Palestine Polytechnic University

College of Engineering and Technology

Electrical and Computer Engineering Department

Communication and Electrical Engineering

Graduation Project

" A measurement based Study on the Electromagnetic Radiation and its Effect in Hebron District"

Project Team

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ABSTRACT

Many studies were published all over the world discussed the side effects of electromagnetic fields (EMFs) related to different electric usage, but we did not get a confirm and a clear evidence or a negative sign about the relation between several disease and electromagnetic radiation sources especially cancer, leukemia, skull, eye tissue, skin and heart.

This project represents a trail to have a global look for different kinds of electromagnetic sources which human were exposed during their daily life indoors and outdoors in Hebron district and indicate the biggest threat EM source based on real and practical measurements.

Measurements have been done using high sensitive instruments; spectrum analyzer model 2650, EMR-21C field meter, personal navigator GPS and high specification Lab top. These instruments were connected and matched to gather with a software program designed to capture measurements automatically on a regular or different times according to our requirements.

The spectrum analyzer is adjusted to operate at the appropriate center frequency and bandwidth that used by each source individually with different scenarios and cases; for The purpose of measuring the electric field at this center frequency and power level at the adjusted band. Also, the field meter is used to measure the electric field, magnetic field and power density. The measured values by these instruments are compared with the international Standards and limits for human exposure.

The first measurements concentrate on GSM where measurements have been taken for the radiation sources on GSM system; the base stations and mobile phones. For the results of base stations measurements, we found that their level of radiation is low, where the maximum measured level at near field was about 0.475 W/m^2, which was measured from Ein Sarh site at distance 3 m away from the cell antenna of the base station. It is lower than the allowed international value by 9 times. However, the average measured value was 0.0226W/m^2 and lower by 200 times from the allowed value.

While, the results of mobile phone measurements were greater in compare with base stations measured values where the maximum value was 2.9 W/m^2 and it is less than the allowed values of IEEE and ICNIRP by 1.5 times and 2 times less than the FCC guideline. The measurement proves that the radiation from the mobile increased when we go away from the base station. In this case, the control signals of the GSM systems control the radiated power from the mobiles and increase their level to make a good connection link with the base station.

Another study was made by measuring the broadcasting stations; FM radio stations and TV stations. For the measurements of the FM radio stations, the maximum power

density was equal to 0.1321 W/m^2, which is lower than the standards by 15 times, and the average power density of the all measurements was about 0.05 W/m^2 and lower by 40 times from the international standards. However, for TV stations, the measurements show that the maximum power density measured 0.0025 W/m^2, which is the least one from the whole of the maximum measured values.

The last mesurements section was for Microwave Ovens, the maximum measured value for the microwave power radiation equal to 1.988 W/m^2, which is lower than the international allowed levels by 5 times . This value is the highest level of radiation by comparing it with the other sources of EM radiation.

DEDICATION

To the candles that burn to light our life and future,
Our parents who made it all possible to receive the stage

To the flower of the earth &
the stars of the sky,
Our brothers & sisters

To whom we can't give them their dues in full,
Our supervisors Dr. Ghandi Manasra &
Dr. Mohammad Abu Samra

To whom we love & can't forget,
Our beloved (R & T), friends, and instructors

To all souls we Respect, Martyrs

To mother land, Palestine

To all people who encouraged us during the preparation of this project

Thank you very deep from our hearts
for all The love and supports
that You have given to us

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We like to express our thanks and gratitude to Allah, the Most Beneficent, the Most Merciful who granted us the ability and willing to start and complete our project. We pray to his greatness to inspire us the right path to his content and enable us to continue the work started in this project to benefits of our country.

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We can find no words to express our sincere, appreciation and gratitude to our parents, brothers and sisters, friends and to whom we love, for their endless support and encouragement, we are deeply indebted to you and we hope

that we may someday reciprocate it in some way.

