the far field, in addition to absorbed energy units. Where appropriate, the reference levels are obtained from the basic restrictions by mathematical modeling and by extrapolation from the results of laboratory investigations at specific frequencies. They are given for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection as shown in table (5).

Table 5: Basic restrictions for time varying electric and magnetic fields for Frequencies up to 10 GHz. (ICNIRP, 1998)

Exposure characteristics	Frequency range	Current density for head and trunk(mA m-2)	Whole-body average SAR (W kg-1)	Localized SAR (head and trunk) (W kg-1)	Localized SAR (limbs) (W kg-1)
occupation	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	*f*/100	—	—	—
	100 kHz–10 MHz	*f*/100	0.4	10	20
	10 MHz–10 GHz	–	0.4	10	20
General public	up to 1 Hz	8/*f*	—	—	—
	1–4 Hz	2	—	—	—
	4 Hz-1 kHz	*f*/500	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	—	0.08	2	4
	10 MHz–10 GHz	—	0.08	2	4

2.7 Effects of Radio Frequency Radiation (RFR)

RF radiation exposure from both mobile phones and mobile towers may have possible thermal/non-thermal effects caused by holding Mobile phones close to the body. More the use of mobile phone, higher will be the temperature increase of ear lobes (Ministry of communication, India, 2012).

Exposure to RF radiation can increase the body temperature by heating of tissues. This is known as the thermal effect. There is some discussion about other effects caused by RF radiation other than by thermal effect. However, no evidence is established yet.

The scientific community and international bodies agree that further research is needed to improve our understanding in some of these areas. At the moment, there is insufficient and inconclusive scientific findings to prove any adverse health effects caused by RF radiation (El-Wasife, 2010).

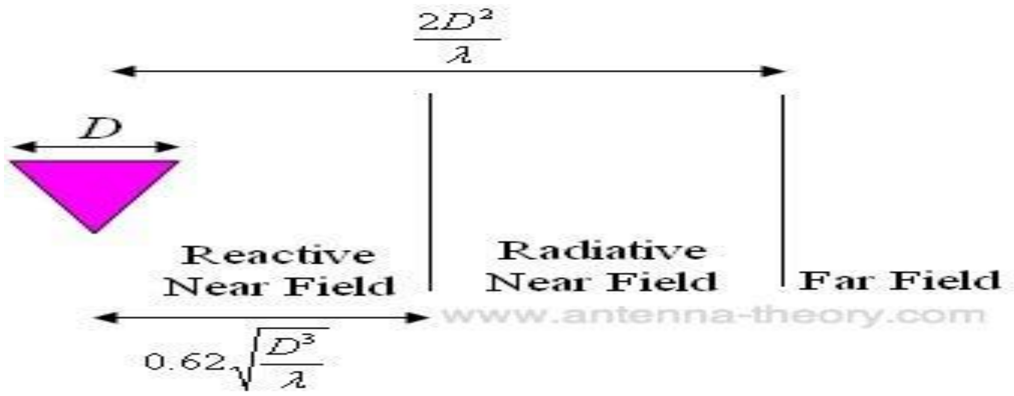
2.7.1 Thermal Effect

A biological tissue will be heating as a consequence of microwave energy absorption by the tissue's water content. The amount of heating produced in a living organism depends on the power density of the radiation which it has penetrated the tissue, electrical properties of the bio matter, and the efficiency of the body's thermoregulation mechanism. Effects on health ensue once the temperature rise exceeds about 1°C. Safety guidelines impose upper limits on the radiation power density to ensure that this does not happen. Heating occurs whether the organism is alive or dead.

2.8 RF Exposure assessment.

Radio wave consists of electric and magnetic field that oscillate sinusoidally at a specific frequency and travel through space as shown in figure (6). At a sufficient distance from the source, beyond the reactive near field, the electric and magnetic fields oscillate in time phase and in directions that are both mutually orthogonal and orthogonal to the direction of propagation. At mobile phone frequencies, the reactive near field exists only within a few centimeters of the source.

In the case of microcell base stations, distances greater than about 1 m from the antenna are in the far field (Fraunhofer region), where the angular distribution of radio wave emitted by the antenna is essentially independent of distance. The region in between a few centimeters and 1 m from the antenna is known as the radiating near field (Fresnel region), in which the angular distribution of the radio waves depends on distance as shown in figure (13).



D = largest dimension of source. λ=wavelength (33 cm for 900 MHz).

Figure (13): Illustration of three zones: reactive near field, radiative near field, far field and its consequences for exposure assessments.

The power density **S** at distance beyond the reactive near field is related to the electric field strength **E** and the magnetic field strength **H** by simple relation

$$S = E\,H \qquad (1)$$

The ratio between electric field strength and magnetic field strength is constant beyond the reactive near field. In free space the ratio is known as the intrinsic impedance of free space Z_0 and takes the value 377 **Ω**. Consequently, equation (1) may be rewritten:

$$S = \frac{E^2}{377} = 377H^2 \qquad (2)$$

The power density may thus be determined from the electric or magnetic field strength a lone. Many commercial instruments make use of this relationship by measuring the electric or magnetic field strength and converting the output to provide a display of plane-wave equivalent power density.

2.8.1 Theoretical exposure assessment:

More than one method has been proposed for the theoretical prediction of the power density of radio waves transmitted by antenna associated with mobile phone base stations. These methods range from the simplest of calculations that assume free – space conditions to sophisticated computer modeling techniques that take into account detailed three-dimensional representation of the environment (Cichon, 1999)

The propagation models considered bellow are based on the assumption that the exposure occurs in the far field of the base station of antenna. The location said to be in the far field of antenna providing the distance **r** between the location and the antenna satisfies the expression:

$$\mathbf{r} > \frac{2\,D^2}{\lambda} \qquad (3)$$

Where:

r: is the distance from the antenna**.**

D: is the greatest linear dimension of the antenna.

λ: is the wavelength.

2.8.1.1 Propagation of radio waves in free space

In free space, the power density $\mathbf{S_0}$ of radio waves reduces with increasing distance from a hypothetical isotropic radiator following the inverse-square law:

$$\mathbf{S_0 = \frac{P_t}{4\pi r^2}} \qquad (4)$$

Where $\mathbf{P_t}$ is the power radiated from the antenna. Real antenna direct power preferentially in certain directions at the expense of reduced power in other directions. Many antennas concentrate power into single main beam, which is emitted in the forward, or boresight direction. The degree of concentration of power is expressed by the antenna gain, the greater the gain, the smaller the angular divergence of the main beam.

The power density in the boresight direction, i.e. In the center of the main beam is given by the expression:

$$S_0 = \frac{P_t G_t}{4\pi r^2} \quad (5)$$

Where G_t is the arithmetic Gain (dimensionless) of the antenna in the boresight direction. The gain, and therefore the power density, in other directions will be reduced by a factor that depends on the radiation pattern of the antenna.

Free space conditions are not the realistic situation for the propagation of radio waves transmitted by mobile phone base stations. Radio waves can be reflected by the ground and diffracted, reflected and scattered by buildings, trees, street furniture and other structures in the environment. So we must consider the effects of the environment on the variation of power density, so we can define path loss.

Path loss can be defined by considering two antennas, one transmitting and one receiving that is situated in free space. The power P_r received by the later antenna is governed by the Friis free space equation:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi r)^2} \quad (6)$$

Where G_r is the gain of the receiving antenna.Equation (6) neglects losses that are not directly related to the separation between the antennas, such as refraction or absorption by the atmosphere. The ratio of received power to transmitted power is known as the path loss.

We can evaluate the free space path loss L_0 by the following equation:

$$L_0\,(dB) = -20\log_{10}\left[\frac{\lambda}{4\pi r}\right] \qquad (7)$$

Derivation of path loss from models based on assumption about the environment that are more credible than free space condition can be used to estimate power density **S** more realistically using the formula:

$$S = S_0 10^{-(L-L_0)/10} \qquad (8)$$

$$S = \frac{4\pi P_t G_t 10^{-L/10}}{\lambda^2} \qquad (9)$$

Where **L** is the path loss (in dB) evaluated using the chosen model.

2.8.1.2 Two- ray ground reflection model

In many physical situations the direct (free-spaces) path between the transmitter and receiver is only one of the numbers of propagation paths that may exist. Often, in the cases where the environment is relatively uncluttered and there is a direct line of sight between the receiving antenna and the transmitting antenna, the two most important paths are the direct path and a second path that arises from a single reflection from the ground. This scenario can be examined on the basis of geometric optics using the two-ray ground reflection model, described by *inter alia* (Bacon ,1996) and (Kagoshima et al ,2001). The two-ray model has been found to be reasonably accurate for predicting the large-scale signal strength for line-of-sight microcell channels in urban environments (Rappaport, 2002).

