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Study and Measurement of Microwave Radiation Emitted from Mobile Stations and Possible Non-Thermal Health Risks in Palestine

Ali Mohammad Abu Abed

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Prepared by
Ali Mohammad Abu Abed

Supervisor
Dr. Salman M. Salman

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Prepared by: Ali Mohammad Abu Abed
Registration No: 20810293
Supervisor: Dr. Salman M. Salman
Master thesis submitted and accepted, date / / 2013

Name and signature of examining committee member are as follows:

1- Head of the committee: Dr. Salman Salman Signature: …………………………...
2. Internal Examiner:Dr. Elias Elias Signature:..
3. External Examiner:Dr.Adnan Judeh Signature:….......................................

Jerusalem – Palestine
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Dedication

I gracefully dedicate this work to my loving parents and dear cherished wife and children with all of my love. I specially dedicate this work to Palestine and to all who have inspired me.

Declaration

I hereby declare that this work is based on the results found by myself or my advisor. Works by other researchers are mentioned by references. This work, neither in whole nor in part, has been previously submitted for any degree.

The work was done under the supervision of Dr. Salman M. Salman, Physics, Alquds University, and Palestine.

Ali Mohammad Abu Abed

Acknowledgement

First I submit my gratitude to Almighty "Subhanoho Wataala" for giving me the strength and will to complete the work.

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Ali Mohammad Abu Abed

Abstract

This work deals with the assessment and measurement of levels and effects of electromagnetic radiation emitted from mobile base stations towers in Palestine.

Power density measurements were made using NBM-550 Narda Broadband Field Meter with probe EF0391 (NBM) 100kHz -3GHz. All investigated base stations in this study are operated by the Palestine cellular communication Ltd (Jawwal). Nineteen Base stations were investigated mainly in the Ramallah and Nablus districts. The Stations have been selected carefully near schools and in residential dense areas.

Measurements were compared to public exposure limits recommended by ICNIRP (4.5 W/m^2); the Palestine Ministry of Environment Affairs (indoor 0.018 W/m^2; outdoor 0.18 W/m^2) and other standards mainly ONIR (0.04W/m^2) and Salzburg (0.001W/m^2). Levels of electromagnetic emission found were below the ICNIRP limits but in many occasions were comparable to ONIR limits and Ministry of Environment Affairs, and that should raise some concerns. The maximum power density of about 6.28W/m^2 along the main beam was measured at 3 meters from A5 station in Ramallah near Ericson Company. The maximum power density of 0.033W/m^2 along the ground level was measured at 15 meters from A2 located in Ramallah near the municipal building.

Taking into account studies and research in non-thermal influences the measured densities face us with responsibilities to reduce the intensity of the radiation to the lowest extent possible. A previous test experiment by the Biomedical Engineering Center, Tallinn University of Technology shows that non-thermal effects are strong enough to necessitate a through investigation.

We recommend an investigation of these phenomena and setting and enforcing limits in Palestine that consider these effects, especially for densely populated areas.

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List of Abbreviations

Abbreviation	Meaning
CDMA	Code Division Multiple Access
dBi	decibels isotropic
dBm	decibels relative to one mW
dBw	decibels relative to one watt
EEG	Electro Encephalo Graphy
EIRP	Effective Isotropic Radiated Power
GSM	Global System For Mobile
ONIR	Ordinance On Non Ionizing Radiation
PD	Power Density
SAR	Specific Absorption Rate
STOA	Science And Technology Options Assessment
WHO	World Health Organization
ICNIRP	International Council on Non-Ionizing Radiation Protection

List of Definitions

Effective Isotropically Radiated Power (IEEE Std, 2000): is the amount of power that a theoretical isotropic antenna (which evenly distributes power in all directions) would emit to produce the peak power density observed in the direction of maximum antenna gain.

EIRP can take into account the losses in transmission line and connectors and includes the gain of the antenna. The EIRP is often stated in terms of decibels over a reference power emitted by an isotropic radiator with equivalent signal strength. The EIRP allows comparisons between different emitters regardless of type, size or form. From the EIRP, and with knowledge of a real antenna's gain, it is possible to calculate real power and field strength values.

EIRP = $P_t 10^{(G(\theta,\ \varphi)-Lc/10)}$

Where EIRP and P_t (power of transmitter) are in W, Gain (G), and cable losses (L_c) in dBi.

Antenna Gain: this is a measure of how effective an antenna is at radiating power in the direction of its main beam and it's a function of Θ and φ

Decibel (**dB**): is a logarithmic unit that indicates the ratio of a physical quantity (usually power or intensity) relative to a specified or implied reference level. A ratio in decibels is ten times the logarithm to base 10 of the ratio of two power quantities.(IEEE Std, 2000). Being a ratio of two measurements of a physical quantity in the same units, it is a dimensionless unit. A decibel is one tenth of a bel, a seldom-used unit.

Formula for Conversion from dBm to Transmit Power (mW) and visa versa:

mW = $10^{(dBm/10)}$ **and** $dBm=10\log_{10}(mW)$

Power Density: is the rate of flow of electromagnetic energy per unit area used to measure the amount of radiation at a given point from a transmitting antenna. This quantity is expressed in units of watts per square meter (W/m^2) or mille-watts per square cm (mW/cm^2).

Chapter One

Review of Mobile Systems used in Palestine

Chapter One

1.1-Introduction

The electromagnetic spectrum from 50Hz to several ten GHz is used for power transport, communication and sensor technology. Terrestrial TV and broadcast are transmitted at frequencies from several 100 kHz to about 800 MHz using transmitting powers ranging from some 100 W to several 100 kW.

The radio waves used in mobile telephony consist of both electric and magnetic components that vary periodically in time. "The electric fields of such waves can affect the motion of charged particles within the human body that can result in currents flow and heat production. In certain circumstances if the current flow occurs within sensitive areas of the human body like the brain nervous system or the heart it can affect the functions beyond simple heat production output"(March, 2012).

In addition, the penetrating power of the microwaves is larger than the optical spectrum and even though the optical range carry, more energy per photon, the absorption of most of the optical photons within the skin prevents similar effect to the body introduced by the microwaves. In fact this is why microwaves are used for cooking while optical light cannot be used even if they are produced at the same power output. For microwaves, it will cook the whole depth while the same power of optical light will burn the surface.

Base stations are normally connected to directional antennas that are mounted on the roofs of buildings or on free-standing masts. The antennas may have electrical or mechanical down-tilt, so that the signals are directed towards ground level.

Those antennas transmit in the frequency range of 869-894 MHz (CDMA), 935-960 MHz (GSM900) and 1810–1880 MHz (GSM1800). In addition, 3G has been deployed in a few cities, in which base station antenna transmits in the frequency range of 2110–2170 MHz.

A base station and its transmitting power are designed in such a way that mobile phones should be able to transmit and receive signals for proper communication up to a few kilometers. The majority of these towers are mounted near the residential and office buildings to provide good Mobile phone coverage for the users **(**Kumar, 2010).

“As towers are being placed within meters from homes, schools, and other sensitive areas, this is causing anxiety in the community. The radiations from these towers have been associated with a range of health problems including birth defects, brain tumors lymphomas, and memory problems” (Cherry, 1999; Mann and Roschke, 1996**).**

Some governmental agencies and organizations around the globe have established guidelines, good practices and recommendations regarding exposure to EMF. These organizations study the effect of EMF on the human body, and specify restrictions on the amount of electromagnetic energy that can be absorbed by the human body without risks (RF Safety Solutions).

1.2 Radiofrequency (RF) Radiation

Power frequency fields, RF radiation, infrared radiation, and visible light, are types of non-ionizing radiation. This radiation, together with ionizing electromagnetic radiation (X and gamma radiation) make up the electromagnetic spectrum as shown in figure 1.1

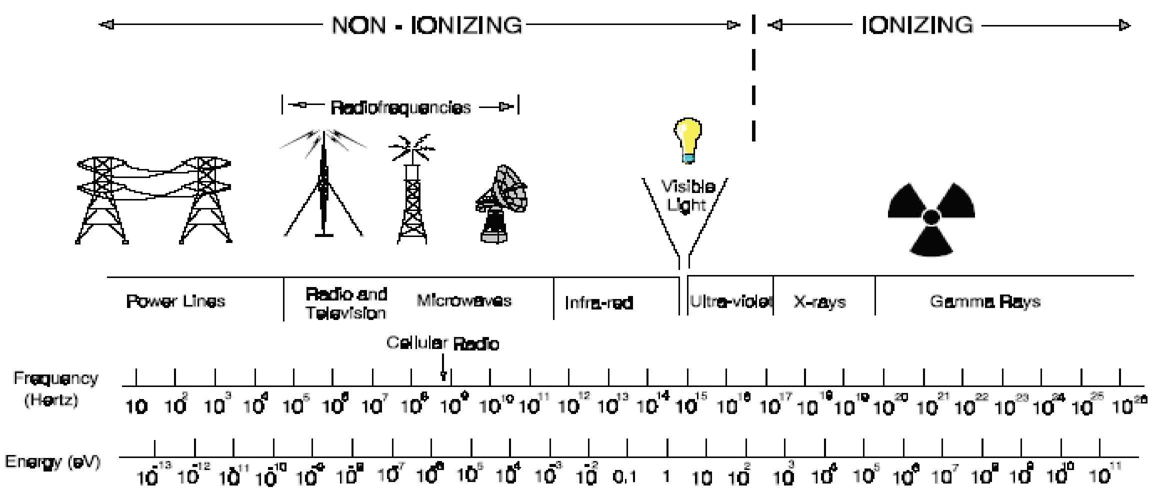


Figure 1.1 The electromagnetic spectrum, energy and some applications .

Ionizing radiation has enough energy to remove bound electrons from the orbit of an atom to become ionized and that is likely to cause health hazard (Mousa, 2011). The non-ionizing radiation does not have sufficient energy to ionize atoms.

Radio and microwaves are electromagnetic waves collectively described by the term Radio Frequency or RF. (Figure 1.1 and Cleveland et al, 1999). RF emissions and associated phenomena can be discussed in terms of energy, radiation or fields. Electromagnetic radiation moves at the speed of light and can be modulated, transmitted and received while conveying the necessary information (Shankar, 2002).

These waves are generated by the acceleration of electrical charges through a substance such as a conductive metal object or antenna. The alternating movement of charge (i.e. current) in an antenna used of a cellular base station generates electromagnetic waves that are emitted away from the transmission antenna and can be intercepted by a receiving antenna integrated into a hand-held device such as a cellular telephone (Cleveland et al, 1999). The energy flux in watts per square meter (W/m^2 or mW/cm^2) across a surface is called the power density.

1.3 Base station characteristic

A base station is comprised of several different components including an equipment shelter, a tower or mast which provides the necessary height to give better coverage because the waves can blocked by building and other barriers, and the transceivers and antennas that sit atop the tower or mast. In some cases they are attached to tops of buildings that can provide sufficient height. The antennas are typically about 15-30 cm in width and up to a few metres in length, depending on the frequency of operation. The wireless connection from the phone to the station is called uplink and carries the user's sound through the phone. The other wireless link from the station to the phone is called downlink and transmits the sound to the user as shown in figure 1.2.

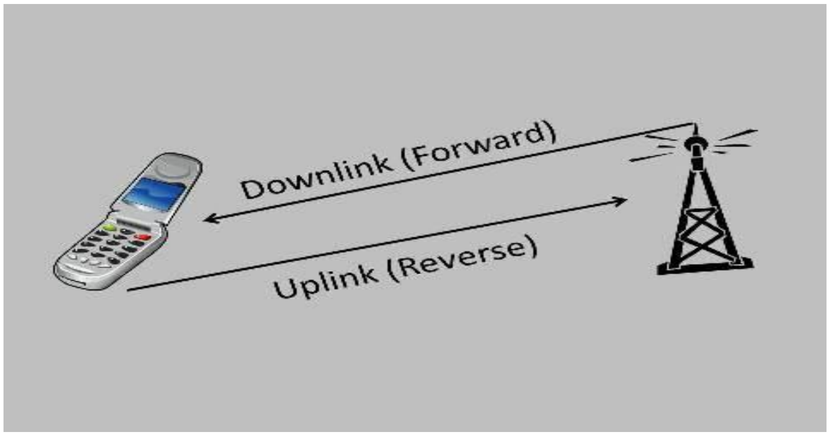


Figure 1.2 Uplink and Downlink

1.3.1 Antenna types

GSM antennas are either directional or omni-directional (Comfast, 2013). **Omni-directional antennas** emit 360° uniform, non oriented transmission, in communication systems for close distances, and large coverage area. The price is low, and the gain is generally less than 9dB. Omni-directional antenna emission looks like an apple.

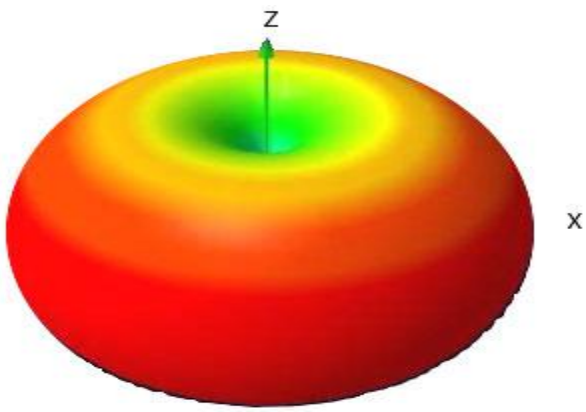


Figure 1.3 : Omni-directional antenna pattern

Directional antennas usually have higher gain that is more sensitivity to signals. They accomplish greater sensitivity because they focus the energy patterns onto smaller areas. To receive a signal however, the directional antennas must be oriented to the specific direction from which the signal is emanating. See figure 1.4.

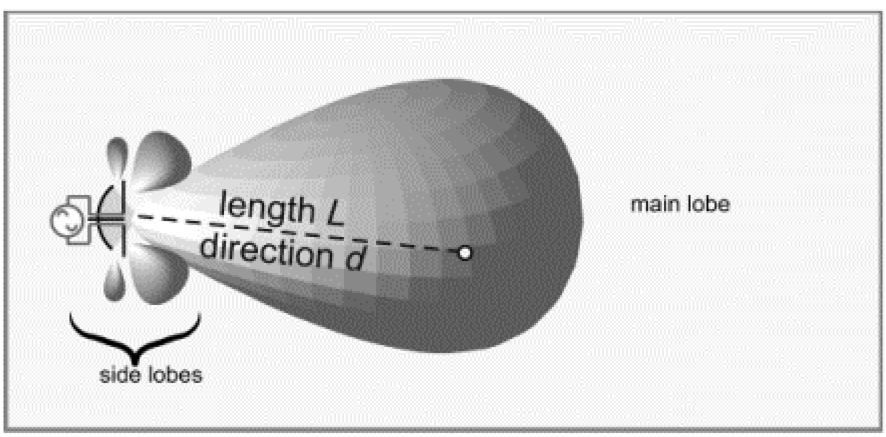


Figure 1.4 : directional antenna pattern

1.3.2 Providing coverage

Signal strength weakens as we move away from the station but it should remain strong for communication within the cell coverage area. The coverage radius is usally around 10 km. This means we need to use many coordinated stations to provide good coverage. The hexagonal fixed configuration and coverage of these stations is given in figure 1.5 (Mann et al .2000).

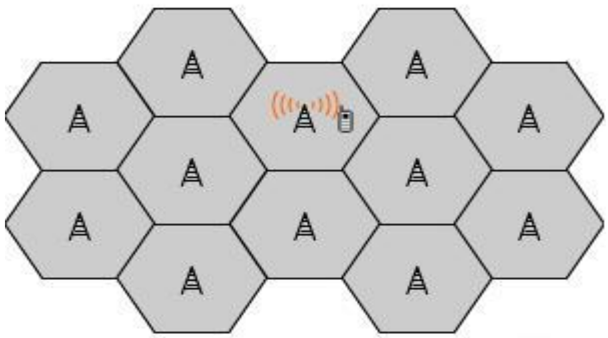


Figure 1.5: Hexagonal coverage area

1.3.3 Power control and net work capacity

Special designs for the distribution of the stations must take into account configurations that achieve reliability and high efficiency. A particular solution is the re-use of the frequencies available, provided that the same frequencies are not reused in adjacent neighboring cells as that would cause co-channel interference. There are special protocols to insure efficient use with minimum cross talk or conflict.

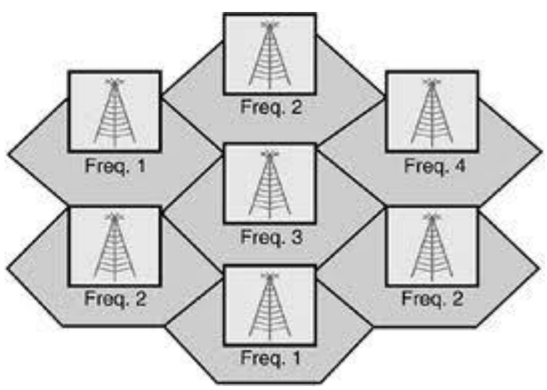


Figure 1.6: Frequency reuse and cellular structure

1.4 General technical aspects

Radio signals are fed through cables to the antennas and then launched into the area, or cell, around the base station. A typical large base station installation would consist of a plant room containing the electronic equipment as well as the mast with the antennas.