Work Team

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AM	Amplitude Modulation
ANSI	American National Standards Institute
BSC	Base Station Controller
BTS	Base Transceiver Station
CEPT	Conference of Postal and Telecommunications administrations
EHF	Extremely High Frequency
EIR	Equipment Identities Register
ELF	Extremely Low Frequency
EM	Electromagnetic
EMF	Electromagnetic Field
EMR	Electromagnetic Radiation
EMW	Electromagnetic Wave
ERP	Effective radiated Power
FCC	Federal Communication Commission
FDA	Food and Drug Administration
FF	Far Field
FM	Frequency Modulation
GPS	Global Position System
GSM	Global System for Mobile Communication
HF	High Frequency
HLR	Home Location Register
ICNIRP	International Commission on None-ionizing Radiation Protection

IEEE	Institute of Electric and Electronic Engineers
IF	Intermediate Frequency
LF	Low Frequency
MF	Medium Frequency
MPBS	Mobile Phone Base Stations
MS	Mobile Station
MSC	Mobile Switching Center
MW	Microwave
NF	Near Field
NRPB	National Radiation Protection Broad
RF	Radio Frequency
RFR	Radio Frequency Radiation
RNCNIRP	Russian National Committee on Non-ionizing Radiation Protection
SAR	Specific Absorption Rate
SHF	Super High Frequency
SMS	Short Message Service
SIM	Subscriber Identity Module
TRAU	Transcoding Rate and Adaptation Unite
TV	Television
VDT	Video Display Terminal
VDU	Visual Display Unite
VHF	Very High Frequency
VLF	Very Low Frequency
VLR	Visitor Location Registers
VSWR	Voltage Standing Wave Ratio
PLMN	Public Land Mobile Network
WAP	Wireless Application Protocol
WHO	World Health Organization
WLAN	Wireless Local Area Network
UHF	Ultra High Frequency

UK	United Kingdom

Chapter One
Introduction

Contents

1.1 Overview

In this chapter, we will provide general literature information that is so importance to address our project. This includes an explanation of the main idea, and the project objectives. After that, we will give a quick overview of all topics directly related to our project, and discuss the mechanisms to be used afterwards. This includes project importance, requirements, challenges, expected outcomes and finally the time frame will be represented as a general guideline.

1.2 Introduction

Wireless communication links have been used worldwide for many years as solutions for connectivity in point-to-point and point-to-multipoint applications. The most common wireless solutions include AM and FM radio, television broadcast stations, mobile and cellular phones, radar and microwave systems. In this work, more emphasis will be given to mobile GSM system where multi-channel two-way radio base stations as well as a single channel two-way radio mobile station.

The rapid development in the world of communications calls for engineers and scientists to intervene and give a justification and reply to public anger; public who are being exposed daily to different types of electromagnetic field (EMF)and radiation. A serious consideration must be taken for this situation and find a real solutions to this challenging technology.

Radiofrequency (RF) and microwave (MW) radiation exposures from the antennas of mobile phone base stations (MPBS), radio stations, and TV broadcast towers have become a serious issue in recent years due to the rapidly evolving technologies in wireless telecommunication systems. In Palestine, hundreds of MPBS have been erected all over the country, most of which are mounted on the rooftops. The height of stations above the ground varies according to locations. Generally, they are installed at the height of 15 – 50 meters from the ground for the rooftop and 40 – 100 meters in the case of tower. Each MPBS has a maximum capacity in term of number of users that it can handle at any one time and this can easily led to call congestion in some parts of districts [3].

Such continuous increase in number of MPBSs, radio stations, and TV broadcast towers erected has triggered concern among members of the public living around the stations on the possibility of health effect caused by the radiation produced by such facilities.

The health risks of exposure to RF/MW radiation have been increasing, particularly for people residing in the vicinity of the base stations. The direct beam and side lobe of radiation from these antennas may expose people within distances of 300 m to MW radiation [21].

For the population living in the vicinity of radiation towers and base stations, RF/MW exposure is in the “far field”. Several factors will influence the strength of the power densities measured from the antennas of the mobile, radio, and TV stations. These include the distance from the antennas where the strength decreases according to the inverse square law. Besides, the power densities from the main beam are higher than those from the side lobe and behind the antennas. The power densities also fluctuate according to the number of calls, also found that other electromagnetic sources such as power lines, transforms and electrical household appliances, affect power densities [24].