The geometry of the two-ray model is depicted in figure (14). The direct path has length r_1 and the path undergoing reflection from the ground has length r_2

Where $r_2 = r_a + r_b$

The difference in path lengths $\Delta r = r_2 - r1$ is given by the expression

$$\Delta r = \sqrt{d^2 + (h_t + h_r)^2} - \sqrt{d^2 + (h_t - h_r)^2} \qquad (10)$$

Where h_t is the height of the transmitting antenna above ground level, h_r is the height of the receiving antenna at the measurement position and d is the horizontal distance between them. If (d) is much greater than $h_t + h_r$ then equation (18) can

be expanded to $\Delta r = \frac{2h_t h_r}{d}$

So the total rms electric field strength at the receiving antenna is

$$E = \sqrt{E_1^2 + E_2^2 - 2E_1E_1 \cos{(\Delta\Phi)}} \qquad (11)$$

Where E1 and E2 are the rms electric field strength of the direct and reflected wave

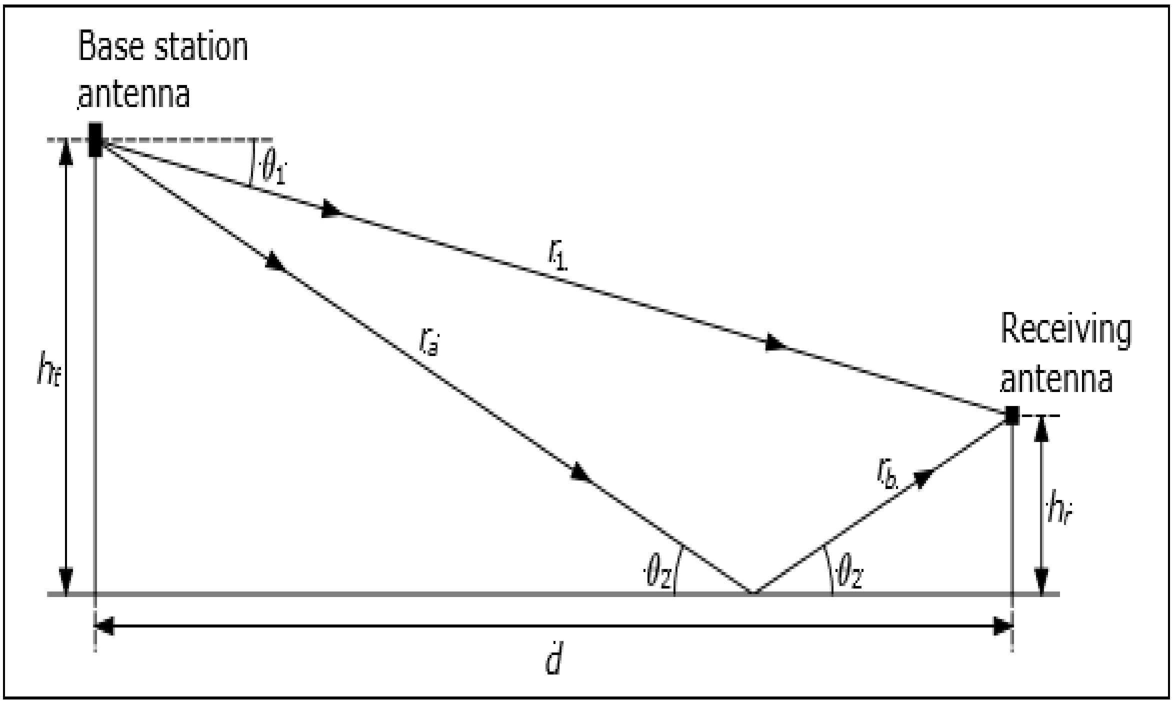


Figure (14): Two - ray ground reflection model

Respectively and $\Delta\Phi$ is the phase difference between the two paths, which may be given in terms of the wave number ***k*** such that

$$\Delta\Phi = k\ \Delta r = \frac{2\pi\Delta r}{\lambda} \qquad (12)$$

So equation 20 may be written

$$E = E_1 \sqrt{1 + [\frac{r_1}{r_2}]^2 - 2[\frac{r_1}{r_2}]\cos(\Delta\Phi)} \qquad (13)$$

Chapter III

Methodology

3.1 Study Area

This study was conducted in selected sites in Hebron and Bethlehem cites, Hebron city is located in the southern part of the West Bank –Palestine, on latitude of 31:31' in the north and longitude of 35:8' in the east. Hebron city is about 35 kilometers south of Jerusalem and extend over an area about 45 km^2. The city is highly populated with more than 200,000 people. It is the most populated city in the west bank. Bethlehem is located in the southern part of the West Bank –Palestine, on latitude of 31:42' in the north and longitude of 35:12' in the east. Bethlehem city is about 15 kilometers south of Jerusalem and extend over an area about 25 km^2. (Palestinian Central Bureau of Statistics, 2008).

The location of Hebron and Bethlehem cities at the historical Palestine map is shown in figure (15) (Palestinian Central Bureau of Statistics, 2016).

3.2 Data Collection about Microcells Mobile Base Stations In Hebron And Bethlehem Cities.

For a microcell base station, a database giving details (location, height, power, frequency, and antenna gain) for all antennas located in Bethlehem and Hebron city was supplied by the Palestine cellular communications ltd. (Jawwal) company. These databases include information about 16 microcells base stations. Watanya mobile base stations are excluded because the company did not use the microcell base station until now.

Digital map was constructed for microcells mobile base stations in Bethlehem city as shown in figures (16) and in Hebron city as shown in Figure (17)

Figure (15): Location of the study area (Palestinian Central Bureau of Statistics, 2008)

Figure (16): Locations of Microcell mobile telephony base stations in Bethlehem city

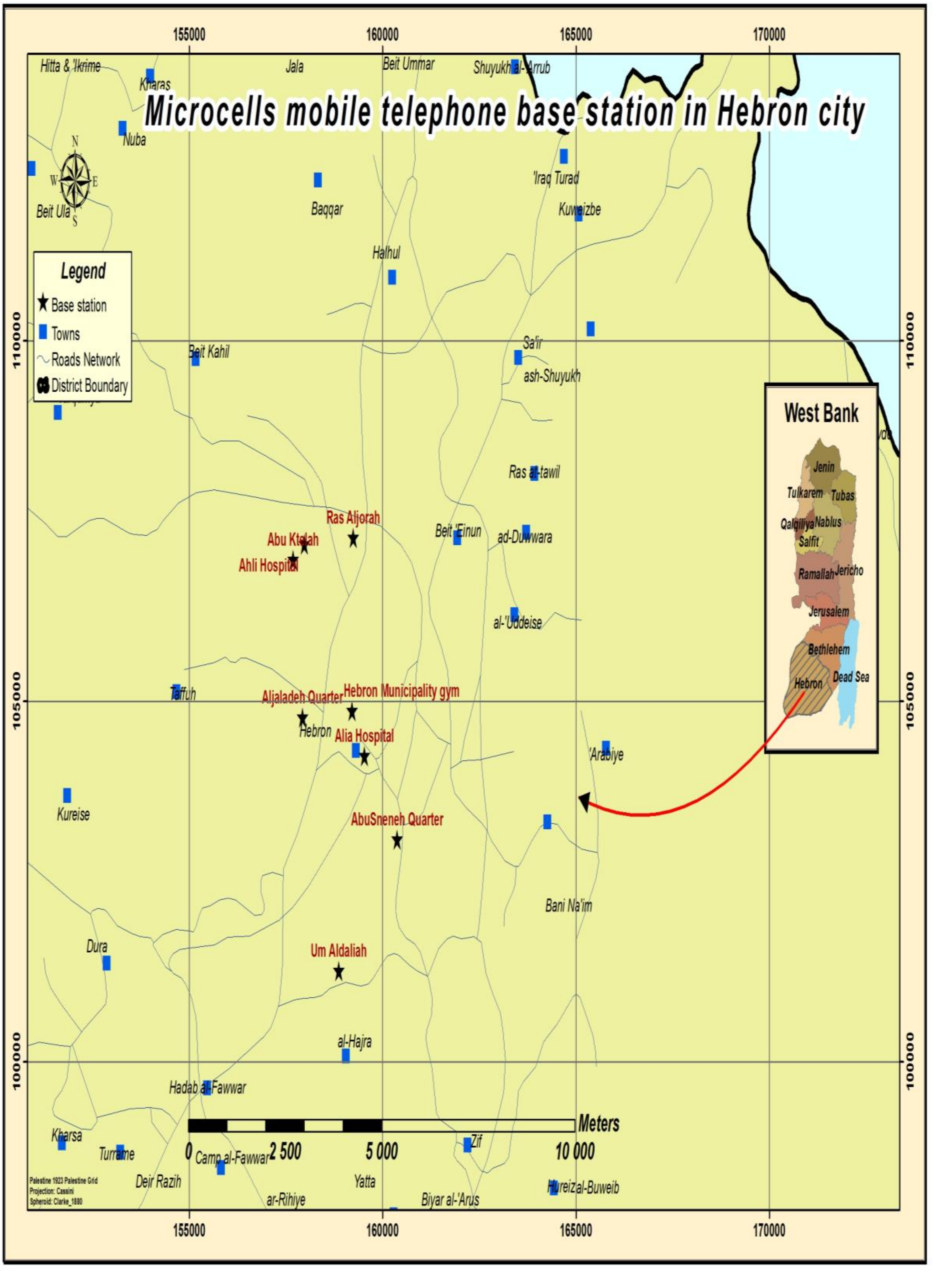


Figure (17): Locations of Microcell mobile telephony base stations in Hebron city

3.3 Instruments

In this work, frequency selective measurements are performed using a selective radiation meter BK 2650 handheld spectrum analyzer are used in measuring the power density of RF radiated from the microcells base stations in the region under investigation.