1.4.1 Electrical characteristics

Due to (radiation safety standards) the intensity of radiation from base stations depends on a number of factors including distance & direction from the station, antenna gain, power output, number of channels used, cables attenuation, and the station location and height. The power density S along the main beam direction can be calculated as a function of distance r from

$$S = NP10^{(G(\theta,\varphi)-L/10)}/4\pi r^2 \qquad (1.1)$$

N is the number of transmitters. **P** is the output power of a single transmitter**. G** is the gain of the antenna and it is a function of two parameters **θ** and φ in decibels that give the degree of focusing of the emitted beam, and will be discussed further later. **L** is the combined loss in decibels from the cable, power splitter, etc.

1.4.2 Field regions

The space around a radiating antenna can be divided essentially into two areas known as the **near field** where the electromagnetic field has cylindrical character and far field (Kamo et al, 2012). In the near field the level of radiation does not depend on the distance from the antenna only, but on the movement in the vertical direction. In the **far field** the electromagnetic field has spherical character and the level of radiation depends mainly on the distance from antenna. This information must be taken into account when taking measurements from the stations in order to get results that are consistent with the theoretical calculations (Kamo et al. 2012).

Equation (1.1) is valid for the far-field region (Karwowski, 2002). In free space for the antenna with overall maximum linear dimension D greater than a wavelength $(D > \lambda)$ the far-field region commonly exist at the radial distance from the antenna r given by

$$r \geq 2D^2/\lambda \qquad (1.2)$$

In the near-field region we can not use equation (1.1). A realistic estimate can be obtained by employing a cylindrical-wave model (FCC, 1997). The cylindrical-wave model assumes inverse distance dependence (1/r), and that spatially averaged plane-wave power density S at the distance r from an omni-directional antenna can be given by dividing the antenna input power P over the lateral area of an imaginary cylinder surrounding the antenna with radius r and height h equal to the aperture height of the antenna.

$$S = P/2\pi rh \qquad (1.3)$$

Compared to the far-field spherical-wave power density inverse squared distance ($1/r^2$) dependence.

1.4.3 Beam shapes and directions

Beams emited from antenna, emition is narrow in the vertical direction with a range from 5° to 10° and the upper level is almost horizental, while the lower level is tilted 10° downward. For typical 25 m anntena height the beam will hit the ground at about 150 meters from the base of the tower and (Mann et al, 2000) The figure 1.7 illustrates this.

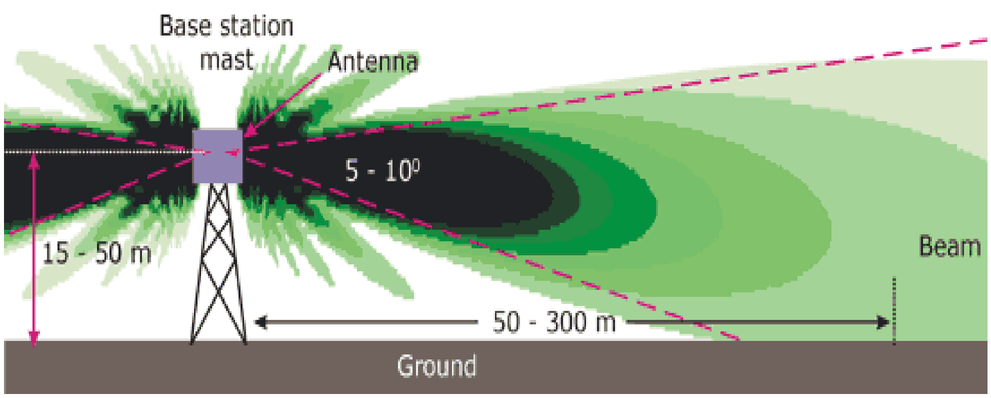


Figure 1.7: elevation showing the shape of the beam by atypical antenna

At distances closer to the mast where the main beam reaches ground level, exposure occurs due to weaker beams known as side lobes. The power density distribution of these lobes is hard to estimate without detailed technical information about the emision beam pattern of the antenna.

1.4.4 Antenna gain

"Gain is an antenna property dealing with an antenna's ability to direct its radiated power in a desired direction, or synonymously, to receive energy preferentially from a desired direction" (Hill, 1976). There are two antenna models to approximate directional antenna patterns: the elliptical area and the rectangular area approximations (Antenna introduction/Basics).

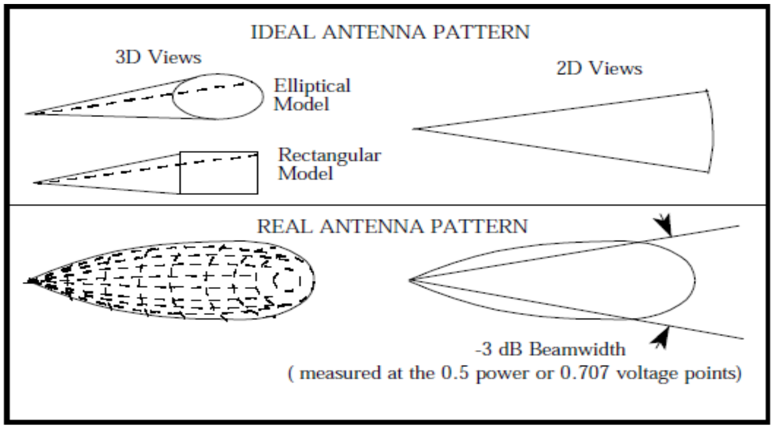


Figure1.8: Antenna beam width

Assuming a uniform antenna pattern, the gain can be given by area of sphere/antenna pattern area

It can be shown that G= $4\pi/(BW_{\varphi az}\ BW_{\theta el})$ or $4\pi\ /\varphi\ \theta$ (radians) Where $BW_{\varphi az}$ = azimuth beam width, and $BW_{\theta el}$ = elevation beam width (radians).

For the elliptical approximation:

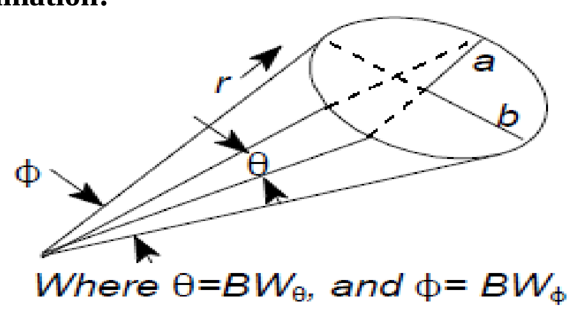


Figure 1.9 Elliptical area

The area of elipse = π a b = π [(r sin θ)/2] [(r sin φ)/2]= $(\pi r^2 \sin\theta \sin\varphi)/4$

$G = 4\pi r^2/ (\pi r^2 \sin\theta \sin\varphi) = 16/(\sin\theta \sin\varphi)$. For small angles, $\sin\theta = \theta$

G= 16 /θ φ (radians) = 52525/θ φ (degrees) or G_{max} (dB) = 10 log (52525/θ φ (degrees).

For a Rectangular Area

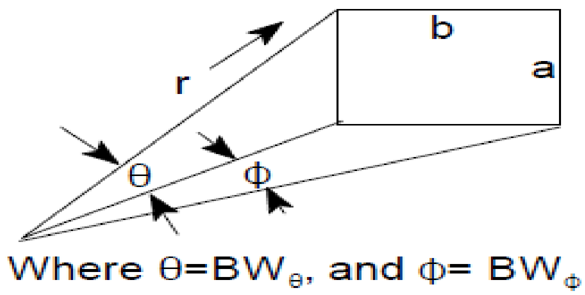


Figure 1.10 Rectangular area

Area = $r^2 \sin\theta \sin\varphi$

$G = 4\pi r^2 / (r^2 \sin\theta \sin\varphi) = 4\pi / (\sin\theta \sin\varphi)$. For small angles

$G = 4\pi / \theta\,\varphi$ (radians) = $41253/\theta\,\varphi$ (degrees) or Gmax (dB) = 10 log ($41253/\theta\,\varphi$ (degrees).

We note that the antenna gain depends on the angles θ and φ and the two models give close results.

1.5 Microwaves links

Base stations communicate with other neighboring base stations in order to relay calls between mobile phone users in two different cells and connect calls into other networks. In some cases this is achieved using cables but it is more usual to communicate via microwave links (Mann et al.2000).

1.6 The Mobile Systems used in Palestine

The GSM (Global System for Mobile) uses digital systems. It is adopted by Jawwal Company in Palestine, and the system is made up of a network of mobile base stations that cover octagon areas. The base stations continuously send and receive signals for mobile exchanges that direct traffic and keep track of where in the network each activated mobile call is initiated and sent (Walke, 1999).

The GSM system operates at 900MHz or 1800 MHz bands. The 900 MHz band utilized in Palestine is divided into two sub bands the uplink (890-915 MHz) used by mobile phones, and the downlink (935-960 MHz) used by base stations, Signals transmitted from the towers are within the frequency band 955.2-960 , the GSM-1800 uses 1,710–1,785 MHz to send information from the mobile station to the base transceiver station (uplink) and 1,805–1,880 MHz for the other direction (downlink), MHz while signals transmitted by mobile phones are within the band 910.2-915 MHz (Sempere, 1997)

Chapter Two

Health Regulatory Limits

Chapter Two

Health Effects Regulatory Limits

"The human body can respond positively to electromagnetic fields. The reactions are used in medicine for healing purposes (e.g. diathermy, hyperthermia)" (Baldauf et al.2002). Unfortunately the effects resulting from exposure to electromagnetic fields can also be adverse. These effects may be sub classified into **thermal** and **non-thermal** or A-thermal effects. Whereas the thermal effects are well studied much work is needed for the A-thermal effects.

2.1 Thermal effects regulations

Biological effects resulting from heating of tissue by RF energy are thermal effects. It is known for that exposure to high levels of RF radiation can be harmful due to the ability of RF fields to rapidly heat the tissues (Hyland, 2000). The use of microwaves in cooking is an established technology.

Thermal effects were discovered by D'Arsonval in 1892. Absorbed in tissues, microwave energy produces heat and the temperature rises and harm can happen if the body regulatory mechanisms cannot inhibit overwhelm heating (Hinrikus et al . 2005).

Under certain conditions, exposure to RF power density levels of greater than $10mW/cm^2$ can result in measurable heating of biological tissues (not necessarily damage). The extent of this heating depends on several factors including: radiation frequency, size, shape, and orientation of the exposed object, duration of exposure, environmental conditions; and efficiency of heat dissipation (Cleveland et al. 1999).

Past studies (Saunders *et al.*, 1991; Adair *et al.*, 1999; Adair *et al.*, 2001) indicate that a temperature rise of about 1K due to RF can affect memory and learning. At lower levels of exposure (lower than the threshold that causes heat), the evidence of harmful biological effects is not established, but it may cause some non thermal effects (FCC).

2.1.1 Regulations Standards (for thermal effects) in units of W/kg and W/m^2

Many of the existing safety guidelines governing controlled/uncontrolled exposure are based on their thermal impact (Nageswari, 2003). The standards that limit microwave exposure were set at 0.4 W/kg SAR for occupational and 0.08W/kg for public exposure. The average time for the determination of SAR is 6 minutes. SAR is defined as (Pllana et al. 2008):

$$\mathbf{SAR = \sigma E^2/ \rho_m} \qquad \mathbf{(2.1)}$$

$\boldsymbol{\sigma}$ is the conductivity of body tissue, E the root mean square of intensity of the electric field at the point of concerning $\boldsymbol{\rho_m}$ is the mass density of tissue. Since SAR, is very difficult and complex to measure in biological tissues, the standards permit using reference levels of power density (W/m^2) in free space. In this section we present four major exposure standards. Tables 2.1-2.4

1- U.S. Federal Communications Commission (FCC) Regulations.
2- Electrical and Electronics Engineers (IEEE) standard.
3- Canada's Safety Code 6 Regulations.
4- International Council on Non-Ionizing Radiation Protection (ICNIRP) guidelines.

1 - U.S. Federal Communications Commission (FCC) Regulations

Table 2.1 The FCC MPE limits for controlled exposure and for uncontrolled exposure

Occupational/Controlled Exposure		**General Population/Uncontrolled Exposure**	
Frequency (MHz)	**Power Density (mW/cm^2)**	**Frequency (MHz)**	**Power Density (mW/cm^2)**
0.03–1.34	100	0.03–1.34	100
1.34-30	$900/f^2$	1.34–30	$180/f^2$
30–300	1	30–300	0.2
300–1,500	f/300	300–1,500	f/1500
1,500–100,000	5	1,500–100,000	1

*Note: f as indicated in the frequency range column

These limits are generally relaxed compared to other more stringent limits that take into account non thermal possible effects. Two different limits are provided for the general public (non-occupational) and workers in the workplace (occupational) and they are less restrictive than non-occupational since some control can be applied over the condition and duration of exposure.

2- Institute of Electrical and Electronic Engineers (IEEE) Standards

Controlled Environments		**Uncontrolled Environments**	
Frequency (MHz)	**Power Density (W/m^2)**	**Frequency (MHz)**	**Power Density (W/m^2)**
0.1–1.0	9,000	0.1–1.34	1,000
1.0–30	$9{,}000/f^2$	1.34–30	$1{,}800/f^2$
30–300	10	30–400	2
300–3,000	f/30	400–2,000	f/200
3,000–300,000	100	2,000–100,000	10

Table 2.2 The IEEE MPE limits for controlled and uncontrolled Environments.
*Note: f as indicated in the frequency range column

3- International Commission on Non-Ionizing Radiation Protection Guidelines

Occupational Exposure			**General Public Exposure**		
F (MHz)	**E (V/m)**	**PD (W/m^2)**	**F (MHz)**	**E (V/m)**	**PD (W/m^2)**
0.065–1.0	610		0.15–1.0	610	
1.0–10.0	610/f		1.0–10.0	$87/f^{1/2}$	
10–400	61	10	10–400	28	2
400–2,000		f/40	400–2,000		f/200
2,000–300,000		50	2,000–300,000		10

Table 2.3 ICNIRP limits for occupational exposure and for the general public
*Note: f as indicated in the frequency range column

In many countries the allowed values follow the ICNIRP guidelines (Mousa, 2011). ICNIRP adopted the limits guidelines published in 1998, and endorsed by WHO are based on the following:

1. Available scientific research on thermal effects with large safety margins.
2. Protecting people from established adverse health effect due to short and long term exposure.
3. Setting limits for both general public and occupational exposure.

4-Canada's Safety Code 6 Regulations.

Uncontrolled Environments			**Controlled Environments**		
F (MHz)	**E (V/m)**	**PD (W/m²)**	**F (MHz)**	**E (V/m)**	**PD (W/m²)**
0.003–1.0	280		0.003–1.0	600	
1.0–10.0	280/f		1.0–10.0	600/f	
10–300	28	2	10–300	60	10
300–1,500		f/150	300–1,500		f/30
1,500–15,000		10	1,500–15,000		50
15,000–150,000		10	15,000–150,000		50
150,000–300,000		6.67×10^{-5}f	150,000–300,000		3.33×10^{-4}f

Tables 2.4 The Canada's limits for uncontrolled and controlled environments.
*Note: f as indicated in the frequency range column

2.2 A-thermal effects and the world limits

2.2.1 New standards and considerations

There is a considerable body of scientific literature which describes effects of RF radiation in biological systems that cannot be directly attributed to heating. According to (Australian Radiation Protection, 2011) "Low levels of RFR have been demonstrated to cause alteration in animal behavior or changes in the functioning of cell membranes". These low level effects, often referred to as A thermal or non-thermal, are controversial but cannot be ignored.
The ICNIRP limits are relaxed compared to many others. Swiss' ONIR (Ordinance Relating to protection from Non Ionizing Radiation, 1999) values for installations at places of sensitive use are over 1000 times smaller. ONIR Places of sensitive use are: buildings that are regularly occupied by persons for prolonged periods or public or private children's playgrounds designated in spatial planning legislation. Table 2.5 shows a comparison between ONIR and ICNIRP.

The (Salzburg Resolution, 2000) recommended an out door exposure of less than 0.001 W/m^2 in publicly accessible areas around a base station. This is 4500 times lower than the FCC guideline value. The Salzburg Resolution defines the intensity below which no health effects have been reported for comparison. Thermal official threshold, other non-thermal recommendations, and cellular tower exposure reference values are listed in the Table 2.6 (Haumann and Sierck, 2002).