Several organizations and government agencies have developed guidelines to protect the general public and the workers from the excessive RF/MW radiation emitted from the antennas of the base stations. IEEE, ICNIRP, NRPB and FCC, for instance have set limits for exposure for the general public and workers.

Exposure to RF/MW fields from a mobile phone is within the short – term period but exposure to RF/MW emitted from MPBS is of long duration. Thus, a study on a measurement of the power densities of the antennas from the MPBS is warranted.

Measurements of power density around such sites will be useful in determining the exposure levels of the general public and this in turn determines whether the exposure levels are within the maximum allowed exposure levels [3].

1.3 Main idea

In this project, we will discuss the electromagnetic radiation and its effect in Hebron district. It also compares between various wireless communications systems : FM and TV broadcasting stations, mobile and base stations (GSM900), and a household microwave oven.

1.4 Scientific Review

There are many research studies have been conducted in this field worldwide, whereas Palestinian territories concern, the research is too rare, only 2-3 small trials are reported.

1.5 Objectives

The project aimed on:

1. To measure the power density, electric field, magnetic field and power level formed around mobile phone base stations (MPBS), mobile stations, FM radio stations, TV broadcast stations, and microwave oven radiation in Hebron district -Palestine.

2. To measure the RF levels emitted by the base stations and broadcasting towers.
3. To monitor the magnitude and trends of elevated radiation levels present in any particular area.
4. To compare the obtained values with international standards and limits for human exposure such as ICNIRP, IEEE, FCC and WHO.
5. Give some recommendations to reduce the concerns about the electromagnetic waves sources and improve base stations transmission and strengthen it without making any harm effect on environment.

1.6 Introduction to Electromagnetic Radiation

Electromagnetic radiation generally described as self-propagating wave in space, and it consists of two components, the electric wave form and the magnetic wave form, which oscillates at right angles to each other [36].

The spectrum of electromagnetic(EM) consists a set of electromagnetic waves with deferent frequencies, extended from extremely low frequency (100 Hz) and very low frequency (ELF/VLF), through radio frequency (RF) and microwaves, to infrared (IR) light, visible light, ultraviolet (UV)light, X-rays, and gamma rays, as shown in Figure 1.1 .

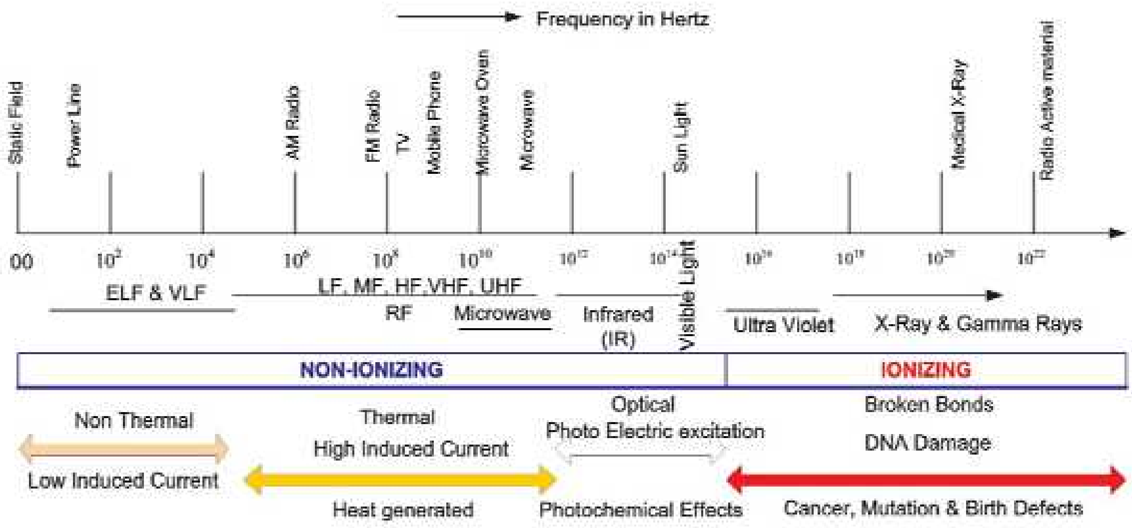

Figure 1.1: Graphical representation of the electromagnetic spectrum.