Brief description of the instrument is given below:

3.3.1 Handheld 3.3GHz Spectrum Analyzer (Model 2650)

The BK 2650 handheld spectrum analyzer is high-performance spectrum analyzers providing excellent performance and functions perfect for many different applications, figure (18). It is a compact, lightweight and inexpensive unit that is ideal for testing CDMA, GSM, WLAN and Bluetooth systems.

Features:

- Adjacent channel power measurement.
- Occupied bandwidth measurement.
- Electric field strength measurement.
- Magnetic field strength measurement.
- Marker measurement
- Peak search
- Save/Load

Figure (18): Handheld 3.3GHz Spectrum Analyzer (Model 2650**)**

Deferent antennas can be used with BK 2650 they are:

- AN301 BK Precision AN301 Dipole Antenna (0.8 to 1) GHz
- AN302 BK Precision AN302 Dipole Antenna (1.25 to 1.65) GHz
- AN303 BK Precision AN303 Dipole Antenna (1.7 to 2.2) GHz
- AN304 BK Precision AN304 Dipole Antenna (2.25 to 2.65) GHz
- AN305 BK Precision AN305 Dipole Antenna (390 to 410) MHz

3.4 Environmental Specifications and Conditions for Mobile Phone Micro Cells Stations

1. Upon installing micro cells stations the distance between them and human beings enough.
2. It is permissible to install mobile phone micro cell antennas of the type installed outside buildings, on facades, walls, billboards, street lighting columns, any towers or separate columns.
3. It is permissible to install micro cell stations of the type installed inside the buildings on the ceilings, hall or corridor walls.
4. In case of installing micro cell stations in places or buildings that contain control and monitoring devices, it must be ensured that those stations would not affect the performance level of the devices, by coordinating with mobile network operators and the entity controlling the site.
5. It is permissible to install linking devices on walls, ceilings or the antenna pylons with no maximum limit for the number of devices on the same pylon. In case this is not applicable, it is permissible to install the linking devices on separate pylons with no minimum limit of the height thereof.
6. The network operators are advised to consider artistic and aesthetical aspects while installing the stations on buildings facades in streets, inside shops, hotels etc.
7. On installing stations, the network operators are advised to comply with the international and Palestinian technical standards and verify safety and security of electric connections, as they undertake full responsibility thereof.

3.5 Methodology and design

The study is a quantitative research study using a selective radiation meter BK2650 handhold spectrum analyzer, which is appropriate to the exploratory nature of the research.

3.6 Sampling

The overall sample composed of sixteen stations (200 locations) at Southern of West Bank, in Bethlehem and Hebron cities purposively selected, that is, Fawaghreh, Bab Al-Der, Reem Al-Bawady, Wady Rahall, Murad Restaurant, Ras Al-Dalih, Al-Khalil Sport, Al-Ahly Hospital, Abu Katela, Ras Al-Jorah, Arab Society, AlHalman, Central Market, Al Jaldeh, Abu Snaneh and Alia Hospital.

3.7 Measurement technique and data processing:

The electric field (E) of the BCCH carrier transmitted by the microcells base station of interest was measured at 200 locations distributed around the 16 base station sites in Bethlehem and Hebron Cites. Most of the measurement locations were outdoors at height 1.7m above ground level corresponding to the head position of average adult (Schmid et al, 2007). The power density then estimated by using the equation No. 2. One of the main objectives of this work was to investigate the variation of power density with distance from microcell antennas. For this reason, wherever possible, series of measurements were made along one horizontal axis. The axes were chosen such that they permitted measurements at a number of locations along a straight line with an obstruction-free line-of sight path to the microcell antenna. So that estimated power density for each station were performed at 10 to 14 locations in the boresight direction, the distance between each two locations was 1 m and were accessible to the general public using.

Estimated power density is performed for the signals in the frequency range from 955 to 960 MHz, the frequency that belong to Jawwal Company. The RF radiation levels were averaged over approximately 6 minutes interval in all cases by using the selective radiation meter BK 2650 handhold spectrum analyzer.

Far field estimation is conducted at a distance of approximately 1 m from devices (microcell mobile telephony base station). (Schmid et al, 2007). So that a separation of usually at least 1 m was maintained from walls, street furniture and any other structures that offered the potential for mutual coupling with the probe or antenna.

The power density levels were expressed in (mW/m^2) and the electric field levels are given in (V/m).

The measurement technique for this study was based on the “variable frequency band scan” method described in Electronic Communications Committee (ECC) Recommendation (02)04 (CEPT, 2002), published by the (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT). At least one procedure was devised for implementation with the narrowband instrumentation to determine the power density due to the base station of interest. The procedure governed the measurement of the time-averaged power density due to the BCCH carrier transmitted by the microcell base station. This allowed the estimation of the maximum power density from the microcell base station.

When using the selective radiation meter the BK 2650 handhold spectrum analyzer was deployed with its “maximum “detection method selected. The frequency was set to 900 MHz and the analyzer was operated in 200 MHz span. The resolution bandwidth was set to 300 KHz in order to optimize detection of the BCCH carrier whilst avoiding detection of adjacent channels. The sweep time was set to 0.1 second manually.

Validation of the measurements proceeded in involved the implementation of a pilot study (N=10) to validate the survey using exploratory factor analysis. Factor loading for all items exceeded 0.90 (0.93 to 0.98), which means that those items are suitable in measuring every item of power density among the survey sample, as indicated in table (6).

Table 6: Factor analysis of emotional intelligence scale

No.	Items	Extraction
1.	Power Density	0.98
2.	Electric field	0.93

3.8 Data analysis

Data were analyzed using statistical package for social sciences (SPSS). Descriptive statistics gauged power density scores among the sampled population. The following statistical techniques were measured: frequencies, means, standard deviation, one-way analysis of variance, and Factor Analysis.

Chapter IV

Results and Discussion

4.1 Estimated electric field and power density:

This chapter presents and discusses the results of the power density for the microcells mobile phone base station in Bethlehem and Hebron cities. The power density levels detected within the frequency range from 955MHz to 960MHz at 200 locations around 16 microcells mobile phone base station at Southern of West Bank, in Bethlehem and Hebron cities purposively selected, that is, Fawaghreh, Bab Al-Der, Reem Al-Bawady, Wady Rahall, Murad Restaurant, Ras Al-Dalih, Al-Khalil Sport, Al-Ahly Hospital, Abu Katela, Ras Al-Jorah, Arab Society, AlHalman, Central Market, Al Jaldeh, Abu Snaneh and Alia Hospital.

In Palestine Jawwal company which is the mobile phone service provider, Jawwal (GSM900 MHz) used mobile phone sector antennas and microwave dish antennas. As these antenna are being placed within meters of homes, schools, and other sensitive area, public concern has increased about indoor RF radiation exposure from these sources in Palestine community.

The maximum power density levels are detected at suitable height 170 cm above the ground level respectively, corresponding to the adult head position for about six minutes over the maximum range of the BK 2650 handhold spectrum analyzer in real live conditions.

The values of power density were varying from one station to another, because there is difference between the height of the antennas and the distance of the coverage area for each station.

The results consist of the observation and analysis that measured for different stations. This analysis includes station data as number of antennas, building types, heights, and measurement.

4.1.1 Stations Data

Station data includes three parts, number of antenna, and building type of the stations and Heights of the antennas

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4.1.1.1 Number of antennas per Station

Sixteen base stations in Hebron and Bethlehem cities were selected for this study. Figure (19) shows that the distribution number of antennas of stations, where the majority have 2 antennas for 12 stations and this value represents (75%), whilst 2 stations has 3 antennas and this value represents (13%) and only 2 stations has one antennas and this value represents (12%).

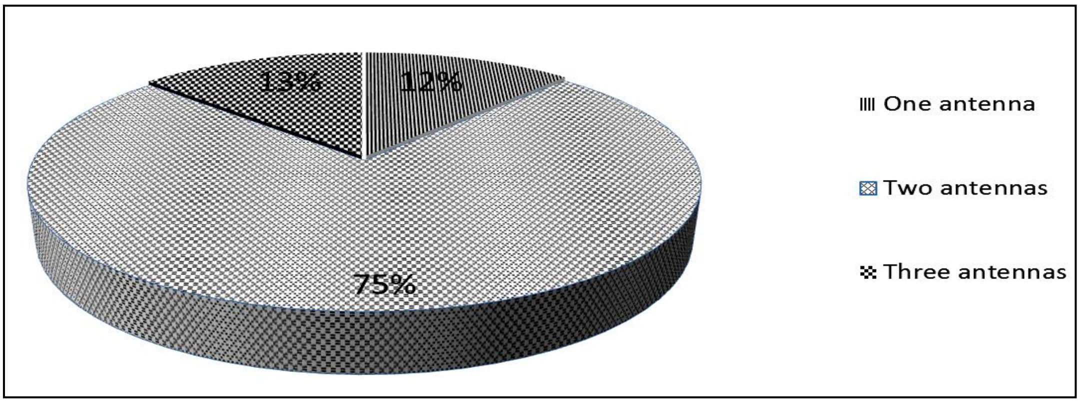

Figure (19) : Distribution of microcell base stations according to the number of antennas

4.1.1.2 Building station types

Figure (20) illustrates that the distribution of the building type for all stations. Antennas of 5 stations has installed on a metal tower or mast above the building and this value represents (31%), antennas of 7 station has installed on exterior wall of the private building which represents (44%), antennas of two stations has installed on exterior wall of the hospitals building which represents (12%) whilst antennas of 2 stations installed on a metal tower or mast at the street which represents (13%).