Regulation	**f in MHz**	**Eeff in V/m**	**Heff in A/m**	**S in mW/cm^2**
ICNIRP	400-2000	$1.375f^{1/2}$	$0.0037f^{1/2}$	0.00051•f
ONIR	900	4	0.0106	0,0042
ONIR	1800	6	0.0159	0.0095
ONIR	900 & 1800	5	0.0133	0.0066

Table2.5 Swiss ONIR vs. ICNIRP Limits for the effective electric field Eeff, magnetic field Heff and power density. *Note: f as indicated in the frequency range column

Standard threshold values and recommendations for non ionizing radiations GSM1800/GSM900	**Power Density W/m^2**
FCC/USA	10
Germany, England , Finland and Japan	10
Belgium	1.2
Switzerland and Italy	0.09
Ecology Study, Germany	10^{-2}
Salzburg. Austria	10^{-3}
High exposure	10^{-4}
EU parliament	10^{-4}
Low exposure	10^{-5}
Night time exposure, Bau-biology Standard	10^{-7}
Successful communication with GSM mobile phone system coverage	10^{-9}

Table 2.6 Comparison of standard threshold values and recommendations

2.2.2 World Health Organization recommendations

According to the World Health Organization (WHO) it will take some years for the RF research to be completed, evaluated and to publish final results of any health risks. In the meantime. WHO recommends

1. Strict adherence to health-based guidelines developed to protect everyone in the population including mobile phone users, those who work near or live around base stations.

2. Introduction of additional precautionary measures if the adopted health-based guidelines don't receive acceptable response from the general public out of concerns of potential risks.

2.2.3 Limits in Palestine

The official limit set in Palestine as given by Ministry of Telecommunication is 4.5W/m^2. According to the Ministry of Environment Affairs the safety limit in Palestine is set to 0.04 of the ICNIRP limit or 0.18 W/m^2 outdoor and 0.018 W/m^2 indoor.

(الوقائع الفلسطينيه , العدد الحادي والثمانون)

The Ministry numbers are fairly good. But it is not clear which limit is binding legally for actual enforcement.

2.3 Scientific Research on A thermal effects

The case for considering athermal effects has many reason for. The scientific research generally unveiled strong evidence of potential harm and risks. In this section we present a summry of research and studies that justify the limits recommended that take into account these effects.

2.3.1 Theoritical basis for the athermal effect case

Microwave radiation generally does not ionize molecules or atoms. The thermal effects were discussed and risk can start if the total heat intake is larger than the disptation resulting in a rise of temprature that can harm the delicate human biological sytems.

Carrying out calculations to explain what actually happens beyond thermal effects is hard because the system is large and the radiation is generally small.

For neutral objects and atoms the non thermal effects seem to be out of consideration simply because there is no mechanism to explain how the harm can occur. Cancer or other effects seem to have no justification.

But we have to consider the following process. The microwave can penetrate the body and the mean penetration depth for the mobile waves in question is around few cms. This means the radiation can inter the biological system, and the waves can interact with the molecular structure or at least initiate exiations [rotational or vibrational modes can be exited by the energy carried by the microwave.)

For the exiation modes we do not break or ionize the moleculers but they can result in effects beyond estimation or expectation because they are highly random and non linear..

The problem becomes more serious if we consider ions and molecules that can open for essential biological operations. (building DNA and RNA passes through stages of opening and closing of the structures). Ions within the brain and heart and over all the nervous system move all the time in their ionic and charged states. These forms certainly are affected by the microwave radiation beyond the thermal factor. This is a simple and a matter of fact. A free charged particle is influenced by an EM field yeilding a dynamic change. This is the main principle behind all accelerating methods from the simple cathode ray tube to the highest energy accelerator.

The design and operation of high energy accelrators is based on the principle of providing RF radiation to accelerate charged prticles. These particles can aquire speeds very close to the speed of light, and energies trilions of electron volts. The mechanism to reach such levels is to synchronise the impact of the microwave electric field to provide maximum kick to the charged particles and repeate the kiking periodly until the particles reach the desired energy. For interested readers in charged particle accelerators please see (Humphries, 1976).

In our case we don’t have the synchronization and the field strength is generally small, but the main dynamic is the same. The RF microwave raditaion photons carry a small electric field. When they hit a charged ion whithin the biological cell they can accelerate the charge particle according to the Lorentz Force.

The accleration force is equal to qE and qvB. Neglecting the magnetic field the effective electric field component for power densities of $5 W/m^2$ (FCC limit) is about 45 volts/m. The field acts on a sodium ion Na^{+1} with a force $F=q\,E = 7.2 \times 10^{-18}$ N, and acceleration

$a = 1.886 \times 10^{8}\ m/s^2$.

For a typical mean free path of 1 nm in the body and at body temperature of 37^o (310K) the ions thermal speed is about 100 m/sec. At this speed the inter-collision time is about 10^{-11} seconds. In such time the particle can acquire a velocity component in the order of 1mm/sec in the field direction. It seems negligible compared to the thermal speed. But it is directional and can result in a net motion along the field direction for long exposures.

For ions localized within a nerve connection this can result in a net change to the distribution relative to other charged particles. Taking the voltage within the brain for most signals in the order of mV and a separation distance in the order of micrometer. The typical field values are bout 1000 volt/m. the microwave field is about 5-10% and we expect an observable effect of the same order. If we take a nerve cell firing mechanism dependence on the potential at the junctions a change of 10% can result in a dramatic change in the firing patterns.

That can certainly influence the whole charge structure of the brain or heart and influence the power and firing. Even though the thermal motion is much larger it is misleading to ignore the potential effects especially non linear ones.

Preliminary calculations by (Salman, 2010) suggest indicators for possible A-thermal effects of the microwave radiation on the neural system. We hope these studies will provide informed basis for setting limits that include the A-thermal effects.

2.3.2 Experimental Research

General review and observations

Experimental evidence of non-thermal influences of microwave radiation on living systems has been published in the scientific literature during the last 30 years. We review the most important aspects (Kholodov, 1966; Baranski and Edelwejn, 1975). Their conclusion is that the most sensitive part to the EMF exposure is the nervous system with changes in the electrical activity in the brain. (Von Klitzing, 1995) and increased permeability of the blood-brain barrier in rats (Persson, 1997). Others reported possible non thermal effects include (Stoa, 2001):

1- Observation of an increase in resting blood pressure during exposure.
2- Increased permeability of the erythrocyte membrane.
3- Effects on brain dopamine/opiate and calcium efflux electrochemistry.

4- Increase of chromosome aberrations and micronuclei in human blood lymphocytes.

5- Synergistic effects with cancer promoting drugs and certain psychoactive drugs.

6- Depression of chicken immune systems.

7- Increase in chick embryo mortality.

8- Increase in *DNA* strand breaks in rat brain.

9- Stressful effects in healthy and tumor bearing mice.

10- Neurogenetic effects and micronuclei formation in peritoneal macrophage.

Based on the previous indicators many states have lowered the standards for radiation. A threshold of 1,000 $\mu W/m^2$ was pointed out for non-thermal biological effects. For locations with any long-term exposure, a further safety factor of 10 was recommended for pulsed cellular phone radiation sources as cellular phone base stations. In this case, the power densities should not exceed 100 $\mu W/m^2$ (Haumann and Sierck, 2002).

Specific experiments

Mustafa et al: (Mustafa et al, 2001): A recent study on 12 human volunteers exposed to continuous cell phone emissions for up to 4 hours showed a slight but statistically significant oxidative stress response and a consistent rise in plasma levels of liquid peroxides combined with decreased levels of antioxidases in the erythrocytes.

Tallinn university biomedical center: (Hinrikus et al. 2005): An Experiment conducted at the Biomedical Engineering Center Tallinn University of Technology in 2005 focused on the origin of interaction mechanism of microwave radiation with nervous system or quasi-thermal field effect. The microwave field can cause fluctuations and vibration to the motion of charged particles and membranes in tissues.

The team applied a 450 MHz microwave radiation modulated at 7, 14 and 21 Hz frequencies with power density at skin of 0.16 mW/cm^2,. The experimental protocol consisted of two series of five cycles of the repetitive microwave exposures at fixed modulation frequencies. Relative changes in EEG theta, alpha and beta rhythms of the group of 13 healthy volunteers were analyzed. Analysis of the experimental data showed that:

- Statistically significant EEG rhythms dependence on modulation frequency.
- Microwave stimulation causes an increase of the EEG energy levels.

- The effect is most intense at beta1 rhythm and higher modulation frequencies.

Concluding that the RF fields can produce a wide range of measurable biological effects. In addition to what can be measured at the present stage of scientific investigation, it is likely that other unknown effects remain to be discovered

2.3.3 Epidemiological studies

According to (Kumar , 2010) There have been several epidemiological studies of people living near cell phone antennas in Spain, the Netherlands, Israel, Germany, Egypt, Austria, etc. All these studies document adverse health effects and exposures are orders of magnitude below the FCC or ICNIRP guidelines. Some of these studies are summarized below:

FRANCE

A study was conducted on base stations for mobile phones, from this study people in the vicinity of base station suffering from the following diseases. Fatigue, sleep disturbances, headaches, feeling of discomfort, and difficulty in concentrating, depression, memory loss, visual disruptions, irritability, hearing disruptions, skin problems, cardiovascular disorders, and this study recommend that the cellular phone base stations should not be sited closer than 300 m to populations. This is probably not possible in urban area, so the solution is to reduce the transmitted power level.

GERMANY

The study aim was to find the relationship between malignant tumors and living near mobile stations the researchers found that the proportion of newly developing cancer cases was significantly higher among those patients who had lived within 400 meters from the cellular transmitter site during the past 10 years, compared to those patients living further away. Examples of such tumors. Pancreas, bowel, skin melanoma, and lung and blood cancer were all increased.

SPAIN

Study created a relationship between the people live near the stations and diseases fatigue, sleeping disorder, difficulty in concentration and cardiovascular problems. The scientists reported the following symptoms within 50 to 150 m of the cell phone antenna at an average power density of $0.11 + 0.19\ \mu W/cm^2$. We Note that $0.11\ \mu W/cm^2$ is considerably lower than

1000μW/ cm^2 established by the FCC. This demonstrates that the FCC guideline does not protect the public from radio frequency radiation exposure.

SWEDEN

Survey studies show that somewhere between 230,000 - 290,000 Swedish men and women out of a population of 9,000,000 are now electro hypersensitive (EHS) and report a variety of symptoms when being in contact with electromagnetic field sources. Symptoms include- allergic reactions, redness of skin, memory loss, sleep disruption, headache, nausea, tingling, altered reflexes, buzzing in the head, palpitations of the heart, visual disorders, cardiovascular problems, respiratory problems etc

AUSTRALIA

The Australian Health Research Institute indicates that due to billions of times more in volume electromagnetic radiation emitted by billions of mobile phones, internet, intranet and wireless communication data transmission, almost one-third of world population (about 2 billion) may suffer from Cell Phone Cancer beside other major body disorders like heart ailments, impotency, migraine, epilepsy by 2020.

Chapter Three

Measurements

Chapter Three

Measurements

This chapter describes the hardware and equipment used to measure the density of the intensity of electromagnetic radiation to a total of ground stations, describe the process of taking measurements analysis of measurements for measuring sites

3.1 Instrumentation

I used a device called a (NBM-550 Narda Broadband Field Meter) with probe EF0391 (NBM) 100kHz -3GHz to measure the density of the intensity of electromagnetic radiation at levels comparable with investigation /reference levels given in protection guild lines, In addition to the use of computer in the analysis of measurements.

Figure 3.1 - NBM-550 Narda Broadband Field Meter

I also used ladders of different lengths in order to take measurements of the intensity of radiation along the main beam above the ground level.

3.2 Theoretical Calculation of power densities along the main beam

As mentioned above in section 1.4.1 the far-field spherical-wave power density model based on inverse squared distance ($1/r^2$) so by the use of equation (1.1) one can calculate the power density of Kathrein antenna (X Pol Panel 790-960 15 dBi gain) at some selected point in the main beam and the following figure show the relation

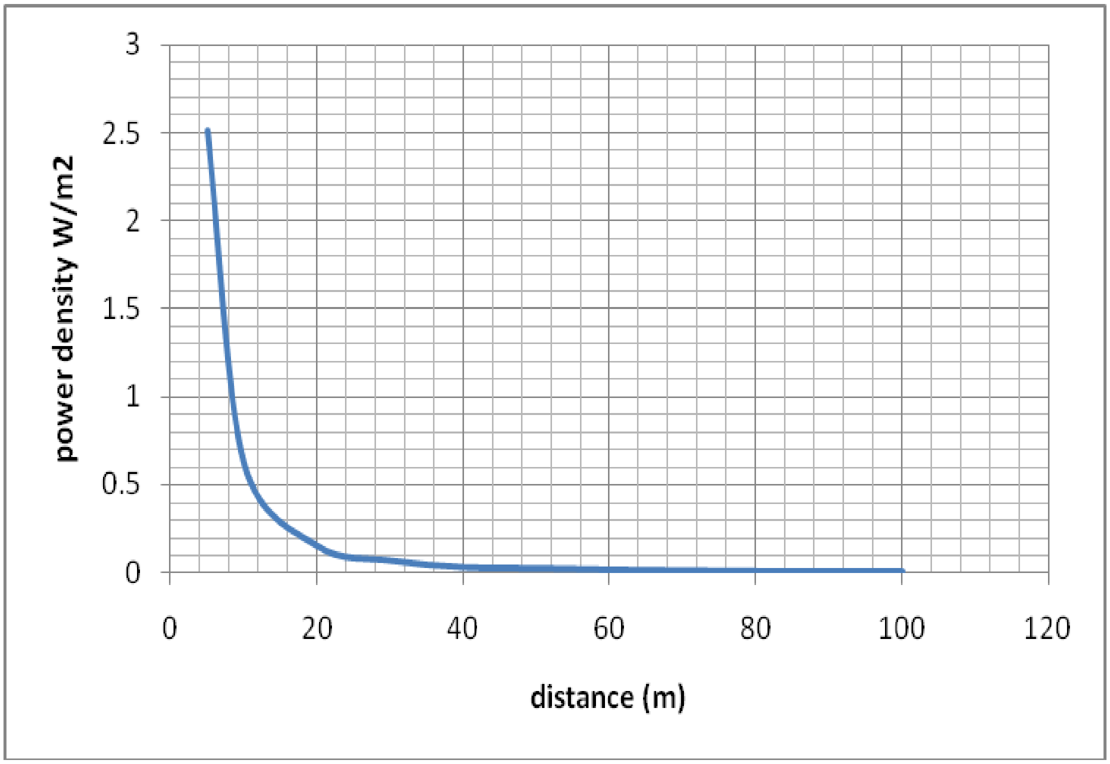
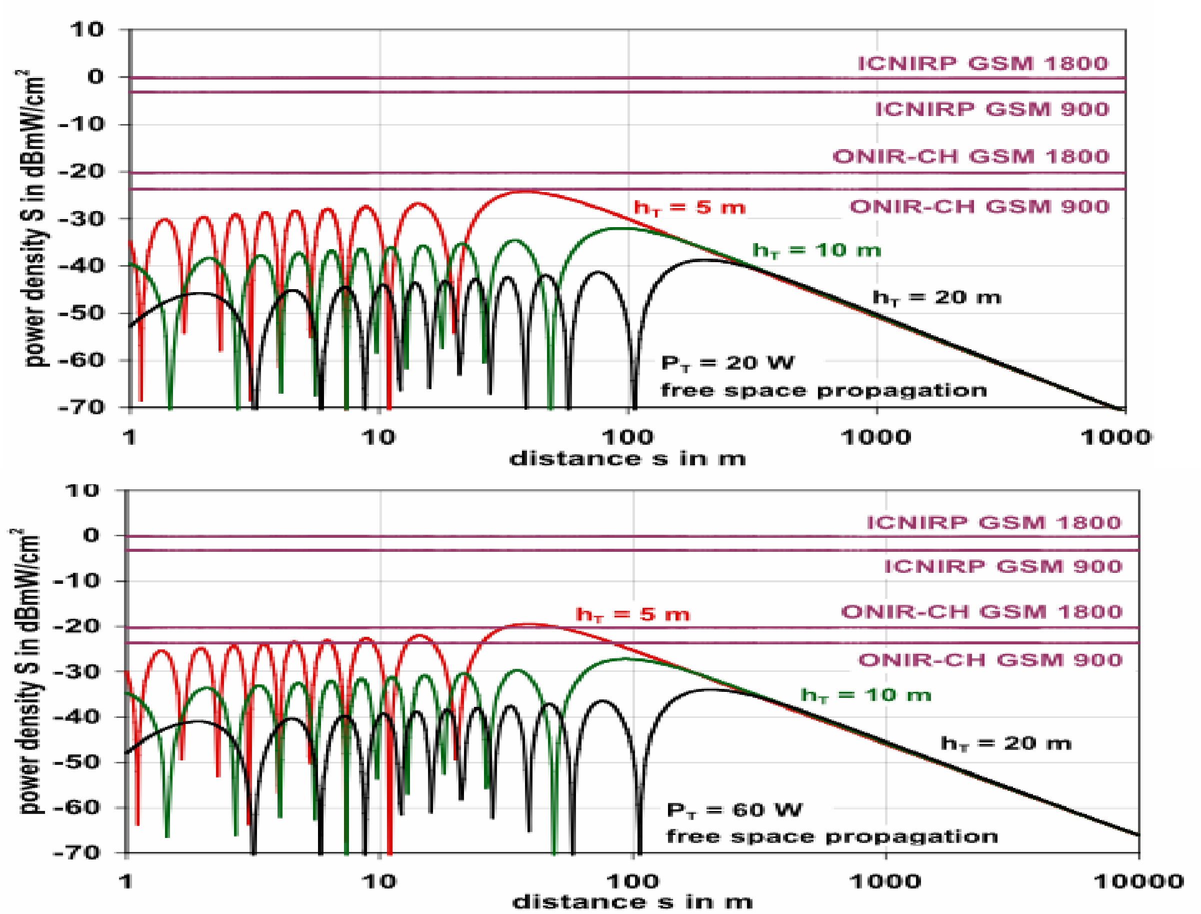


Figure 3.2 Calculated power density distributions as a function of distance for GSM 900 antenna producing EIRP of 800 W. (pt=50W, G= 15 dBi , L= 3dbi).