1.7 Classifications of Radiation

1.7.1 Ionizing Radiation

This type of radiation possesses enough energy to ionize atoms or molecules such as X-rays and gamma radiations. It is the radiation that contains electromagnetic energy that changes the chemical reactions in the body (ionizing all the molecules or part of them) which causes a lot of damage, two forms of ionizing radiation is X-Rays and Gamma rays .

1.7.2 Non-Ionizing Radiation

It is the lower part of the frequency spectrum and contains energy levels below that required for effects at the atomic level. Radio Frequencies (RF), including low frequency (LF), medium frequency (MF), microwave (MW) are all examples of non-ionizing radiation.

Some studies suggest that it could have long-term health effects, and potential health hazards could be linked to excessive exposure to non-ionizing radiation[4].

Our project is aimed basically on investigating the power densities transmitted from the non-ionizing radiation emitted from the broadcasting towers of radio stations, TV stations, base stations of mobile stations and towers and microwave in Hebron.

1.8 Specific Absorption Rate (SAR)

SAR is the term stands for Specific Absorption Rate, which is the unit of measurement for the amount of power absorbed by a mass element when exposure to radiations. This is the most appropriate metric for determining EM effect exposure in the near field of a radio frequency, hence that the higher the SAR the more radiation is absorbed.

It will be calculated by using the measurements of electric field strength, and compared with the global standards, and compare the fields and SAR with their corresponding reference levels and basic restrictions.

So it is important to be able to perform accurate measurements of electromagnetic field. Both the electric and magnetic field have to be determined when performing measurements in the near field of the base stations [51].

1.9 Electromagnetic Radiation and healthy concern

Concerning the effect of electromagnetic waves, a lot of people fear about the impact of these radiations especially growing number of visible sources of radiation, but at the same time there have been several excitation studies about health symptoms which produces from exposure to EMF especially radio frequency (RF) , where found that there was no relation between the health symptoms and EMF exposure [50].

However, is there any healthy concern? This issue related to many reason such as the amount of energy that contained، kind of source, position of source...etc .that what we will explain it in the next chapter.

1.10 Mechanism

The main devices that we will use are the Spectrum Analyzer (Model 2650), Field Meter (EMR-21C) to measure the level of power, electric field, magnetic field, and power density, at different distances from the radiation sources. Then, by using specific software(AK2650), we will edit the measurement after ensuring of the graphs and values. And use these measurements to compare it the international standards and regulations.

1.11 Project Importance

In Palestine, especially in Hebron district a lot of people fear from the broadcasting towers and the base stations, especially JAWWAL towers. As a result of high number of MPBS in Hebron district which lead to many environmental hazards led people live near MPBS. Complain against these companies. The above event led Hebron region municipalities make a requisite to Hebron University to investigate the possible environmental hazards. Thus, the importance of project is motivated by

a. Investigating, if there is, health hazard effect from these towers based on the results that we will get, which is not conclusive judgment as we expect, but it will be as a recommendations.

b. The other importance of the project is to monitor and to measure the RF/MW levels and the power density formed around broadcast towers and base stations in Hebron district – Palestine and to study the biological effects on people health living in the vicinity of MPBS. And hence it is important to know how many companies follow installation rules when they install base stations and broadcast stations and how much these rules obey specific environmental conditions. This study will cover almost all Palestinian regions.

1.12 Requirements

1.12.1 References and Resources

For completion of this project, a literature review is required. Thus, books and article resources about electromagnetic radiations, antennas, Word Health Organization (WHO) publications, Specific Absorption Rate (SAR), researches from the IEEE publications are required and should be mentioned in brief so as to compare our results.

1.12.2 Hardware used

1- Spectrum Analyzer (Model 2650 -Handheld 3.3GHz -B&K Precision), Figure 1.2.