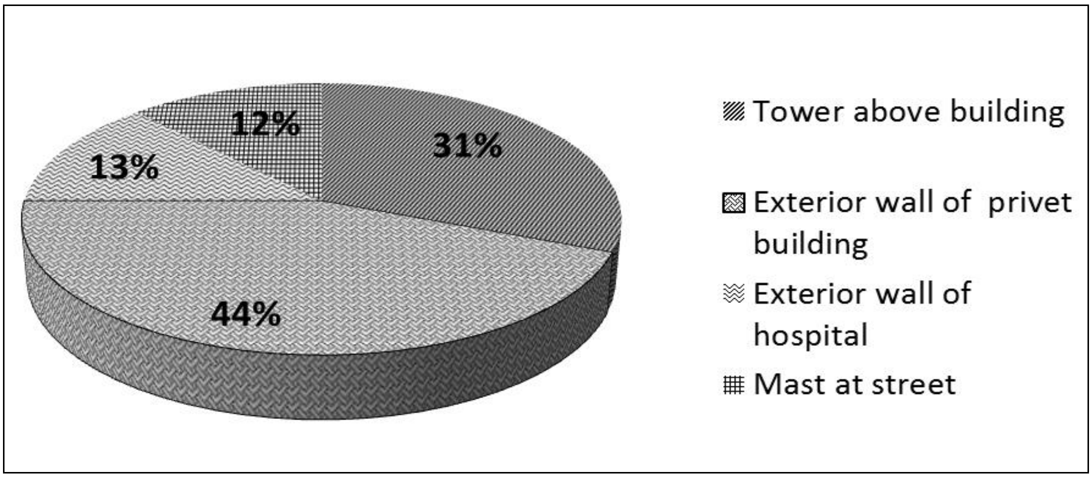

Figure (20): Distribution of microcell base stations according to the building station type

4.1.1.3: Heights of the antennas

Figure (21) illustrates that the distribution of the heights of the antennas. This height represents the distance between ground and antenna. 4 m for 3 antennas and this value represents (19%). 7to8 m for 3 antennas and represent (19%).10 m for 5 antennas and represent (31%), 12 m for 5 antennas which represent (31%).

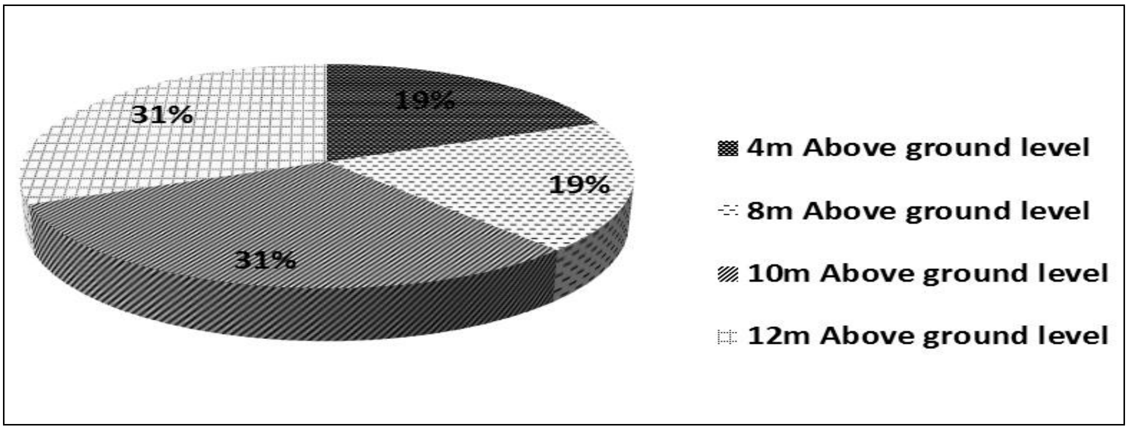

Figure (21): Distribution of microcell base stations according to the heights of the antenna above ground level.

4.2 Measurements of Electromagnetic Power Density for all Stations

Estimating of the power density for electromagnetic radiation emitted from sixteen microcells mobile phones base stations in Hebron and Bethlehem Cities are carried out then compared with ICNIRP standard levels (4.8 W/m^2) and EQA standard levels for short stay condition (0.19 W/m^2):

4.2.1 Al Fuaghra Street base station is connected to two antennas mounted on the face of exterior wall of a building at Al Fuaghra Street, the height of the antenna above ground level was 8 m. Measurement of electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 4.4 mW/m^2 which is 0.1 % of the reference level advised by ICNIRP and 2.3 % of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 12 m from the antenna, while the minimum value was 1.11 mW/m2, the average value was 2.1 mW/m^2 which is 0.04% of the reference level advised by ICNIRP and 1.1% of the reference level advised by EQA for exposure of the general public.

4.2.2 Bab Al Dar base station is connected to two antennas mounted on the face of exterior wall of a building at Bab Al Dar, the height of the antenna above ground level was 4 m. Measurement of electric field and Estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 8.51 mW/m^2 which is 0.2 % of the reference level advised by ICNIRP and 4.5% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 10 m from the antenna, while the minimum value of the power density was 1.1 mW/m^2; the average value of the power density was 4.2 mW/m^2 which is 0.1% of the reference level advised by ICNIRP and 2.2% of the reference level advised by EQA for exposure of the general public.

4.2.3 Reem Al Bawdy restaurant base station: was connected to two antennas mounted on the face of exterior wall of a building of Reem Al Bawady restaurant at al Mahed street, the height of the antenna above ground level was 4 m. Measurement of electric field and Estimation of the power density were detected at 10 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 3.1mW/m^2 which is 0.1% of the reference level advised by ICNIRP and 1.6 % of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 5 m from the antenna, while the minimum value was 0.56mW/m^2; the average value was 1.3 mW/m^2 which is 0.3% of the reference level advised by ICNIRP limits and 0.7% of the reference level advised by EQA for exposure of the general public.

4.2.4 Wady Rahall base station: was connected to two antennas mounted on a tower over a house building at Wady Rahall village, the height of the antenna above ground level was 12 m. Measurement of the electric field and estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 1.11mW/m^2 which is 0.02% of the reference level advised by ICNIRP and 0.6 % of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 9 m from the antenna. While the minimum value was 0.101 mW/m^2, the average value was 0.45 mW/m^2 which is 0.01% of the reference level advised by

ICNIRP and 0.24% of the reference level advised by EQA for exposure of the general public.

4.2.5 Murad Rest base station: was connected to two antennas mounted on a tower at Murad Rest, the height of the antenna above ground level was 12 m. Measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 0.06 mW/m^2 which is 0.001% of the reference level advised by ICNIRP and 0.03% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 5 m from the antenna, while the minimum value was 0.01 mW/m^2, the average value was 0.03 mw/m^2 which is 0.001% of the reference level advised by ICNIRP and 0.02% of the reference level advised by EQA limits for exposure of the general public.

4.2.6 Arab society base station: was connected to three antennas mounted on the face of exterior wall of a building at Bet Jala city, the height of the antenna above ground level was 10 m. measurement of the electric field and estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 1.12mW/m^2 which is 0.02% of the reference level advised by ICNIRP and 0.59% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 9 m from the antenna, while the minimum value was 0.10 mW/m^2, the average value was 0.45 mW/m^2 which is 0.01% of the reference level advised by ICNIRP and 0.24% of the reference level advised by EQA for exposure of the general public.

4.2.7 Al Hlman base station: was connected to three antennas mounted on the face of exterior wall of a building at Bethlehem city, the height of the antenna above ground level was 7 m. Measurement of the electric field and estimation of the power density were detected at 14 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 0.3 mW/m^2 which is 0.01 % of the reference level advised by ICNIRP and 0.16% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 6 m from the antenna, while the minimum value was 0.06 mW/m^2 and the average value was 0.16 mW/m^2 which is 0.003% of the reference level advised by ICNIRP and 0.08% of the reference level advised by EQA for exposure of the general public.

4.2.8 Central market base station: was connected to two antennas mounted on a tower over the building at Bethlehem city, the height of the antenna above ground level was 10 m. measurement of the electric field and estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 7 mW/m^2 which is 0.15 % of the reference level advised by ICNIRP and 3.7% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 7 m from the antenna, while the minimum value was 0.25 mW/m^2, the average value was 1.5 mW/m^2 which is 0.03% of the reference level advised by ICNIRP and 0.8% of the reference level advised by EQA for exposure of the general public.

4.2.9 Ras Al Dalih base station: was connected to two antennas mounted on a tower over a building at Ras Al Dalih, the height of the antenna above ground level was 12 m. measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 0.08mW/m^2 which is 0.002 % of the reference level advised by ICNIRP and 0.04% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 8 m from the antenna, while the minimum value was 0.003 mW/m^2 ,the average value was 0.03 mW/m^2 which is 0.001% of the reference level advised by ICNIRP and 0.02% of the reference level advised by EQA for exposure of the general public.

4.2.10 Hebron municipality gym base station: was connected to one antenna mounted on the face of interior wall of a building at Hebron municipality gym, the height of the antenna above ground level was 8 m. measurement of the electric field and estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 0.1 mW/m^2 which is 0.002% of the reference level advised by ICNIRP and 0.05% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 5 m from the antenna while the minimum value was 0.02mW/m^2 ,the average value was 0.05 mW/m^2 which is 0.001% of the reference level advised by ICNIRP and 0.03% of the reference level advised by EQA for exposure of the general public.