3.3 Theoretical Calculation of power density at ground level

As we mentioned in section (1.4.1) the gain of antenna is a function of θ, φ so if one knows the gain at the point of measurement at the ground level one can find the power density using equation (1.1). Due to (Baldauf et al, 2002) figures 3.3 and 3.4 show the power density distribution as a function of distance from the station.



Figures 3.3 & 3.4: Power densities 1.5 m above the ground depicted for different antenna heights. G_T = 18 dBi. Transmitting powers are P_T = 20 W and P_T = 60 W The horizontal lines denote the limit values according to the ICNIRP guidelines and the Swiss' ONIR at places of sensitive use, respectively.

The non-monotonous behavior, can be seen up to a distance of several tens meters from the antenna. It originates from the side lobes of the vertical antenna pattern. Increasing the antenna height shifts the maximum power density further away from the antenna. The maximum power densities are lower there because of their $1/r^2$-dependence. The oscillatory behavior extends to about 6 times the height. Recalling from page 8 and figure 1.7 this is in fact the place where the beam hits the ground.

Lowering the antenna height and/or increasing of transmition power leads to power densities that can easily exceed the Swiss' ONIR limit values for installations at places of sensitive use. In countries where comparable low limit values are introduced some sites can be lost.

To avoid this situation, power densities in the vicinity of base stations have to be reduced. In the next section we will show how this can be achieved.

3.4 Safety distances calculation in the main beam

To estimate the safety distances along the main beam we solve equation (1.1) for r, using the limiting value of $S_{\lim}$ **for** the standard in question. The calculated safety distances done by Baldauf et al. are given in Table 3.1. For the calculation they used mid-downlink frequencies fmid, dl = 942.5 MHz (GSM 900) and f mid, dl = 1842.5 MHz (GSM 1800), respectively. Antenna data: G_T = 18 dBi, DAZ = λ/2, DEL = 14λ/2.

		safety distances $r_{\lim}$ in m			
transmitting power P_T		GSM 900		GSM 1800	
in watt	in dBmW	acc. to ICNIRP	acc. to Swiss' ONIR[1)]	acc. to ICNIRP	acc. to Swiss' ONIR[1)]
5	37	1.86	24.30	1.49	16.21
10	40	2.95	34.39	2.21	22.93
20	43	4.38	48.65	3.20	32.44
50	47	7.11	76.94	5.13	51.29
80	49	9.06	97.32	6.51	64.88

Table 3.1: Safety distances in the main lobe direction for typical transmitting powers resulting from different regulations or guidelines (Baldauf et al. 2002).

For transmitting powers up to 50 watts the safety distances are below (7.11) m according to the ICNIRP guidelines and below (76.94) m according to the Swiss' ONIR at places of sensitive use.

3.5 The process of taking measurements

Two methods were adopted to take measurements from the selected base stations.

3.5.1 Measurement along the main beam

Under this heading measurements of the intensity of electromagnetic radiation were taken at points located along the line of the main beam connecting the top of the tower and the earth level. The use of ladders of different lengths was important to reach to those points. on other hand to facilitate taking the measurements we selected low towers. Figur 3.5 shows the setup.

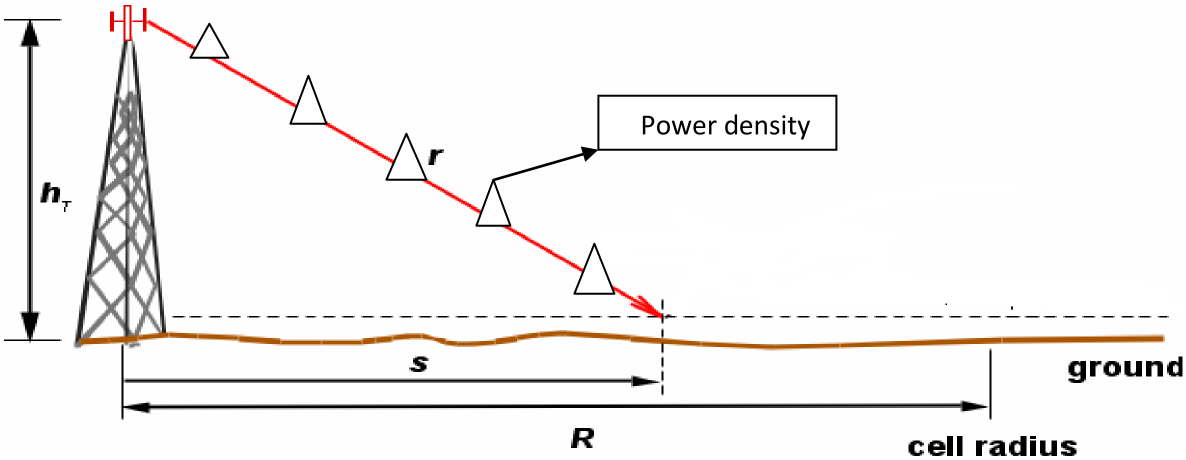


Figure 3.5: Delineated triangles indicate points of measurement

We expect the power density dependance on distance will follow the inverse square law as discused in section 1.4

3.5.2 Measurement along the ground level

Under this heading the power density was measured at the 1.75 m above the ground for a range of points located along the line connecting the base of the station to the crossing point of the main beam as shown in figure 3.6.

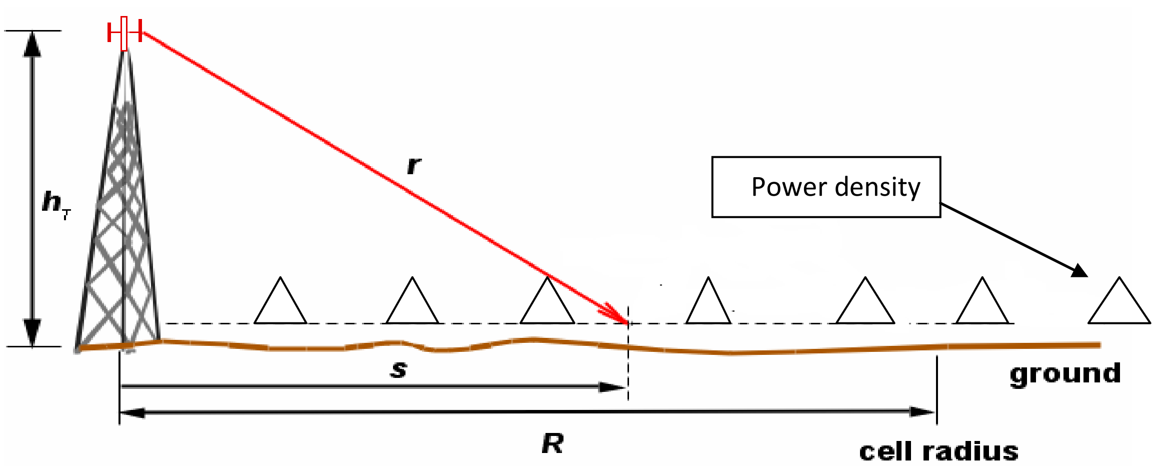


Figure 3.6: Delineated triangles indicate points of measurement

Theoreticaly we expect to see power densities within the proximity of the station and the further we awaty we move the behaviour follows the inverse square low. The actual data varied from this behavior as the figures (3.7 - 3.10) show.

3.6 Analysis of measurements of the sites chosen

When we selected the stations we considered the ones that are located within dense populated areas, and with easy access for a long the lobe measurements. This is important because in some locations the station are closer than 100 m to the nearest home and that can have strong influences. But such option was not always feasible. Sometimes the access was not possible because of the private homes. Overall the net optimum choices are tabulated in Table 3.2

Code	Location	GSM Power (W)	Height (m)	Gain (dBi)	Loss (dBi)
A1	Ramallah mail box building	50	6	12	3
A2	Ramallah municipal building	50	6	15	3
A3	Near Taxi 24 office Tira	50	6	15	3
A4	Near Ericson company(Ramallah)	50	8	15	3
A5	Near Ericson company(Ramallah)	50	9	12.5	2
A6	Al Bireh near java company	50	9	12.5	2
A7	Tira near Saria building	50	10	15	3
A8	Near Jawwal company	50	11	15	3
A9	In Birzeit	50	12	15	3
A10	Near best buy	50	12	15	3
A11	Jefna	50	12	15	3
A12	Near Latin school Birzeit	50	15	15	3
A13	In Nablus	50	15	15	3
A14	Near Hulul company	50	18	15	3
A15	Tira near restaurant values	50	19	15	3
A16	In Beitunia near school	50	21	15	3
A17	Near Jawwal company	50	21	15	2
A18	In Beitunia	50	24	17.5	3
A19	In Beitunia	50	30	18	3

Table 3.2 Selected stations specifications and locations.

3.6.1 Graphs of the measurement along the main beam

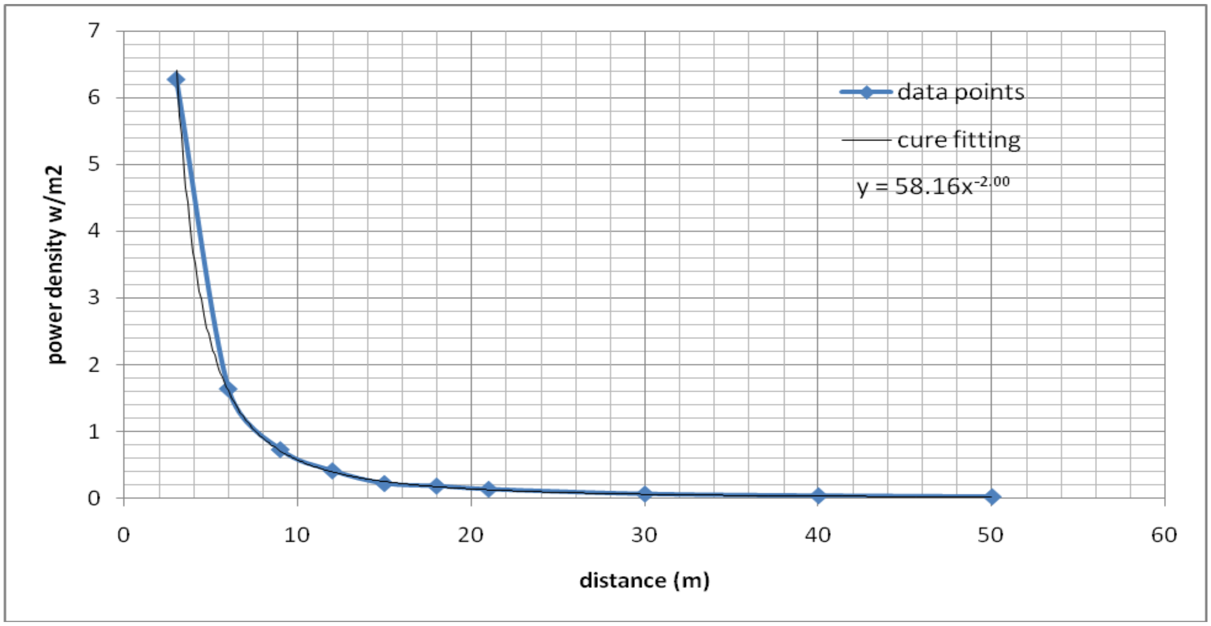


Figure 3.7 Power density vs. distance along the main beam for station A5.

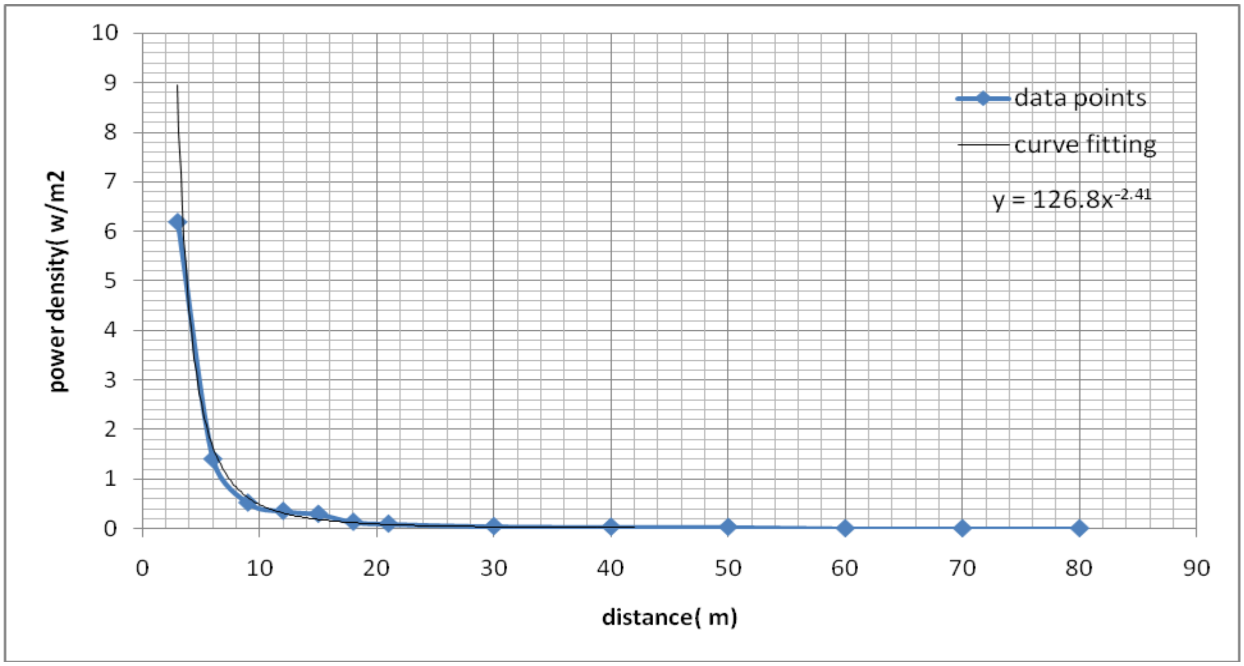


Figure 3.8 Power density vs. distance along the main beam for station A12.

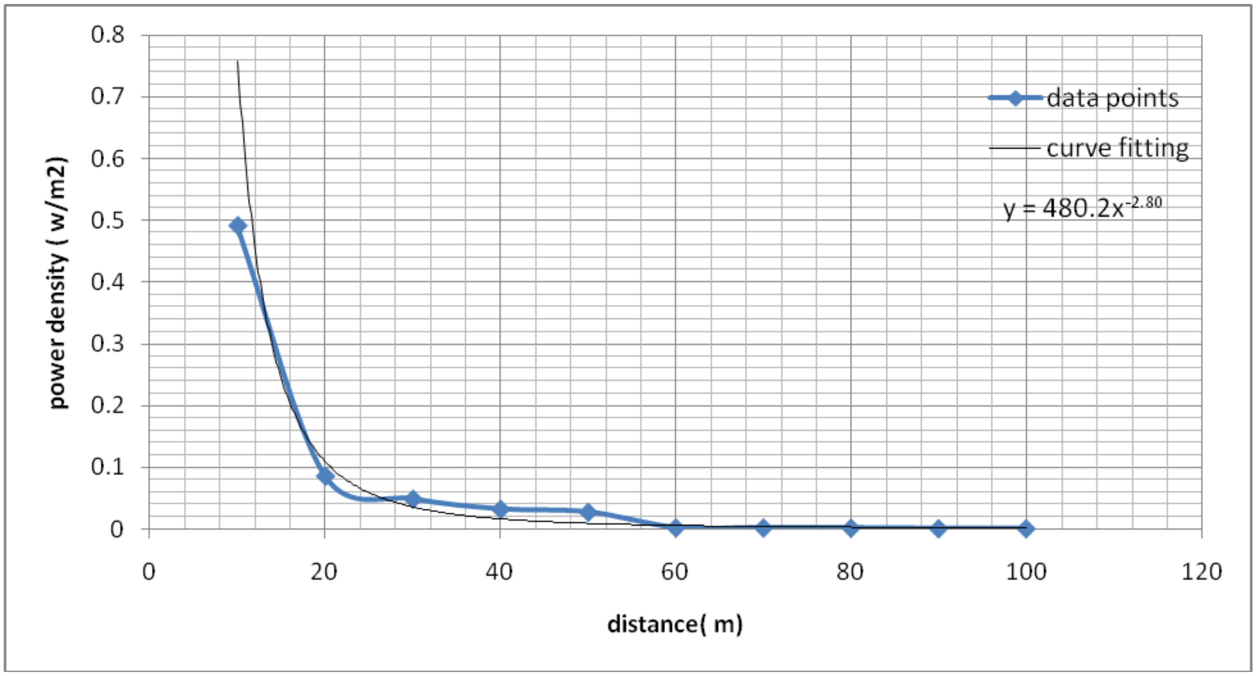


Figure 3.9 Power density vs. distance along the main beam for station A11.