Figure 1.2: Spectrum Analyzer Model 2650

2- Field Meter (EMR-21C).

Figure 1.3: Field Meter (EMR-21C).

3- Global Positioning System (GPS).
4- Laptop with high specifications.

1.12.3 Software

AK2640 Software, which is a soft program designed to capture measurements of the radiated power from the spectrum analyzer automatically at certain or individual interval times according to our requirements.

1.13 Area of Study

This study occurred in Hebron district – Palestine, on latitude of 31:31’ to 32:50’ and length line 34:8’ to 35:80’. The district is about 1070 square kilometers. It has also arranged of mountains and heights which are from (400 m to 1030 m) above the sea level.

This area consists of the main city of Hebron surrounded with a number of main and small villages all with average population of 500,000.

1.14 The Scope of the Project

The research agenda summarizes the scope: Telecommunication technologies based on radiofrequency (RF) transmission, such as radio and television, have been in widespread use for many decades. However, there are numerous new applications for the broadcast and reception of RF waves and the use of RF devices such as mobile phones are now ubiquitous. The attendant increased public exposure to RF fields has made its effects on human health a topic of concern for scientists and the general public.

To respond to these concerns, an important research effort has been mounted over the past decade and many specific questions about potential health effects of RF fields have already been investigated by scientists around the world. Nonetheless, several areas still warrant further investigation and the rapid evolution of technology in this field is raising new questions. Social concern has accrued over the years and is influencing risk management at national and local levels and public acceptance of scientific health risk assessments.

Risk management is built on evidence stemming from both scientific knowledge and insights from social studies that investigate this concern. Therefore, this document identifies specific research needs in both basic science relevant to health risk assessment and social science areas pertaining to public concern and risk communication, highlighting their importance in meeting public health needs [50].

1.15 Challenges

Our project depends on movement in different places in the Hebron district where we will use the maps that provided by JAWWAL Company to locate the base stations and the power emitted from these base stations, and take the necessary measurements, which requires a lot of time and effort.

While taking measurements using Spectrum Analyzer it needs 6 minutes to determine the real and exact measured values.

The comparison between the different wireless networks will not be easy where we will discuss the Radio broadcast towers, Television stations, Microwave Ovens in addition to Mobile base stations and Mobile Stations (MS). This study done at the first time in our region.

1.16 Organization of Subsequent Chapters

In chapter one, we included introduction, basic definitions and information about electromagnetic waves (EMWs) and the project plane. In chapter two, we present more details about EMWs and general background of all collected information from papers and other reference. In chapter three, we explain the methodology of the project and the way that has been used to take the measurements.

We present and discuss our measurements from the different sources and compared the obtained values with international standards and limits for human exposure in chapters four. In chapter five, we provide the project conclusion and some recommendations to the decision makers and ordinary people to reduce the concerns about the included electromagnetic waves sources in the project.

Chapter two
General Background

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2.6 Antennas.

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2.7.5 FCC Limits for Maximum Prermissible Exposure (MPE).

2.1 Overview of Electromagnetic radiation

2.1.1 Definitions of electromagnetic radiation

Radiation is energy transmitted through space as particles or electromagnetic waves or the process of their emission. Particle radiation refers to the radiation of energy by means of small, fast-moving particles that have energy and mass. Electromagnetic radiation is emitted in discrete units known as photons that travel at the speed of light as electromagnetic waves. Electromagnetic energy is classified by increasing energy or decreasing wavelength into radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma-rays (Figure 2.1).

Energy of a photon:

$$Eph = \frac{hc}{\lambda} \qquad \ldots\ldots\ldots\ldots..(2.1)$$

Where:
h = Planck constant = 6.626×10^{-34}Js.
c = speed of light = 2.998×10^{8} m/s.
λ= wavelength (m).

Radiation is divided into two categories, ionizing and non-ionizing, to denote the energy and danger of the radiation. The amount of electromagnetic radiation emitted by a body is directly related to its temperature. Is the process of emitting energy as waves or particles, so the energy thus radiated. Frequently the expression used for ionizing radiation except when it is necessary to avoid confusion with non-ionizing radiation [16].