4.2.1 1 Al Ahly Hospital base station: was connected to one antenna mounted on the face of interior wall of a building at Al Ahly Hospital, the height of the antenna above ground level was 4 m. Measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 4.83mW/m^2 which is 0.10% of the reference level advised by ICNIRP and 2.5% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 4 m from the antenna, while the minimum value was 0.48 mW/m^2, the average value was 2.31 mW/m^2 which is 0.05% of the reference level advised by ICNIRP and 1.2% of the reference level advised by EQA for exposure of the general public.

4.2.12 Abu ktalah base station: was connected to two antennas mounted on a tower over a building at Abu ktalah, the height of the antenna above ground level was 10 m. Measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 5.3mW/m^2 which is 0.11% of the reference level advised by ICNIRP and 2.8% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 7 m from the antenna, while the minimum value was 0.18 mW/m^{2,} the average value was 1.52 mW/m^2 which is 0.03% of the reference level advised by ICNIRP and 0.8% of the reference level advised by EQA for exposure of the general public.

4.2.13 Raas Aljorah base station: was connected to two antennas mounted on the face of exterior wall of a building at Raas Aljorah, the height of the antenna above ground level was 10 m. measurement of the electric field and estimation of the power density were detected at 12 boresight direction sites at 1.7 m above ground level. The maximum value of the power density from the microcells base station was 0.58mW/m^2 which is 0.01% of the reference level advised by ICNIRP and 0.3% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 6 m from the antenna, while the minimum value was 0.10 mW/m^2, the average value was 0.31 mW/m^2 which is 0.01% of the reference level advised by ICNIRP limits and 0.16% of the reference level advised by EQA for exposure of the general public.

4.2.14 Al Jaldeh base station: was connected to two antennas mounted on a tower over a building at Al Jaldeh, the height of the antenna above ground level was 12 m. Measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 0.08mW/m^2 which is 0.002% of the reference level advised by ICNIRP and 0.04% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 8 m from the antenna, while the minimum value was 0.003 mW/m^2, the average value was 0.03 mW/m^2 which is 0.001% of the reference level advised by ICNIRP and 0.01% of the reference level advised by EQA for exposure of the general public.

4.2.15 Abu Snaneh street base station: was connected to two antennas mounted on the face of exterior wall of a building at Abu Snaneh street, the height of the antenna above ground level was 8 m. measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 4.40 mW/m^2 which is 0.09% of the reference level advised by ICNIRP and 2.3% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 12 m from the antenna, while the minimum value was 1.11 mW/m^2, the average value was 2.28 mW/m^2 which is 0.05% of the reference level advised by ICNIRP limits and 1.2% of the reference level advised by EQA for exposure of the general public.

4.2.16 Alia Hospital base station: connected to two antennas mounted on the face of exterior wall of a building at Alia Hospital, the height of the antenna above ground level was 10 m. Measurement of the electric field and estimation of the power density were detected at 13 boresight direction sites at 1.7 m above ground level. The maximum value of the power density was 5.3mW/m^2 which is 0.11% of the reference level advised by ICNIRP and 2.8% of the reference level advised by EQA for exposure of the general public. This value was at a horizontal distance 7 m from the antenna, while the minimum value was 0.18 mW/m^2, the average value was 1.41 mW/m^2 which is 0.03% of the reference level advised by ICNIRP and 0.74% of the reference level advised by EQA for exposure of the general public.

4.3 Analysis of Results:

For Al Ahly Hospital base station, as example, the power density was estimated as a function of horizontal distance at 13 locations at 1.7 m above ground level. The maximum value of the power density was 4.83mW/m^2 which is 0.10 % of the reference level advised by ICNIRP and 2.5% of the reference level advised by EQA for exposure of the general public. This value was at a location that far 4 m from the antenna as shown in figure (22). This location may on the axe that makes a downtilt angle with the horizontal axe as shown in figure (11).

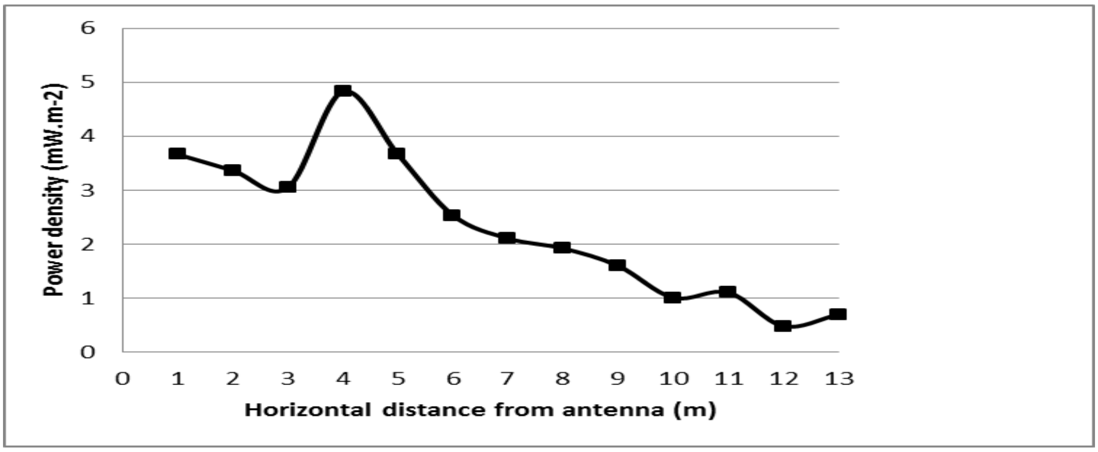

Figure (22): Power density as a function of horizontal distance from the base station antenna for Al Ahly Hospital base station

The measured power density are compared for the sixteen microcells base stations as shown in figure (23), most of the measurements of the power densities were under 6 mW/m^2.

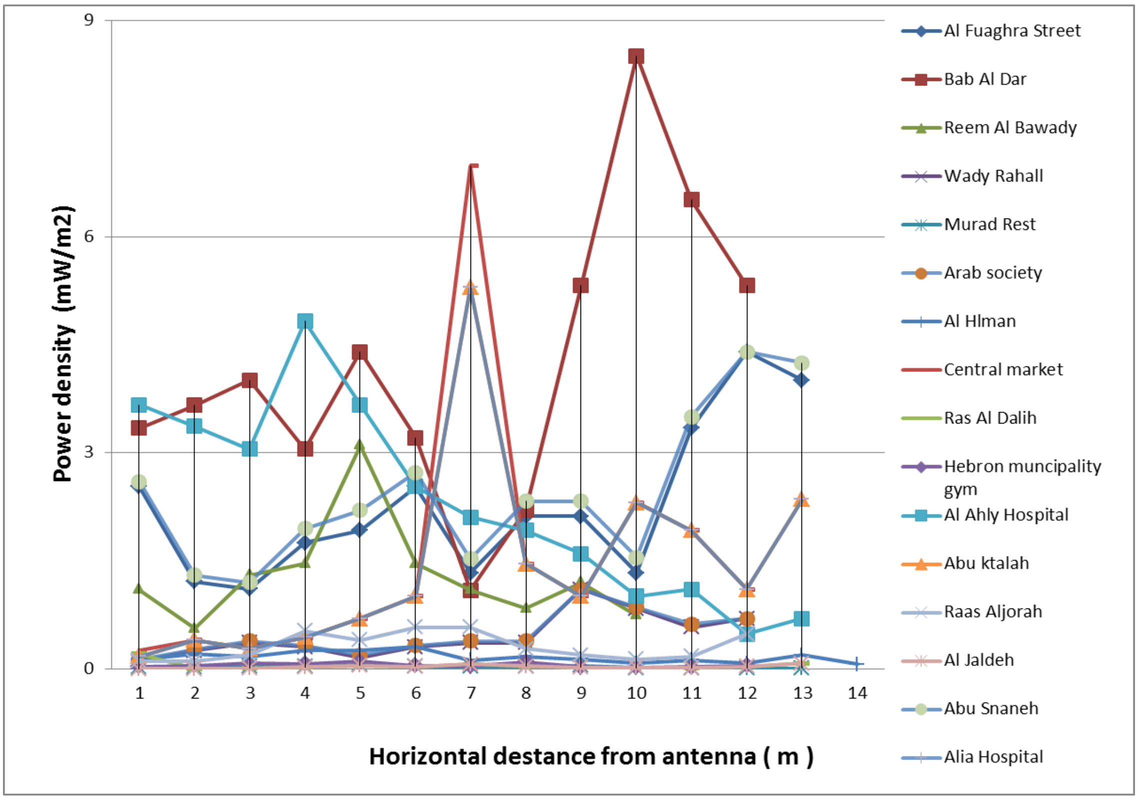

Figure (23): Comparison between power densities for all microcells base stations as a function of horizontal distance from the antenna.

The power density was measured for two base station ,Alfwghreh and Bab al Dar in two direction, the first one was with the boresight direction and the other was at 45^o with the boresight, as indicated in figure (24 and 25).