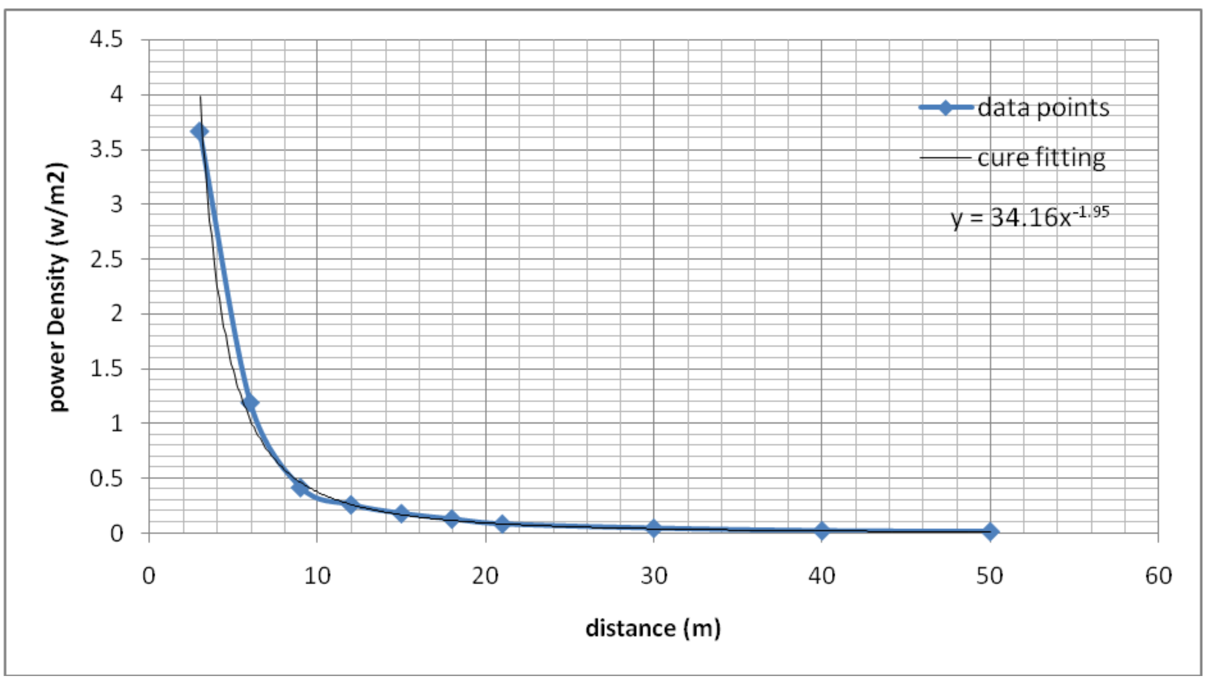


Figure 3.10 Power density vs. distance along the main beam for station A4.

As mentioned previously in section 3.2 the change in the power density along the main beam consistent with equation (1.1) and through the investigation of the previous four stations measured the measurements are consistent with the theoretical results, all readings at distances less than manned less than ICNIRP, but there are some readings fall within the range of ONIR. Telecommunications companies must take into consideration the Safety distance for each base station .

3.6.2 Graphs of measurements at ground level

For the figures 3.11-3.26 the measured oscillatory behavior for all of the stations agrees in principle with the calculations given in figures 3.3 and 3.4. The oscillatory behavior extends to the points where the beams hit the ground. In most stations that was equal to about 7 times the height. However it can be seen that the tilt angle of the various stations was not set steady between 5-10^{o} below the horizontal. In some cases the antenna tilt was large to make the beam hit the ground at shorter distances of 2-3 times the height (A2 and A7). For the far field radiation the spherical-wave gives power densities $1/r^2$-dependence and the measured values agree with the calculations.

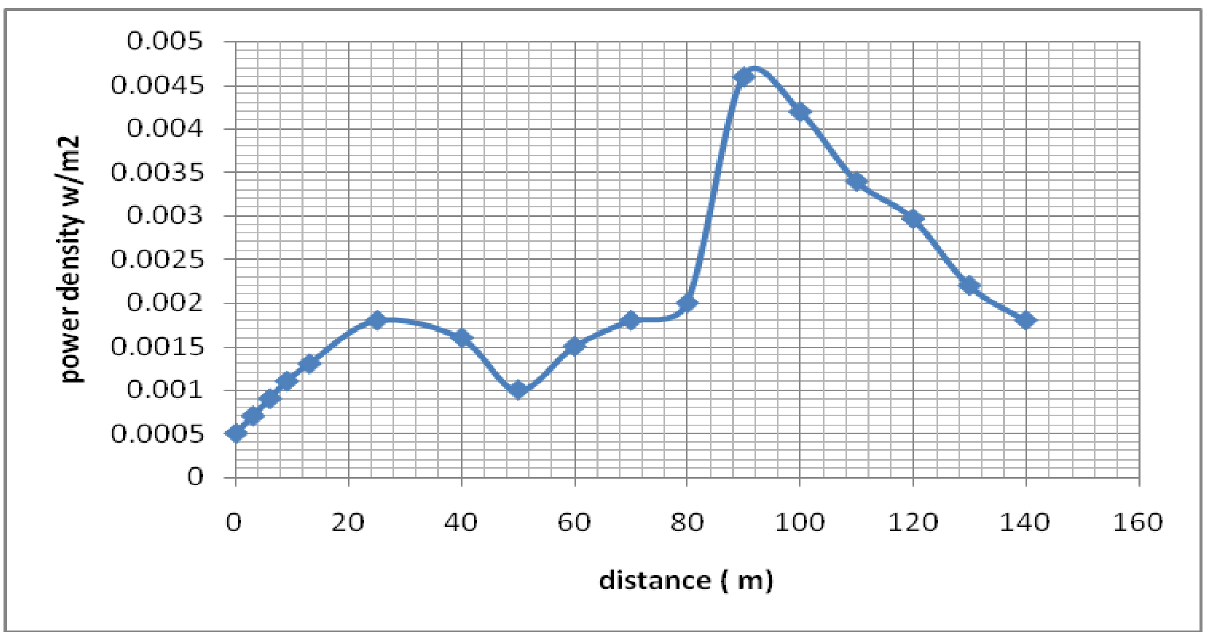


Figure 3.11: Power density vs. distance at ground level for station A8 .

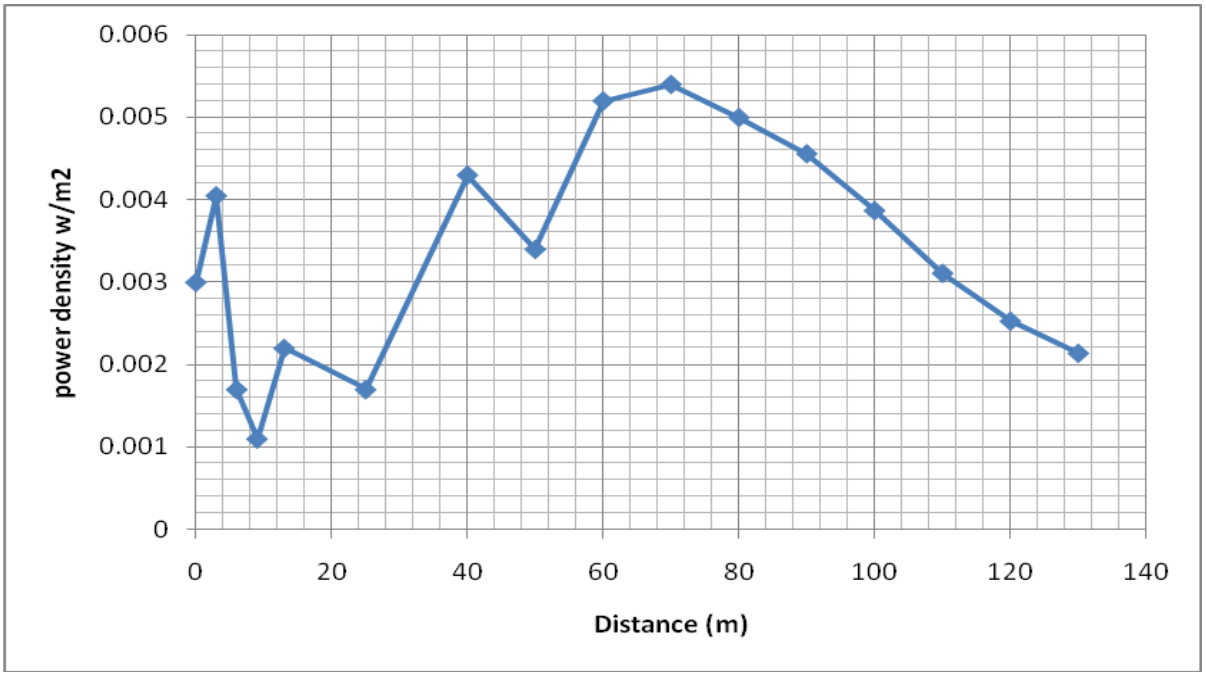


Figure 3.12: Power density vs. distance at ground level for station A6.

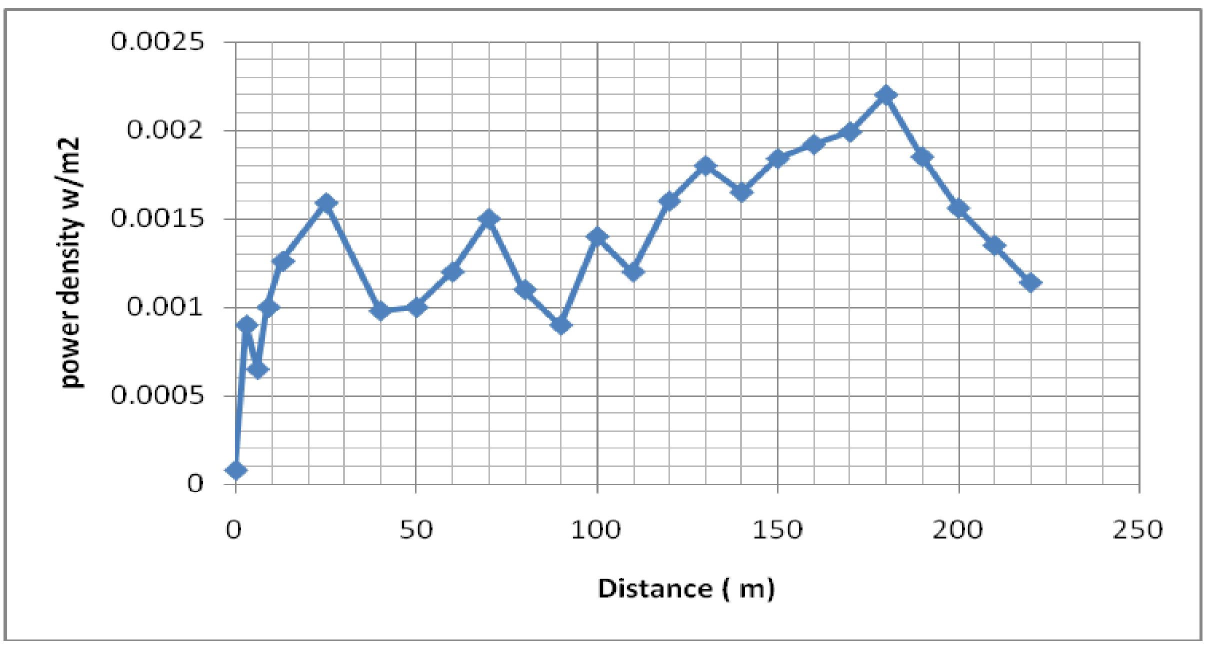


Figure 3.13: Power density vs. distance at ground level for station A17.

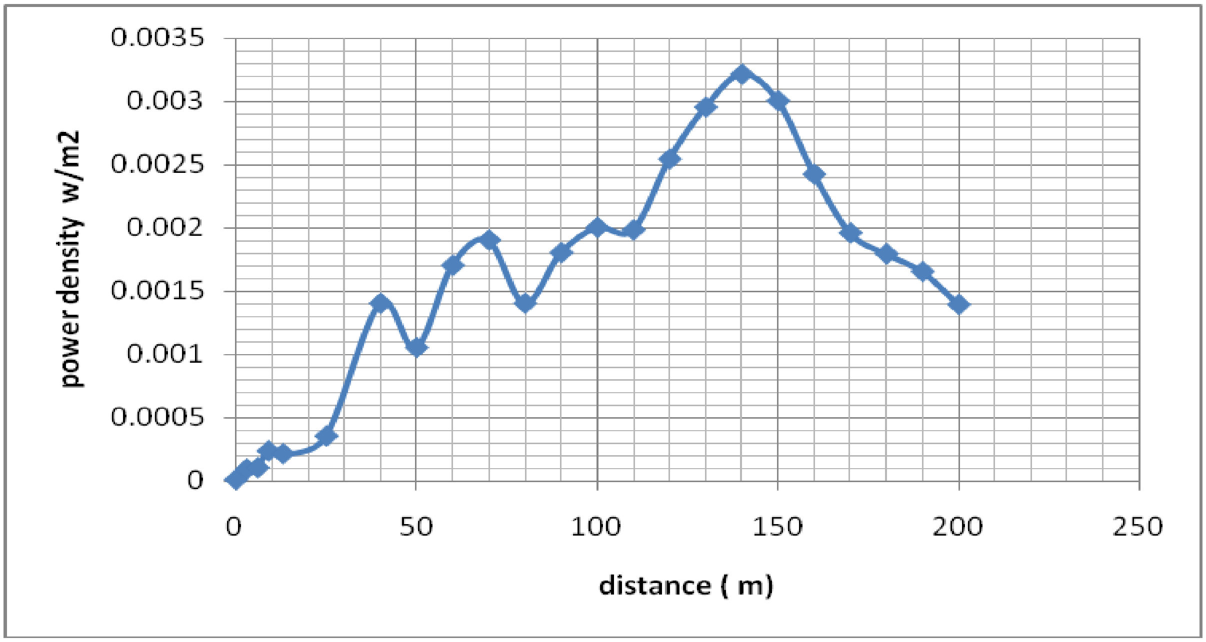


Figure 3.14: Power density vs. distance at ground level for station A14 .

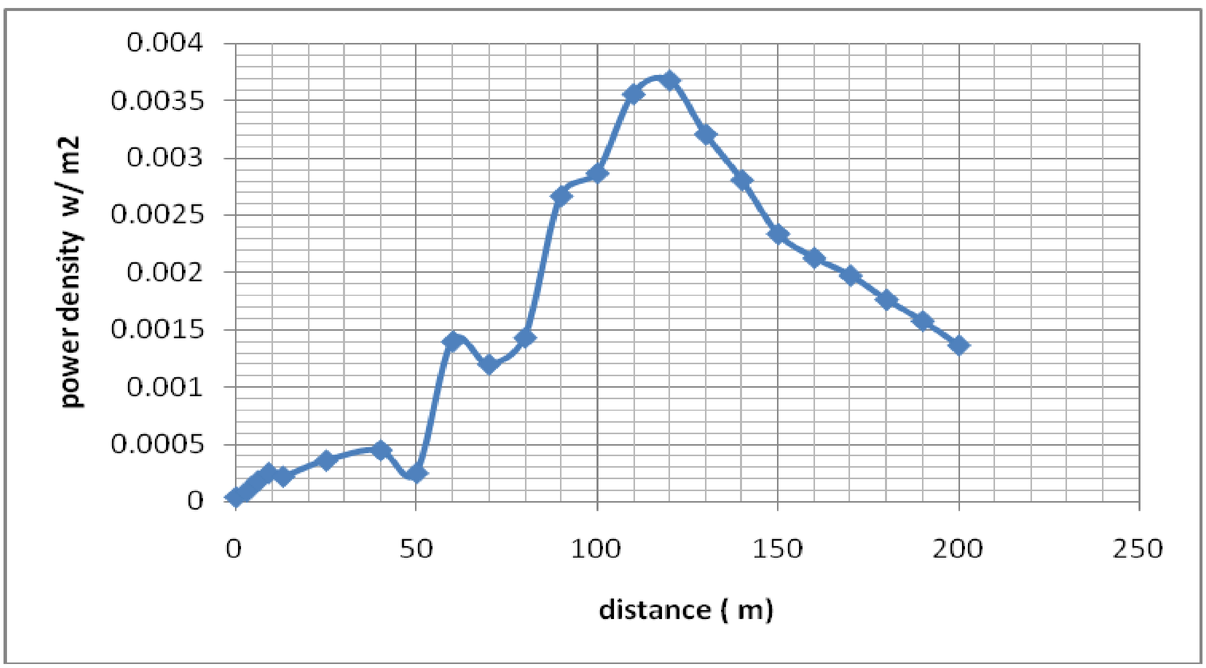


Figure 3.15: Power density vs. distance at ground level for station A12.

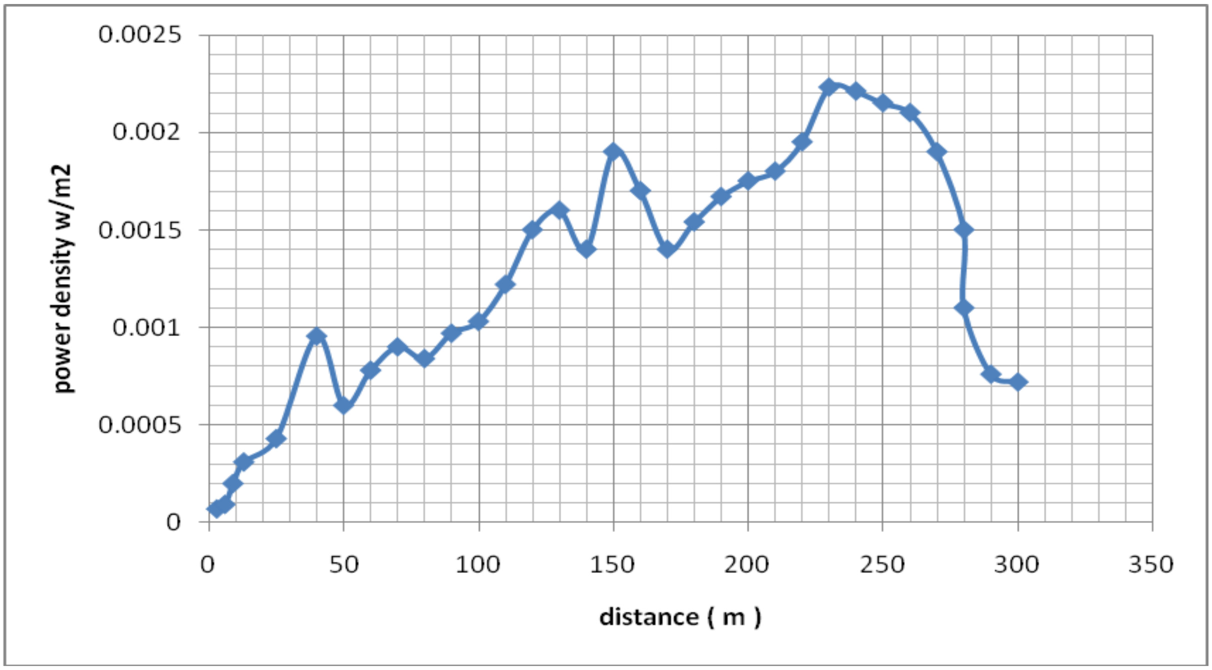


Figure 3.16: Power density vs. distance at ground level for station A19.

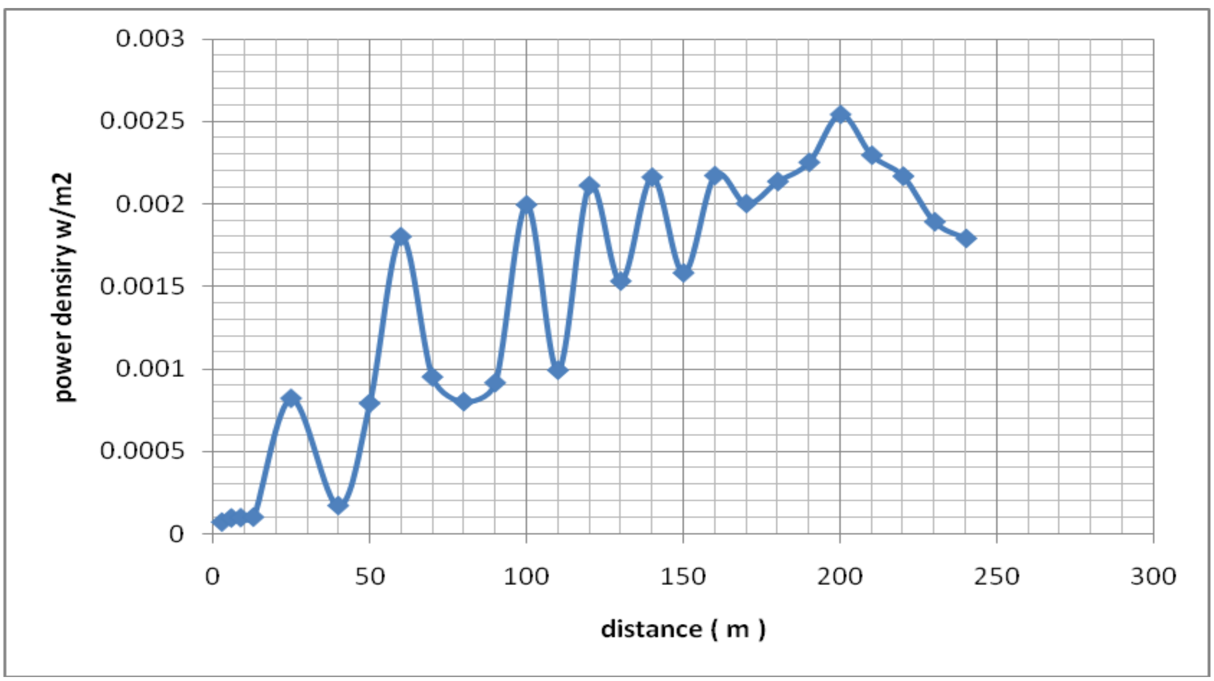


Figure 3.17: Power density vs. distance at ground level for station A18.

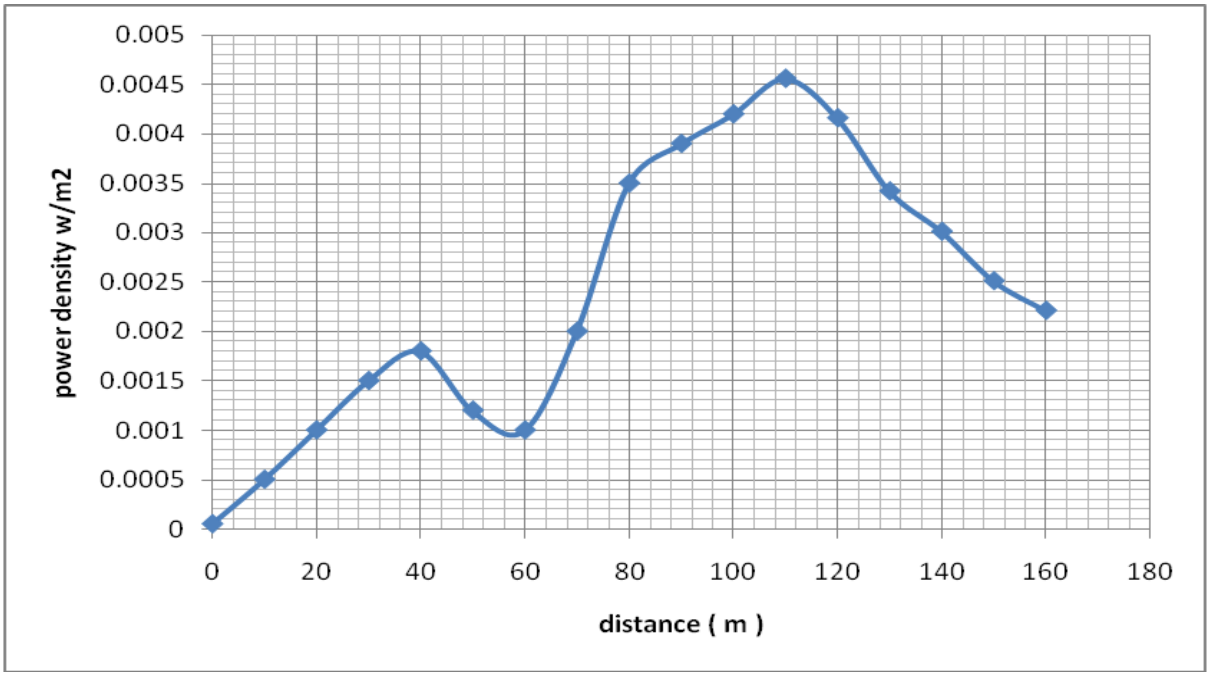


Figure 3.18: Power density vs. distance at ground level for station A13.

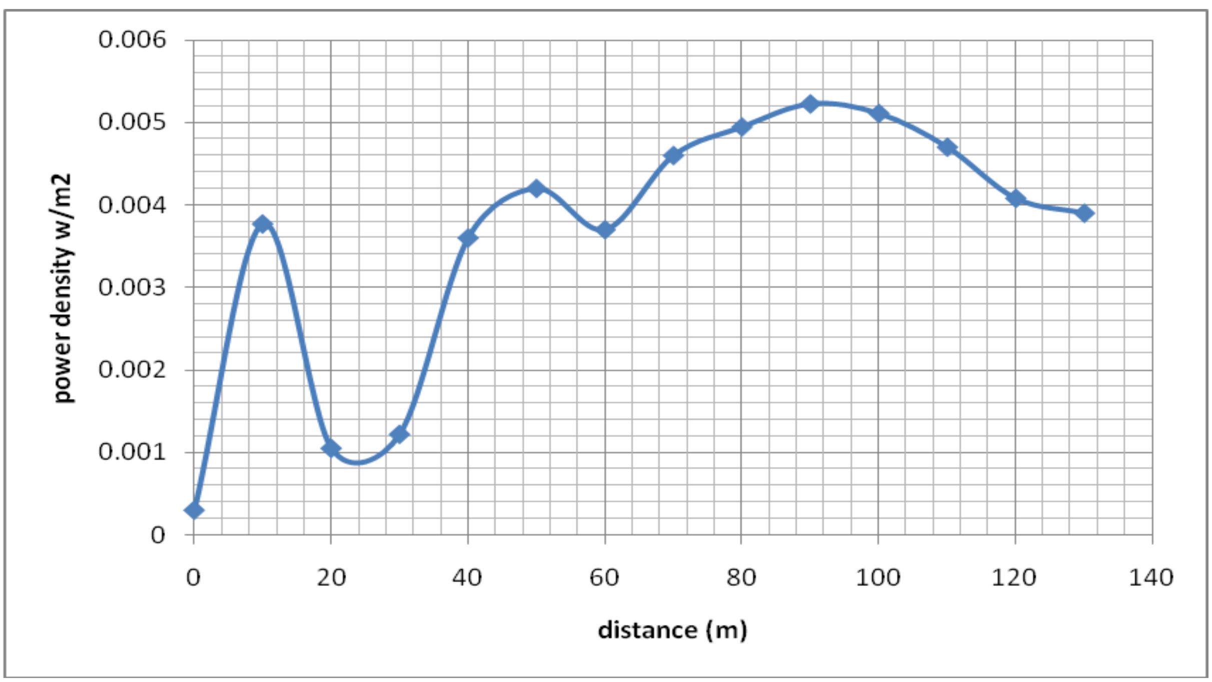


Figure 3.19: Power density as a function of distance at ground level for station A 9.

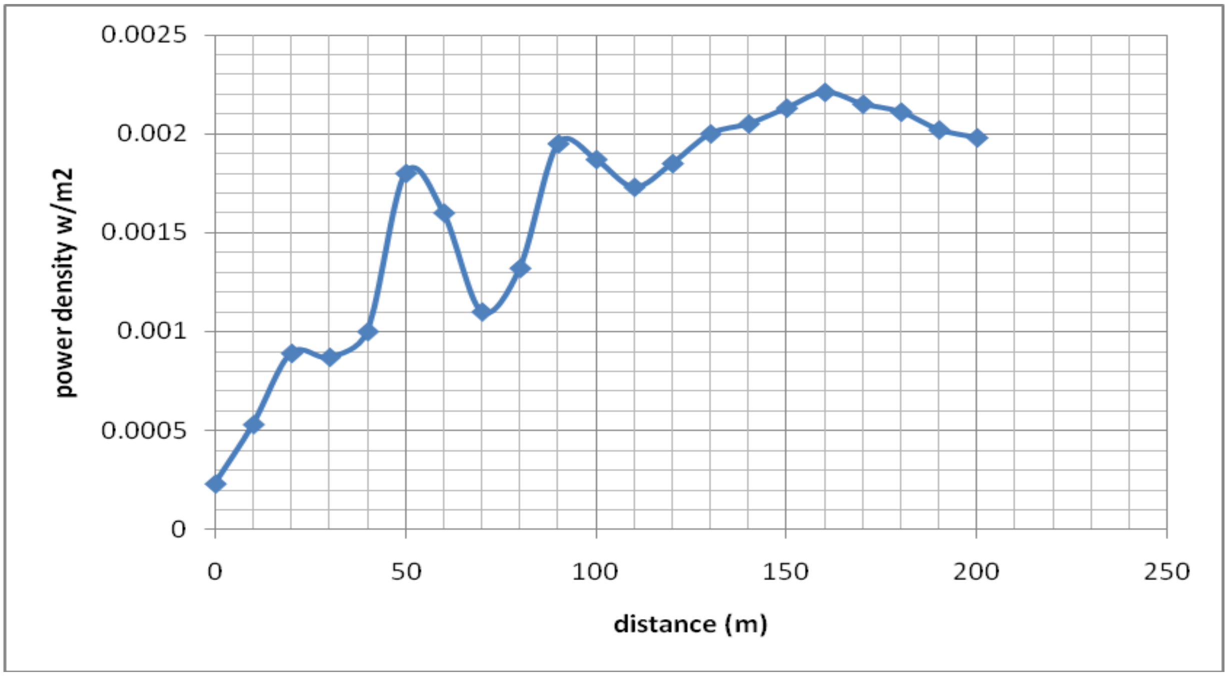


Figure 3.20: Power density vs. distance at ground level for station A16.

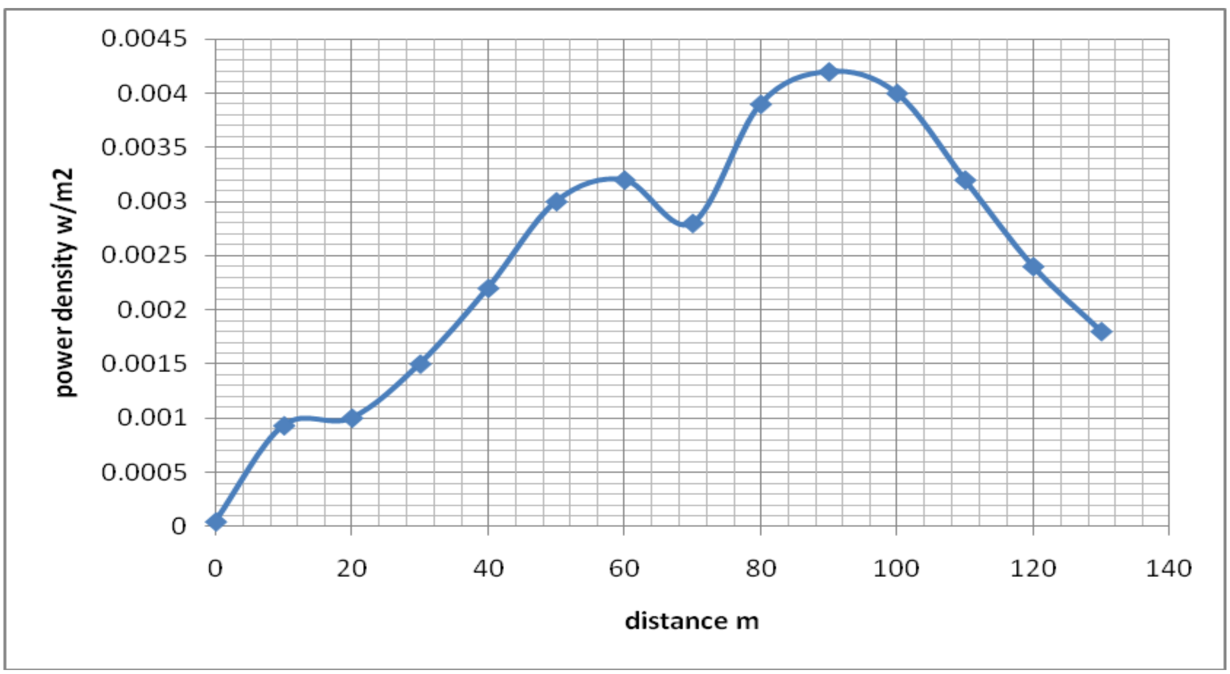


Figure 3.21: Power density vs. distance at ground level for station A10.