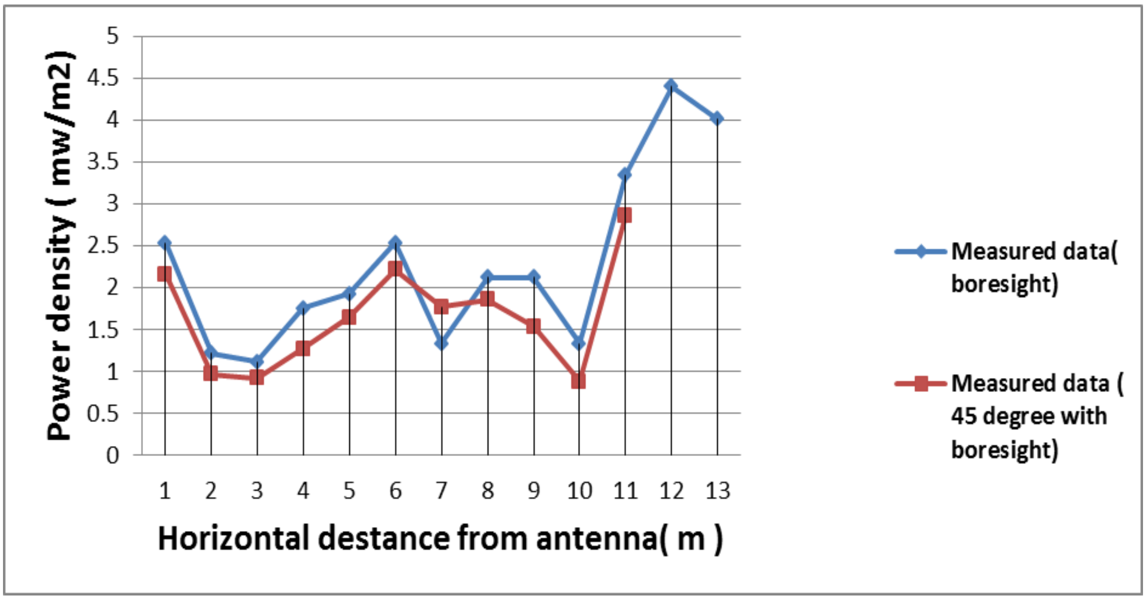

Figure (24): Power density of al Fwaghreh base station as afunction of horizontal destance from the base station antenna. The mesurements were made along two axes , the first with boresight and the second made 45^0 with boresight.

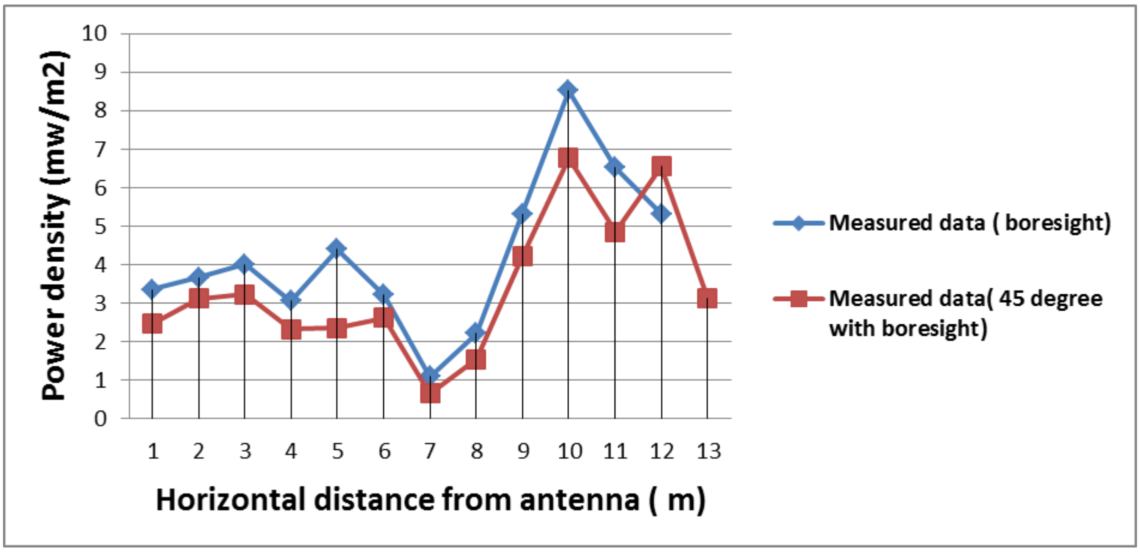

Figure (25): Power density of al Bab Al Dar base station as afunction of horizontal destance from the base station antenna. The mesurements were made along two axes , the first with boresight and the second made 45^0 with boresight.

In general the average values of the power density as found at the sample of sixteen stations (200 locations) are vary from 0.003 mW/m^2 to 8.51 mw/m^2 with a average value very low (1.14 mW/m^2), as indicated in table (7). This value is considered below the reference level advised by ICNIRP and EQA for exposure of the general public.

Table no. (7). Number, Minimum, Maximum Average, of the sampled population

Variable	**N**	**Minimum (mW/m2)**	**Maximum (mW/m2)**	**Average (mW/m2)**
Power density	200	0.003	8.51	1.14

Moreover, the study investigated demographic breakdown of the power density score of the sampled population with the aim of identifying any differences by station. The differences were very small (not significant), as indicated in tables (8- 9) and figure (26)

Table (8). One-way analysis of variance for the differences in the power density scores of the sampled population by station

Source	**Df**	**Sum of squares**	**Mean square**	**F-value**	**Sig.**
Between groups	15	15239.3	1015.9		
Within groups	184	6118.7	33.3	30.6	0.000*
Total	**199**	**21357.9**	**-----**		

The average values of the power density evaluated in 16 sites as shown in table (9). As it can be seen in figure (26), the highest average power density level is obtained from Bab al Dar Base station, probably due to the reflection of the beam since the area was close.

Table (9). Average scores and standard deviation for the differences in the power density scores of the sampled population by station.

Station	N	Average of power density (mW/m^2)	Std. Deviation
Fawaghreh street	13	2.08	1.06
Bab Al-Der	**12**	**4.2**	**2.39**
Reem Al-Bawady	10	1.3	1.32
Wady Rahall	12	0.45	0.30
Murad Rest	13	0.03	0.01
Ras Al-Dalih	13	0.03	0.02
Al-Khalil Sport	12	0.053	0.03
Al-Ahly Hospital	13	2.31	1.34
Abu Ktalah	13	1.52	1.38
Ras Al-Jorah	12	0.31	0.19
Arab Society	12	0.45	0.29
AlHalman	14	0.16	0.07
Central Market	12	1.49	1.85
Al Jaldeh	13	0.03	0.02
Abu Snaneh	13	2.28	1.06
Alia Hospital	13	1.42	1.38

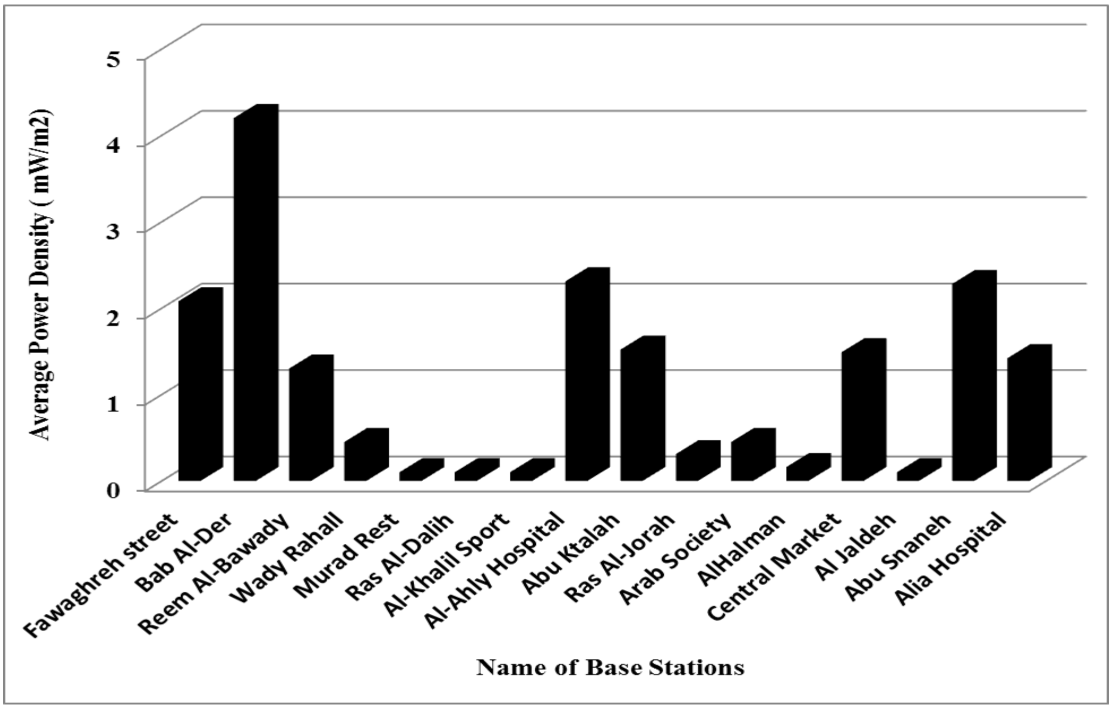

Figure (26). Distribution of mean power density values by base station.

Additionally, findings indicated that there are statistical significant inverse (negative) correlation between the high of antenna and the power density scores of the sampled population, Beta-value was (Beta – value= -0.470 P=0.000).as shown in table (10).