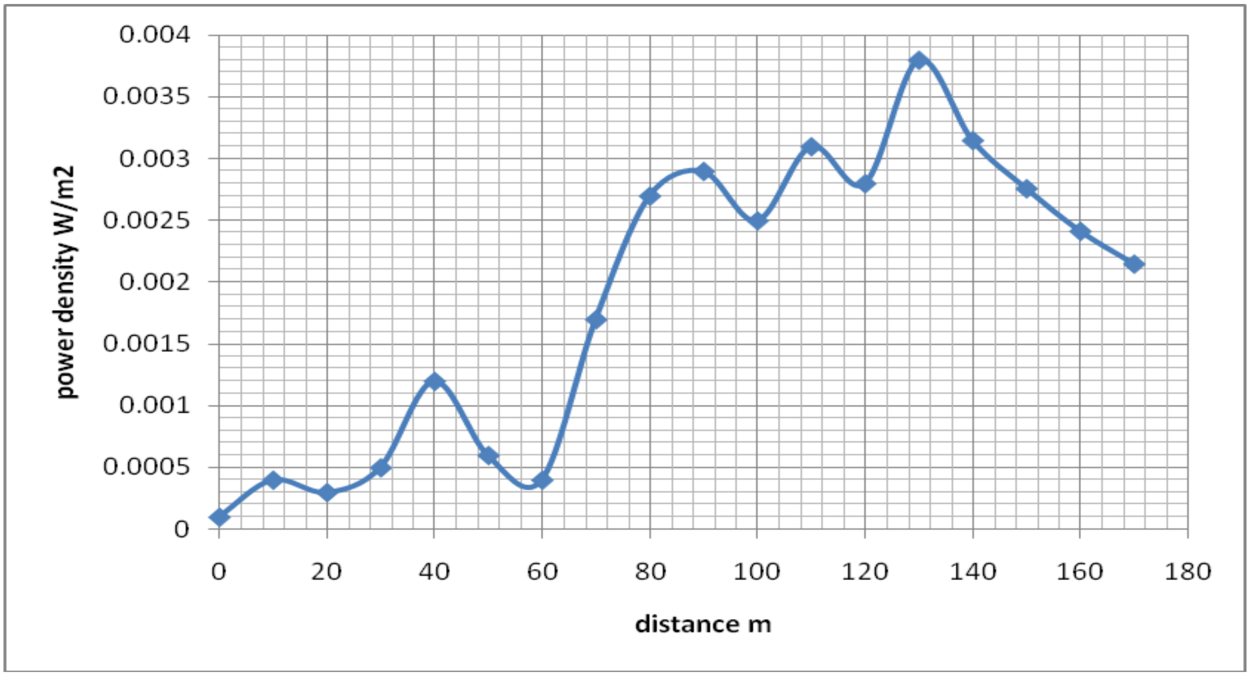


Figure 3.22: Power density vs. distance at ground level for station A15.

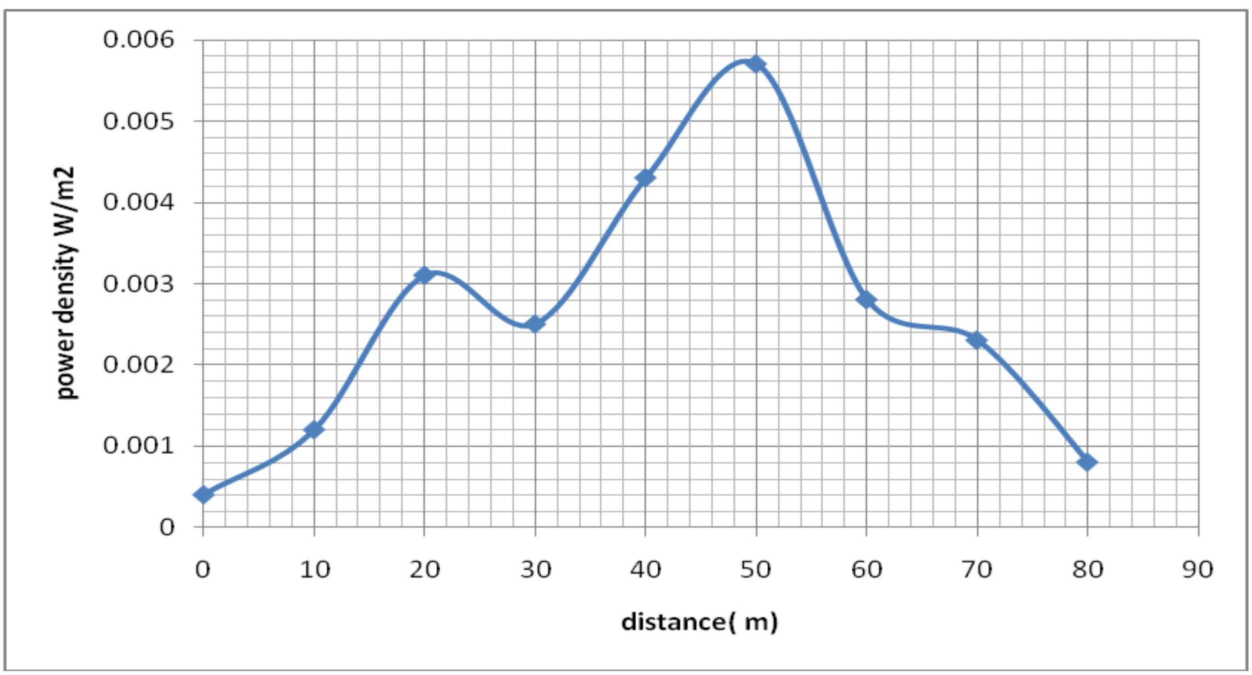


Figure 3.23 : Power density vs. distance at ground level for station A3.

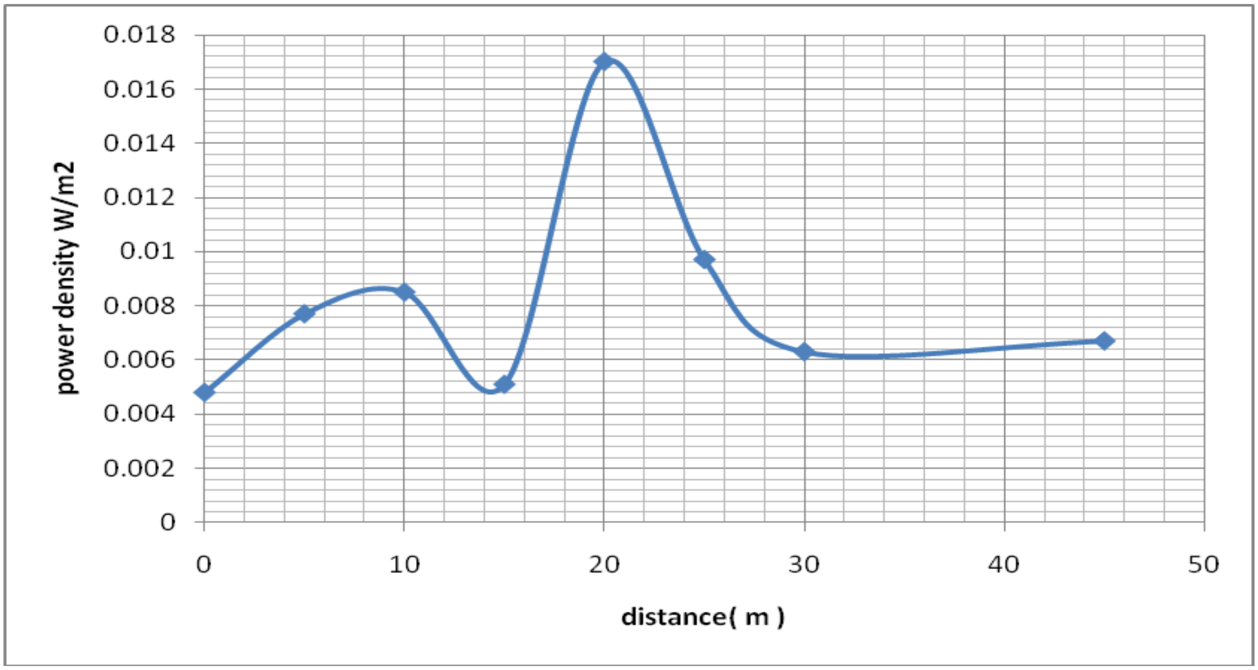


Figure 3.24: Power density vs. distance at ground level for station A7 .

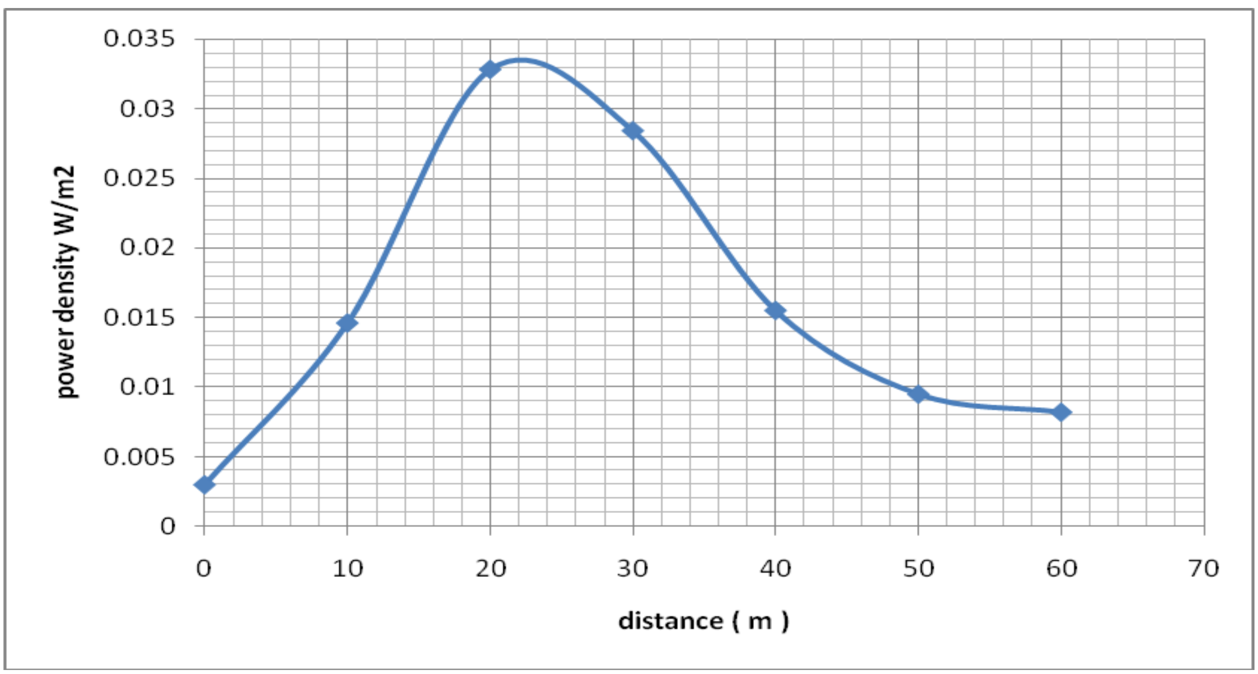


Figure 3.25: Power density vs. distance at ground level for station A1.

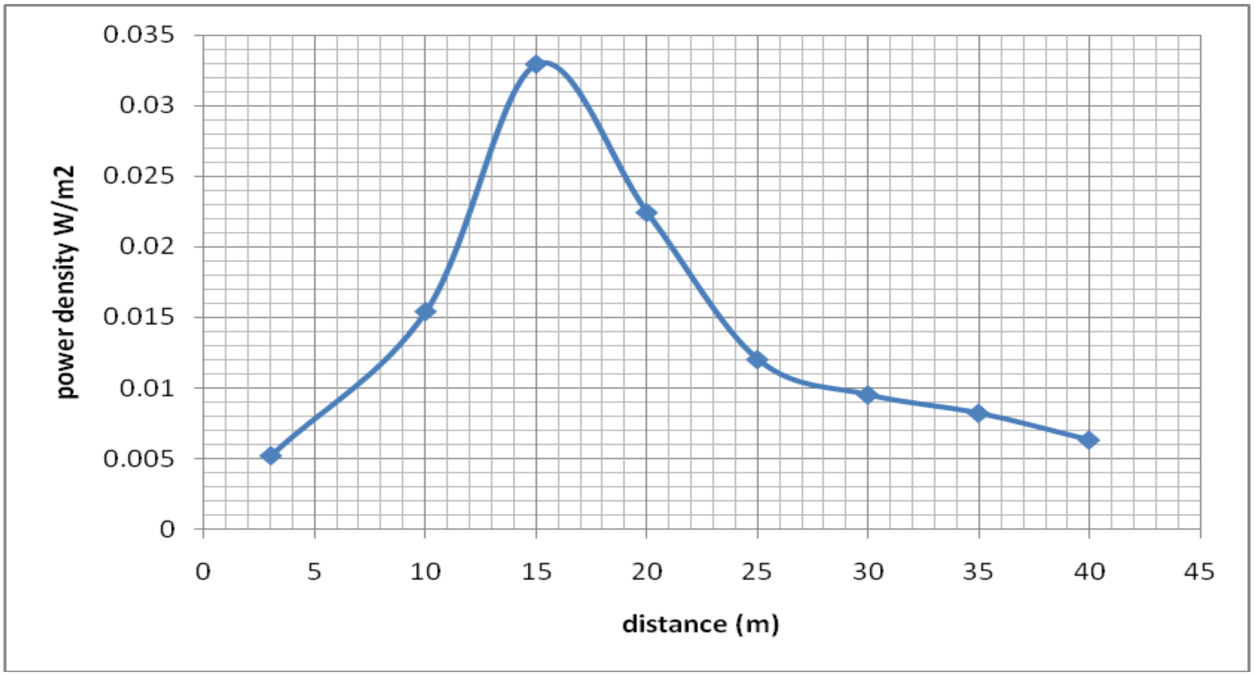


Figure 3.26: Power density vs. distance at ground level for station A2.

From the figures above, we can summarize the highest values of the intensity of radiation to the selected base stations by the following table in order to compare those values with standard guidelines

3.6.3 Maximum power density measured at ground level and in main beam

Station Code	Station Location	EIRP (W)	Height (m)	Power Measured W/m^2	Power Measured $dBmW/cm^2$	Distance (m)
A1	Ramallah mail box building	400	6	0.0328	-24.84	20
A2	Ramallah municipal building	800	6	0.0329	-24.82	15
A3	Near Taxi 24 office Tira	800	9	0.0057	-32.44	50
A6	Al Bireh near java company	561	9	0.0054	-32.67	70
A7	Tira near Saria building	800	10	0.017	-17.69	20
A8	Near Jawwal company	800	11	0.0046	-33.37	90
A9	In Birzeit	800	12	0.00522	-32.82	90
A10	Near best buy	800	12	0.0042	-33.76	90

A12	Near Latin school Birzeit	800	15	0.00368	-34.34	120
A13	In Nablus	800	15	0.00456	-33.41	110
A14	Near Hulul company	800	18	0.00321	-34.93	140
A15	Tira near restaurant values	800	19	0.0038	-34.20	130
A16	In Beitunia near school	800	21	0.00221	-36.55	160
A17	Near Jawwal company	1000	21	0.0022	-36.57	180
A18	In Beitunia	1409	24	0.00254	-35.95	200
A19	In Beitunia	1581	30	0.00223	-36.51	230

Table 3.3a Base stations measured maximum power density on the ground

Station Code	Station location	EIRP (W)	Height (m)	Power Measured W/m^2	Power measured $dBmW/cm^2$	Distance (m)
A4	Near Ericson company	800	8	3.66	-4.36	3
A5	Near Ericson company	561	9	6.28	-2.02	3
A11	Jefna	800	12	0.49	-13.09	10
A12	Near Latin school, Birzeit	800	15	6.18	-2.09	3

Table 3.3b Base stations measured maximum power density along the beam line**.**

According to section 3.3 the power density behavior resulting from the ground station can be divided into two zones, the first is the area between the bottom of the station and the meeting point of main beam with the ground, the intensity of radiation increases gradually but not continuous (non monotonous behavior) and this is due two factors, change in the distance and the change in antenna gain. The second zone extends from the first end point of the first zone to large distances from the station, the power density then falls off according to the inverse square law. From the previous results we note the following:

1- The data is consistent with the theoretical calculations.

2- Increasing the antenna height shifts the maximum power density further away from the antenna

3- Many of the measured power densities violate the Ministry of Environment affairs limits especially for direct beam measurements.

3.6.4 Measurement uncertainty

Some stations were selected that were measured, and then was re-measurement at some points after one week, in order to determine the change in measured values. In table 3.4 we note that the change is up to 15%. This is due to power output ordinary variations.

Station	**Distance**	**past reading W/m^2**	**current reading**	**% change**
A12	120	0.00368	0.0042	+14
A16	160	0.00221	0.0019	-14
A10	90	0.0042	0.0048	+14.2
A1	25	0.0328	0.029	-11.6
A2	15	0.0329	0.031	-6

Table 3.4 Data comparison at different times for some of the base stations.