Table (10). Standard Regression between the high of antenna and the power density scores of the sampled population

Variable	Beta-value	R-square Value	Sig.
High of antenna*power density	-0.470	0.221	0.000*

Moreover, findings indicated that there are statistical significant differences in the power density scores and the direction with the boresight for Al Fawaghreh base station, T-vale was (3.6 P=0.005), taken in consideration that the mean differences was (0.29), as indicated in table (11).

Table (11). Paired-Samples T-test for the differences in power density scores of Fawaghreh base station along boresight and 45^o with boresight direction

Angle with boresight	N	Mean	Standard Deviation	Mean Difference	DF	T-value	Sig.
0^0	11	1.93	0.68	0.29	10	3.6	0.005
45^o	11	1.64	0.62				

Finally, findings indicated that there are statistical significant differences in the power density scores and the direction with the boresight for Bab Al Dar base station, T-vale was (2.924 P=0.014), taken in consideration that the mean differences was (2.21), as indicated in table (12).

Table no. (12). Paired-Samples T-test for the differences in power density scores of Fawaghreh base station between 0-45 degree

Angle with boresight	N	Mean	Standard Deviation	Mean Difference	DF	T-value	Sig.
0	12	7.13	4.58	2.21	11	2.924	0.014
45	12	4.92	3.13				

It has been noticed electromagnetic radiation levels of all stations was very low. This low radiation could be due to the restrictions put on the local mobile communication operator in using a limited number of frequencies and so the same frequency must be reused again in a short distance and hence the radiated power should be kept minimum so as to prevent interference.

Chapter V

Conclusions

1. The distribution of more than 30 GSM microcell base stations in terms of antenna height and radiated power has been examined from information provided by the network operator (JAWWAL) in Hebron and Bethlehem cities.

2. The distribution showed a distinct population of microcell base stations with low antenna height, typically (4 – 12 m), and power of a few watts with total radiated power not exceeded 5 watts.

3. It has been noticed that the power density of RF radiation levels from all the microcell base station was very low because coverage area of the station is a short distance. Also this low radiation could be due to the restrictions put on the local mobile communication operator in using a limited number of frequencies.

4. The obtained readings of RF radiation levels were less than the reference level advised by ICNIRP and EQA for exposure of the general public and.

5. It has been noticed that the maximum measured value of power density of the RF radiation levels for 200 locations around the sixteen microcell base stations was only 8.51 mW/m^2 which represent 0.2% of the reference level advised by ICNIRP and 4.5 % of the reference level advised by EQA for exposure of the general public.

6. There is an inverse (negative) relationship between the electromagnetic power density and the antenna heights at different distances for the microcell base station.

7. All stations are licensed by the EQA.

8. On the basis of the results of the measurements, members of the public would not be exposed in excess of the ICNIRP and EQA guidelines whilst standing on the ground near any of the microcell base stations. Exposures that comply with the guidelines are not considered hazardous.

References

Abdelati, M (2005). Electromagnetic Radiation from Mobil Phone Base Stations at Gaza. Journal of the Islamic University of Gaza (Natural Sciences Series) Vol.13 (2), 129-146.

Bacon, D (1996). Introduction to diffraction, reflection and scattering. In Propagation of Radio Waves, Edited by (Hall M, Barclay L and Hewitt M, Eds). London, UK, Published by the Institution of Electrical Engineers, 60-81.

European Conference of Postal and Telecommunications Administrations (2002). Measuring mom-ionizing electromagnetic radiation (9 KHz -300 GHz). ECC Recommendation. Copenhagen, Denmark.

Canadian Nuclear Safety Commission (2012). Introduction to Radiation, 15-20.

Cichon, D (1999). Propagation models for small- and micro-cells. In Digital Mobile Radio towards Future Generation Systems (COST 231 Final Report) (Damosso E and Correia L M, Eds). Luxembourg, Published by the Office for Official Publications of the European Communities, 149-166.

El-Wasife, K (2010). Experimental and theoretical in vitro study for the effect of electromagnetic waves produced by mobile phone base station on life tissues, (PH. D thesis) Sudan University of science and Technology,10-25.

European Information Technology Observatory (2010). Press Release 2010. http://www.eito.com/reposi/PressReleases/eito-pr-20100811.pdf.

International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)," Health Physics, Vol. 74 (4) 494-522.

Institute of Electrical and Electronics Engineers (1991). Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, Standards Coordinating Committees. (IEEE C95.1-1991)

Institute of Electrical and Electronics Engineers, (2005). IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300GHz. (IEEE C95.1-2005).

Irwin, (2002): Radiofrequency radiation risk a study focused on wireless telephones. Degree of Doctor of science in work environment. University of Massachusetts Lowell UMI Number: 3041336.

ITU International Telecommunication Union. (2016). ICT FACTS AND FIGURES 2016. https://www.itu.int/en/ITU-/Statistics/Documents/facts/ICTFactsFigures2016.pdf

Kagoshima K, Lee W, Fujimoto K and Taga T (2001). Essential techniques in mobile antenna systems design. In Mobile Antenna Systems Handbook (2^{nd}ed) (Fujimoto K and James J R, Eds). Norwood, MA, USA, Artech House, 23-88. ISBN 1-58053-007-9.

Khatib M. (2014). Evaluation of Electromagnetic Radiation Safety from Wireless Transmission Systems in Tulkarm City – Palestine. Palestine Technical University – Kadoorie, Palestine (International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 10, April 2014.

Koprivica M, Petric N, Neskovic A, Neskovic. (2016). Statistical Analysis of Electromagnetic Radiation Measurements in the Vicinity of Indoor Microcell GSM/UMTS Base Stations in Serbia. University of Belgrade, Belgrade, Serbia, Bioelectromagnetics, 37(1) 69-76.

Lahham, A, Hammash, A (2011): Outdoor radiofrequency radiation levels in the West Bank—Palestine, Radiat Prot Dosimetry (2011) 149 (4) 399-402

Ministry of communication, 2012 - Mobile Communication, Radio Waves and Safety, India, P: 5.

Mobile Operators Association, (2003). Radio frequency safety signage at cellular base station. Document RFCG 12/2003

Mobile Operators Association, (2013). Base Stations and Masts. http://www.mobilemastinfo.com/base-stations-and-masts/cited15/08/2013.

Palestinian Central Bureau of Statistics, (2008). Population, Housing and Establishment Census 2007, Final Results in the West Bank – Summery. Ramallah-Palestine.

Palestinian Territories (2009). The Economist Intelligence Unit, London, United Kingdom, P: 21-23.

Rappaport T. (2002). Wireless communications: Principles and practice (2nded). Upper Saddle River, NJ, USA, Prentice Hall PTR.

Ramsdal, P. and Wiener, A. (1999): Cellular phone Base Stations: Technology and Exposures. Radiation protection Dosimetry. 83(1-2) 125-130.

Repacholi, M. (1998). Low-level exposure to radiofrequency field: health effects and research needs. Bioelectromagnetics 19(1) 1-19.

Schmid, G., Lager, D., Preiner, P., Uberbacher, R. and Cecil, S. (2007). Exposure Caused by Wireless Technologies Used for Short-Range Indoor Communication in Homes and Offices. Radiation protection Dosimetry. 124(1)58-62

Uniformed Services University of the Health Sciences. (2014). http://www.usuhs.edu/afrri/outreach/ionizing.htm, cited 15/03/2014.

Viel J, Clerc S, Barrera C, Rymzhanova R, and Cardis E.(2009).Residential Exposure to Radiofrequency Fields from Mobile Phone Base Stations, and Broadcast Transmitters: A Population-Based Survey with Personal Meter.

Walke, B. (1999). Mobile Radio Networks. John Wiley & Sons Ltd, Chichester, England.

World Health Organization. Electromagnetic fields and public health.(2014) http://www.who.int/peh-emf/publications/factsheets/en/ , cited 2/04/2014.

World Health Organization (Media Center), (2006). Electromagnetic Fields and Public Health: Base Stations and Wireless Technologies.

World Health Organization (2008). Electromagnetic Radiation.WCR2008-212.World Health Organization.

Yassin K, Khair S, Yasin S (2010). Study of levels of exposure to electromagnetic fields from mobile phones base-stations in Khartoum & Khartoum Nort, Directorate of Scientific Research & Cultural Relations (Conference 2010), University of Khartoum.

Zamanian A, Hardiman C. (2005). Electromagnetic Radiation and Human Health. Fluor Corporation, Industrial and Infrastructure Group.17-20

Annex

بسم الله الرحمن الرحيم

Palestinian National Authority

Environment Quality Authority

السلطة الوطنية الفلسطينية

سلطة جودة البيئة

No : ______________ الرقم: ____________

Date: ______________ التاريخ: ____________

العدد الحادي و الثمانون الوقائع الفلسطينية 09 أيار (مايو) 2009 م

قرار وزاري رقم (1) لسنة 2009 بشأن اجراءات منح الموافقة البيئية لانشاء و تشغيل محطات البث الخلوي – صادر عن رئيس سلطة جودة البيئة

رئيس سلطة جودة البيئة،

و بعد الاطلاع على القانون رقم (7) لسنة 1999 بشأن البيئة،

و سياسة التقييم البيئي الفلسطينية لعام 2000،

و تعليمات سلطة جودة البيئة بشأن الاشعاع غير المؤين لعام 2003،

و بتنسيب من دائرة الاشعاع البيئي بالتنسيق مع الجهات المختصة،

نصدر القرار الوزاري بالاجراءات التالية:-

مادة (1) تسمى هذه الاجراءات باجراءات سلطة جودة البيئة بشأن منح الموافقة البيئية لانشاء و تشغيل محطات البث الخلوي.