3.7 Field intensity and power density

Field intensity or field strength is a general term that usually means the magnitude of the electric field vector, commonly expressed in volts per meter. At frequencies above 100 MHZ, and particularly above one GHz, power density (Pd) terminology is more often used than field strength. In "far field" areas, power density radiated by antenna can also be calculated by

$$\mathbf{S=E\times H=(E^2/377)} \qquad \mathbf{(3.1)}$$

Where: E is the intensity of electric filed in V/M and H is the intensity of magnetic field in A/M. In far field zones, E and H are considered to be orthogonal to each other, from the previous equation we can convert some measurements that we obtained as given in Table 3.5

Pd	0.000	0.000	0.000	0.001	0.002	0.01	0.02	0.032	5	25
E_f V/m	0.2	0.3	0.5	0.7	1	2	3	3.5	72	350

Table 3.5 Power density and field intensity

Chapter four

Conclusions and Future Work Recommendations

Chapter Four: Conclusions and Future Work Recommendations

4.1 Conclusions

1. The space around a radiating antenna division into near field and far field is justified. The measured oscillatory behavior for all of the stations agrees with the calculations given in figures 3.3 and 3.4. The oscillatory behavior extends to the point where the beams hit the ground in most stations that was equal to about 7 times the height. However it can be seen that the tilt angle of the various stations was not set steady between 5-10^o below the horizontal. In some cases the antenna tilt was large to make the beam hit the ground at distances twice the height. For the far field radiation the spherical-wave gives power densities $1/r^2$-dependence and the measured values agree with the calculations.

2. The increased height of the station results in extending the oscillatory behavior further and that results in lowering the power density to within the limits, for masts higher than 20 meters provided no place of occupancy is located directly along the beam line. This situation occurs frequently in the slopes of Nablus.

3. The data along the main beam violated the limits of ONIR, and the Ministry of Environment Affairs. Direct beam measurements indicate that for occupied places within 35m the ONIR limits are violated and for distance less than 90 m they represent risk according to many Salzburg standards. For distances less than 20 m the density was about 0.1 W/m^2 which is comparable to the ministry of environment affairs outdoor limit.

4. For direct beams the height brings a difficult problem. Exceeding the limits of many standards for places of sensitive use can occure despite the height of the mast if a house is located at a distance less than 35 meters from the station top and crosses along the beam line. This means the height is one factor that can reduce the risk. Three solutions can be tried to insure values below the limits. 1- Increase the height in a way to insure no living occupants are within 60 m from the direct beam. 2-Reduce the power density to lower the safe distance. 3- Remove the station from the place.

5. Some RF safety standards and regulations are mainly concerned with the thermal exposure (ICNRP, FCC, and IEEE). Other standards adopted very strict limits compared to these

standards because they took a-thermal effects into consideration (ONIR, Salzburg). A standard of 1000 $\mu W/m^2$ was pointed out to be a suitable limit taking into account non-thermal biological effects. According to this limit many regions around the stations represented health risk

6. Experimental evidence and epidemiological studies were conducted on people living near cell phone antennas. Many of these studies documented adverse health effects for exposures orders of magnitude below the FCC or ICNIRP guidelines. For example for power densities of about 50 W/m^2 the theoretical safety distance is greater than 7 m according to the ICNIRP guidelines but greater than 77 m according to the Swiss' ONIR for places of sensitive use. This is a strong indicator of the wide variation between the standards.

4.2 Future work and recommendations

1. The experimental evidence supports theoretical calculations in principle. Applying rules that take into account both thermal and a-thermal effects is necessary to protect health of living beings. Data indicates that the non thermal limits are generally broken and that should be considered by the authorities to put stronger regulations if the standards are not adequate.

2. If it was for thermal effects alone no body will care much. But if we take into account other non thermal and direct field affects then the problem becomes worth investigation. The study by the Biomedical Engineering Center, Tallinn University of Technology is a good case to follow through, and we strongly recommend others to do similar work. We certainly encourage one of the students from Alquds University who is planning to do such measurements to follow through.

3. Our rule here is to help define justification for the limits and from Table 2.10 the natural exposure from microwave radiation is 12 orders of magnitude less than the normal mobile stations output. This cannot be overlooked. We think the limit of 10^{-3} W/m^2 represent a reasonable optimum trade between the very restricted and the very relaxed regulations, and we suggest that the authorities set this limit for the occupational areas.

4. From data and using the ONIR limit, it is not safe to be exposed along the line of direct beam for distances less than 80 m for power densities of the existing stations. In many stations inside the cities especially in the mountains like Nablus there are many houses located at a direct distance of less than this along the beam line. This should be addressed adequately. Our recommendation is to prevent installing stations over houses that can have direct beam access to any house for less than 20 meters. This can be achieved by removing the stations or decreasing the power, or making it higher to prevent such occurrences.
5. The idea that the further the station the more power from the cell phone will be needed for good connections sustainability is true, but we don’t have to trade these too bad options. Still there is a difference between the two cases: For the mobile the person is not using continuously and he is responsible for his actions, while for a person living in the proximity of the station he is basically exposed for a very long time without his consent or ability to protect himself.
6. It may seem trivial to say that the further the power station the less exposure will be, but reality is more complicated. Under the station the exposure power can be small and that can be used as a reason to convince the owner of the building to provide the space. In addition, around the stations the exposure takes oscillatory form and there it will be hard to be sure even about this assumption. Still for distances less than 20 m with direct exposure to the main beam, the neighbor is exposed beyond many international limits and he should know that.
7. The official limit set in Palestine as given by the Ministry of Communication is $4.5 W/m^2$. According to the Ministry of Environment Affairs the safety limit is set $0.018 W/m^2$ indoor and $0.18 W/m^2$ out door. The Ministry numbers is fairly good, but it is not clear which limit is binding legally for actual enforcement. This should be handled adequately.

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46 – قرار وزاري رقم (1) لسنة 2009 بشأن اجراءات منح الموافقة البيئية لانشاء و تشغيل محطات البث الخلوي صادر عن رئيس سلطة جودة البيئة , مجلة الوقائع الفلسطينيه , العدد الحادي و الثمانون .

Appendix (data for figures 3.2,3.7,3.8-3.25 respectively)

Table 4.1 data for figure 3.2

D(m)	5	10	20	30	40	50	60	70
Pd(W/m^2)	2.5	0.62	0.15	0.069	0.031	0.025	0.017	0.013
D(m)	80	90	100					
Pd(W/m^2)	0.0090	0.0077	0.0063					

Table 4.2 data for figure 3.7

D(m)	3	6	9	12	15	18	21	30	40	50
Pd(W/m^2)	6.3	1.6	0.73	0.41	0.22	0.18	0.13	0.063	0.037	0.022

Table 4.3 data for figure 3.8

D(m)	3	6	9	12	15	18	21	30	40
Pd(W/m^2)	6.2	1.4	0.52	0.35	0.29	0.13	0.094	0.044	0.032
D(m)	50	60	70	80					
Pd(W/m^2)	0.028	0.0026	0.0024	0.0022					

Table 4.4 data for figure 3.9

D(m)	10	20	30	40	50	60	70	80	90	100
Pd W/m^2	0.49	0.086	0.049	0.033	0.028	.0025	.0023	0.002	0.001	0.001

Table 4.5 data for figure 3.10

D(m)	3	6	9	12	15	18	21	30	40	50
Pd(W/m^2)	3.7	1.2	0.42	0.26	0.18	0.13	0.085	0.047	0.023	0.016

Table 4.6 data for figure 3.11

D(m)	0	3	6	9	13	25	40	50	60	70
Pd(W/m^2)	.0005	.0007	.0009	.0011	.0013	.0018	.0016	.0010	.0015	.0018
D(m)	80	90	100	110	120	130	140			
Pd(W/m^2)	.0020	.0046	.0042	.0034	.0029	.0022	.0018			

Table 4.7 data for figure 3.12

D(m)	0	3	6	9	13	25	40	50	60
Pd(W/m^2)	0.0030	0.0041	0.0017	0.0011	0.0022	0.0017	0.0043	0.0034	0.0052
D(m)	70	80	90	100	110	120	130		
Pd(W/m^2)	0.0054	0.0050	0.0046	0.0039	0.0031	0.0025	0.0021		

Table 4.8 data for figure 3.13

D(m)	0	3	6	9	13	25	40	50	60
Pd(W/m^2)	0.000080	0.00090	0.00065	0.0010	0.0013	0.0016	0.00098	0.0010	0.0012
D(m)	70	80	90	100	110	120	130	140	150
Pd(W/m^2)	0.0015	0.0011	0.00090	0.0014	0.0012	0.0016	0.0018	0.0017	0.0018
D(m)	160	170	180	190	200	210	220		
Pd(W/m^2)	0.0019	0.0020	0.0022	0.0019	0.0016	0.0014	0.0011		

Table 4.9 data for figure 3.14

D(m)	0	3	6	9	13	25	40	50	60
Pd(W/m^2)	0.000006	0.000090	0.00010	0.00023	0.00021	0.00035	0.0014	0.0011	0.0017
D(m)	70	80	90	100	110	120	130	140	
Pd(W/m^2)	0.0019	0.0014	0.0018	0.0020	0.0019	0.0025	0.0029	0.0032	
D(m)	150	160	170	180	190	200			
Pd(W/m^2)	0.0030	0.0024	0.0019	0.0018	0.0017	0.0014			

Table 4.10 data for figure 3.15

D(m)	0	3	6	9	13	25	40	50	60
Pd(W/m^2)	0.000040	0.000090	0.00018	0.00025	0.00022	0.00036	0.00045	0.00025	0.0014
D(m)	70	80	90	100	110	120	130	140	150
Pd(W/m^2)	0.0012	0.0014	0.0027	0.0029	0.0036	0.0037	0.0032	0.0028	0.0023
D(m)	160	170	180	190	200				
Pd(W/m^2)	0.0021	0.0020	0.0018	0.0016	0.0014				

Table 4.11 data for figure 3.16

D(m)	3	6	9	13	25	40	50	60	70
pd(W/m^2)	0.000070	0.000093	0.00020	0.00031	0.00043	0.00096	0.00060	0.00078	0.00090
D(m)	80	90	100	110	120	130	140	150	160
Pd(W/m^2)	0.00084	0.00097	0.0010	0.0012	0.0015	0.0016	0.0014	0.0019	0.0017
D(m)	170	180	190	200	210	220	230	240	250
Pd(W/m^2)	0.0014	0.0015	0.0017	0.0018	0.0018	0.0020	0.00223	0.00221	0.00215
D(m)	260	270	280	280	290	300			
Pd(W/m^2)	0.0021	0.0019	0.0015	0.0011	0.00076	0.00072			

Table 4.12 data for figure 3.17

D(m)	3	6	9	13	25	40	50	60	70
Pd(W/m^2)	0.00007	.000095	.000097	0.00010	0.00082	0.00017	0.00079	0.0018	0.00095
D(m)	80	90	100	110	120	130	140	150	160
Pd(W/m^2)	0.00080	0.00091	0.0020	0.00099	0.0021	0.0015	0.0022	0.0016	0.0022
D(m)	170	180	190	200	210	220	230	240	
Pd(W/m^2)	0.0020	0.0021	0.0023	0.0025	0.0023	0.0022	0.0019	0.0018	

Table 4.13 data for figure 3.18

D(m)	0	10	20	30	40	50	60	70	80
Pd(W/m^2)	0.00005	0.00050	0.0010	0.0015	0.0018	0.0012	0.0010	0.0020	0.0035
D(m)	90	100	110	120	130	140	150	160	
Pd(w/m2)	0.0039	0.0042	0.0046	0.0042	0.0034	0.0030	0.0025	0.0022	

Table 4.14 data for figure 3.19

D(m)	0	10	20	30	40	50	60	70
Pd(W/m^2)	0.00030	0.0038	0.0011	0.0012	0.0036	0.0042	0.0037	0.0046
D(m)	80	90	100	110	120	130		
Pd(W/m^2)	0.0049	0.0052	0.0051	0.0047	0.0041	0.0039		

Table 4.15 data for figure 3.20

D(m)	0	10	20	30	40	50	60	70
Pd(W/m^2)	0.00023	0.00053	0.00089	0.00087	0.0010	0.0018	0.0016	0.0011
D(m)	80	90	100	110	120	130	140	150
Pd(W/m^2)	0.0013	0.0020	0.0019	0.0017	0.0019	0.0020	0.0021	0.0021
D(m)	160	170	180	190	200			
Pd(W/m^2)	0.0022	0.0022	0.0021	0.0020	0.0020			

Table 4.16 data for figure 3.21

D(m)	0	10	20	30	40	50	60	70
Pd(W/m^2)	0.000042	0.00093	0.0010	0.0015	0.0022	0.0030	0.0032	0.0028
D(m)	80	90	100	110	120	130		
Pd(W/m^2)	0.0039	0.0042	0.0040	0.0032	0.0024	0.0018		

Table 4.17 data for figure 3.22

D(m)	0	10	20	30	40	50	60	70	80
Pd(W/m^2)	0.00010	0.00040	0.00030	0.00050	0.0012	0.00060	0.00040	0.0017	0.0027
D(m)	90	100	110	120	130	140	150	160	170
Pd(W/m^2)	0.0029	0.0025	0.0031	0.0028	0.0038	0.0032	0.0028	0.0024	0.0022

Table 4.18 data for figure 3.23

D(m)	0	10	20	30	40	50	60	70	80
Pd(W/m^2)	0.00040	0.0012	0.0031	0.0025	0.0043	0.0057	0.0028	0.0023	0.00080

Table 4.19 data for figure 3.24

D(m)	0	5	10	15	20	25	30	45
Pd(W/m^2)	0.0048	0.0077	0.0085	0.0051	0.017	0.0097	0.0063	0.0067

Table 4.20 data for figure 3.25

D(m)	0	10	20	30	40	50	60
Pd(W/m^2)	0.0030	0.015	0.033	0.028	0.016	0.0095	0.0082

Table 4.21 data for figure 3.26

D(m)	3	10	15	20	25	30	35	40
Pd(W/m^2)	0.0052	0.015	0.033	0.022	0.012	0.0095	0.0082	0.0063

ملخص

قياس ودراسة شدة إشعاع الميكروويف الصادر من محطات بث الهواتف النقاله في فلسطين وإمكانية مخاطر صحية غير حرارية الأساس

إعداد: علي محمد أبو عابد
إشراف: د. سلمان محمد سلمان
دائرة الفيزياء جامعة القدس2013

يتعلق هذا العمل بتقييم وقياس مستويات وتأثيرات الإشعاع الكهرومغناطيسي الصادر عن محطات بث الهواتف الخلوية في فلسطين. وتم قياس كثافة القدرة او شدة الإشعاعات باستخدام جهاز قياس نوع:

NBM-550 Narda Broadband Field Meter with probe EF0391 (NBM) 100kHz -3GHz.

وكانت جميع المحطات المقاسة تابعة لشركة جوال الخلوية الفلسطينية. وقد تم اختيار تسعة عشرة محطة في مناطق رام الله ونابلس والواقعة ضمن مراكز سكانية وبمحيط مؤسسات عامة كالمدارس.

وتمت مقارنة القراءات بالمعايير المعتمدة في فلسطين الصادرة عن وزارة البيئة الفلسطينية (indoor 0.018 W/m²; outdoor 0.18 W/m²) واللجنة الدولية للحماية من الإشعاعات غير المؤينة ICNIRP(4.5 W/m2) ومعايير أخرى أكثر صرامة في تطبيق المعايير مثل Salzburg (0.001 W/m²) and ONIR (0.04 w/m²).

سجلت القراءات قيما أقل من معيار ICNIRP بينما كانت متقاربه في أحيان عديدة من معيار ONIR ومعايير وزارة جودة البيئة وهذا يستدعي اهتماما خاصا. وقد تم قياس كثافة شدة الاشعاع القصوى وكانت حوالي (6.28 W/m²) على طول الشعاع الرئيسي وعلى بعد 3 أمتار من محطة A5 الواقعه في رام الله بالقرب من شركة اريكسون. وقد تم قياس كثافة شدة الاشعاع القصوى وكانت حوالي (0.033 W/m²) على طول مستوى سطح الأرض وعلى بعد 15 مترا من A2 الموجوده في رام الله بالقرب من مبنى البلدية

اخذين بالاعتبار الدراسات و الأبحاث التي تحتسب المؤثرات غير الحرارية الناتجة عن الإشعاع الميكروويف فإن القيم المسجلة تضعنا أمام مسؤوليه لتقليل شدة الإشعاع إلى أكبر حد ممكن وقد أشارت دراسة سابقة في مركز الهندسة الطبية الحيوية في جامعة تالين التكنولوجية أن هناك تأثيرات مقاسة وقوية بما يكفي لاستدعاء دراسات وتحقيقات أكثر شمولا.

نوصي مزيدا من الفحص في هذه الظاهره ووضع وانفاذ حدود في فلسطين تأخذ بعين الاعتبار الأثار الناجمه عنها وخصوصا في المناطق ذات الكثافه السكانيه العاليه .