مادة (2) يكون للكلمات و الالفاظ الواردة في هذه الاجراءات المعاني المخصصة لها بالقانون و سياسة التقييم البيئي و التعليمات بشأن الاشعاع غير المؤين الا اذا دلت القرينة على خلاف ذلك. و لغايات احكام هذه الإجراءات يقصد بالشركة كل شخص اعتباري مرخص له للعمل في قطاع الإتصالات الخلوية.

مادة (3) تهدف هذه الاجراءات الى:-

1- الحد من التلوث الإشعاعي الناتج عن المجالات الكهرومغناطيسية و الكهربائية و المغناطيسية غير المؤينة و العمل على تخفيض مستواه في البيئة الى ادنى درجة ممكنة و بما يتوافق مع المعايير و التعليمات المقررة في هذا المجال.

2- تحديد قيمة الحد الاعلى و المسموح للاشعاع الصادر عن محطة البث الخلوي وفقا للمعايير و التعليمات المعمول بها في سلطة جودة البيئة.

3- تسريع اجراءات منح الموافقة البيئية لانشاء و تشغيل محطات البث الخلوي الجديدة او عند اجراء تعديلات على محطات قائمة، مما يسهل عمل الشركة.

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4- الزام الشركة بنظام الرقابة الذاتية بحيث تضمن مطابقة المحطة للمعايير و التعليمات المقررة بالطريقة المناسبة.

5- تفعيل نظام الرقابة الدورية و الفجائية من قبل سلطة جودة البيئة على محطات البث الخلوي للتأكد من استمرار التزام الشركة بالمعايير و التعليمات المقررة بهذا الخصوص طوال فترة التشغيل.

مادة (4) تطبيقا لاحكام المادة 47 من القانون رقم (7) لسنة 1999 بشأن البيئة، تعتبر محطات البث الخلوي و أي تعديلات عليها من المشاريع و النشاطات الواجب حصولها على موافقة بيئية مسبقه.

مادة (5) وفقا لاحكام سياسة التقيم البيئي في الحصول على الموافقة البيئية، تلتزم الشركة بعدم البدء بانشاء اي محطة بث خلوي قبل الحصول على الموافقة البيئية الخاصة بهذه المحطة.

مادة (6) يقدم طلب الحصول على الموافقة البيئية على النموذج المرفق مع هذه الإجراءات و يرفق به المخططات والوثائق المشار اليها في النموذج و اية وثائق اخرى ترى دائرة الاشعاع انها ضرورية.

مادة (7) تتحمل الشركة كامل المسؤولية القانونية في حال اقامت اياً من الإنشاءات الخاصة بالمحطة قبل الحصول على الموافقة البيئية، و لسلطة جودة البيئة اتخاذ الاجراءات التي تراها مناسبة و التي منها قبول او رفض اصدار الموافقة البيئية لهذه المحطة و الطلب من الشركة تفكيكها و ازالتها.

مادة (8) للشركة اجراء تعديلات على محطة البث الخلوي و تلتزم الشركة بابلاغ و اعلام سلطة جودة البيئة بكافة هذه التعديلات خلال اسبوع واحد من تاريخ القيام بها، و خلاف ذلك تعتبر هذه التعديلات غير قانونية، و لسلطة جودة البيئة اتخاذ الاجراءات التي تراها مناسبة بشأنها.

مادة (9) على الشركة الإلتزام عند انشاء و تشغيل اي من محطات البث الخلوي او عند اجراء تعديلات عليها و تحت طائلة المسؤلية القانونية و طوال فترة تشغيل المحطة بالتعليمات الصادرة عن سلطة جودة البيئة لعام 2003 م بشأن الوقاية من الإشعاع غير المؤين، و التي تحدد الحد الأعلى المسموح للمواطنين التعرض له (حد التعرض المسموح) من هذا النوع من الإشعاع بكافة تردداته و من كافة مصادره مجتمعة.

مادة (10) عند استخدام محطة البث الخلوي لعدة ترددات فان حد التعرض المسموح يحسب تبعا لنسبة مساهمة كل من هذه الترددات في مستوى اشعاع المحطة.

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مثال توضيحي: في حال كان ثلث اشعاع المحطة من تردد 900 MHz و ثلثيه من تردد 1800 MHz، تكون قيمة التعرض المسموح: $(1/3)(4.5) + (2/3)(9) = 7.5\ watt/m^2$

مادة (11) بعد اخذ كافة الإعتبارات، و انسجاما مع المعايير و التعليمات المقررة و المعمول بها في سلطة جودة البيئة، و انطلاقا من مبدا خفض مستوى الإشعاع الى ادنى درجة ممكنة، تلتزم الشركة عند انشاء اي من محطات البث الخلوي او عند اجراء تعديلات عليها و طوال فترة تشغيل المحطة، و تحت طائلة المسؤلية القانونية بما يلي:

1- أن لا يزيد مستوى اشعاع المحطة الواحدة محددا بقيمة كثافة القدرة الإشعاعية الصادرة عنها في اي مكان يحق للمواطنين الوصول اليه عن جزء من مائتين و خمسين (1/250) من حد التعرض المسموح و المبين في المواد (9،10).

2- تسمح سلطة جودة البيئة استثنائيا بقيم اعلى لمستوى اشعاع المحطة تصل الى، ولا تتجاوز باي حال من الأحوال، جزء من خمسة و عشرين (1/25) من حد التعرض المسموح في الأماكن المخصصة فقط للمرور كالشوارع و الممرات و ادراج المباني.

3- في حال كان المكان مخصص لاغراض اخرى غير المرور، و لا يتواجد فيه المواطنون بالعادة سوى فترات قصيرة و بصورة غير يومية، تحدد سلطة جودة البيئة قيمة الحد الاعلى المسموحة لاشعاع المحطة في هذا المكان بعد دراسة تفاصيل المكان و طبيعة استخدامه، على أن تكون هذه القيمة بين تلك القيم المبينة في البنود (1،2).

مادة (12) لسلطة جودة البيئة و من اجل تسهيل عمل الشركة و تشجيعا لعمليات الاستثمار و التنمية اصدار الموافقة البيئية بناء على البيانات المقدمة في الطلب و تعهد الشركة بصحتها و الالتزام بها. على ان ذلك لن يؤثر على حق سلطة جودة البيئة في القيام بالكشف الميداني قبل اصدار الموافقة البيئية في الحالات التي ترتئي فيها ضرورة ذلك.

مادة (13) لسلطة جودة البيئة القيام بعمليات الكشف الميداني في أي وقت للتاكد من مطابقة المحطة للمواصفات و البيانات التي صدرت الموافقة البيئية بناء عليها و للقيام بالقياسات الضرورية لمستوى اشعاع المحطة في المنطقة المحيطة للتأكد من الإلتزام بهذه الإجراءات.

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مادة (14) على الشركة أن تلتزم بتنفيذ الرقابة الذاتية من خلال اعداد تقرير دوري يقدم لسلطة جودة البيئة، سنويا على الأقل، عن كافة محطات البث الخلوي يبين مستوى اشعاع هذه المحطات و مدى مطابقته للحدود المقررة في هذه الإجراءات.

مادة (15) في حال تبين ان محطة ما مخالفة للمواصفات و البيانات الواردة في طلب الحصول على الموافقة البيئية او لشروط الموافقة البيئية الصادرة او لهذه الإجراءات، لسلطة جودة البيئة اتخاذ احد او بعض الاجراءات التالية:-

1- الطلب من الشركة ازالة اسباب المخالفة بما يتطابق مع هذه الإجراءات. و في حال تكرار المخالفات في نفس المحطة يطلب من الشركة التوقيف الفوري لبث المحطة و تصويب وضعها و عدم تشغيلها قبل صدور قرار يسمح بذلك.

2- التوقيف الفوري لبث المحطة و تصويب وضعها و عدم تشغيلها قبل صدور قرار يسمح بذلك في حال تبين ان مستوى اشعاع المحطة تعدى الحدود المسموحة.

3- التوقيف الفوري لبث المحطة و ازالتها نهائيا في حال كون المخالفة المرتكبة لا يمكن تصحيحها.

4- أي اجراءات اخرى يتم تقريرها بناءا على التقرير الفني.

مادة (16) لسلطة جودة البيئة الغاء الموافقة البيئية و ازالة اسباب المخالفة على نفقة الشركة في حال رفض الشركة تنفيذ أي من الإجراءات المنصوص عليها في المادة رقم (15).

مادة (17) تسري هذه الإجراءات على كافة محطات البث الخلوي، و على الشركة تصويب اوضاع المحطات القائمة قبل صدور هذه الإجراءات و بما يتلائم مع كافة ما جاء فيها خلال فترة لا تتجاوز ثلاثة شهور من تاريخ صدورها.

مادة (18) على جميع الجهات المختصة الالتزام بتنفيذ هذه الإجراءات و تكون سارية المفعول من تاريخ صدورها و تنشر في الجريدة الرسمية.

صدر في مدينة رام الله بتاريخ 2009/4/9 ميلادية

الموافق: 13/ربيع الآخرة/1430 هجرية

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