Electric fields are created by difference in voltage and increase in strength as the voltage increase. The electric field strength is measured in unit of volt per meter (V/m). An electric field will exist even when a device is switched off and current does not flow.

Magnetic field result from the flow of current through wires or electrical devices, it creates from the motion of electric charge and increase in strength as the current increases. The strength of the magnetic field is measure in amperes per meter (A/m) [37].

Magnetic field is measured in unit of gauss (G) or tesla (T). A magnetic field is produced only if the device is switch on and current flows. The higher the current, the greater the strength of magnetic field. Electric fields and magnetic fields are strongest close to their origin and beginning decrease at greater distances from the source. Magnetic fields are not blocked by common material or object such as walls of building.

So the electric and magnetic fields usually collected together and called electromagnetic field.The effect of electromagnetic field on human body depend not only on the concern field intensity but also on its frequency and energy as well[26].

2.1.2 Electromagnetic field nature

Electricity is used to the benefit of people all over the world .Wherever electricity is generated, transmitted or used; electric fields and magnetic fields are created .These fields are direct Result of existence and/or motion of electric charge. It impossible to generate and use electrical energy without creating these fields.

Human exposure to electric and magnetic fields was limited to those fields arising naturally. An electromagnetic field (EMF) is generated when charged particles such as electrons are accelerated. By nature these charged particles are surrounded by electric field, if the particles are moves produces the magnetic field, so when the particles change of velocity whether accelerate or slow down, an EMF is produced .

The (EMF) spectrum is divided in frequencies, from an electrical point of view the spectrum has divided into three main fields; Extremely low frequency (ELF)fields usually contain all frequencies up to 300Hz .Intermediate frequencies (IF)fields also contain all frequencies from 300Hz to 10MHz .Radiofrequency (RF)field concern frequencies between 10MHz and 300GHz [4].

2.1.3 Electromagnetic waves

Waves are vibration or oscillation moving through the space .When the waves move it transfers energy .Light, sound, water waves, seismic waves, earthquakes, radio waves X-rays and gamma rays are all examples of waves.

Some of waves do not need material to pass through; this is the case for the electromagnetic waves which include radio microwaves, infrared, ultra-violet, X-rays and gamma rays.

The theory of electromagnetic radiation was developed by James Maxwell and published in 1865; he showed the speed of propagation of electromagnetic radiation should be identical with that of light, above $3x10^8$ m/sec .he approved also that the electromagnetic radiation does not require a material medium and can travel through a vacuum [12].

2.1.4 Electromagnetic measurements and its spectrum

There has been concern on the part of the public for many years about the possible health effect of exposure to radio frequency (RF) radiation and other radiations .For example high levels of RF fields are known to cause variety of physical effect on the human body .At the frequencies of operation of most of these devices, there is quantity used to measure how much RF energy is actually absorbed in a body is called the Specific Absorption Rate (SAR). As part of worldwide efforts to proceed on consumer health and safety aspect, many require products placed on the market to meet on SAR. It is usually expressed on units' w/kg [6].

The strength of the electric field is measured by the unit volt per meter (V/m); also the strength of magnetic field is measured by the unit ampere per meter (A/m). Another commonly used unit for characterizing an RF field is named power density .Power density is most accurately used when the point of measurement is far enough away from an antenna to be located in what is commonly referred to as the "far field zone " of the antenna

In the far field, the electric and the magnetic fields are related to each other and it's only necessary to measure one of these quantities in order to determine the quantity or the power density.

In the near field zone, the physical relationships between the electric and magnetic component of field are usually complex, in this case it necessary to determine both the electric field and magnetic field on RF case, but at frequencies above 300MHz measure only the electric field.

Electromagnetic spectrum is a continuum of all electromagnetic waves arranged according to frequency and wavelength as shown in the Figure 2.1.

The electromagnetic spectrum include the various forms of electromagnetic radiation from extremely low frequency (ELF) radiation (with very long wave length) to X-rays and gamma rays, which have very high frequencies and short wavelength.

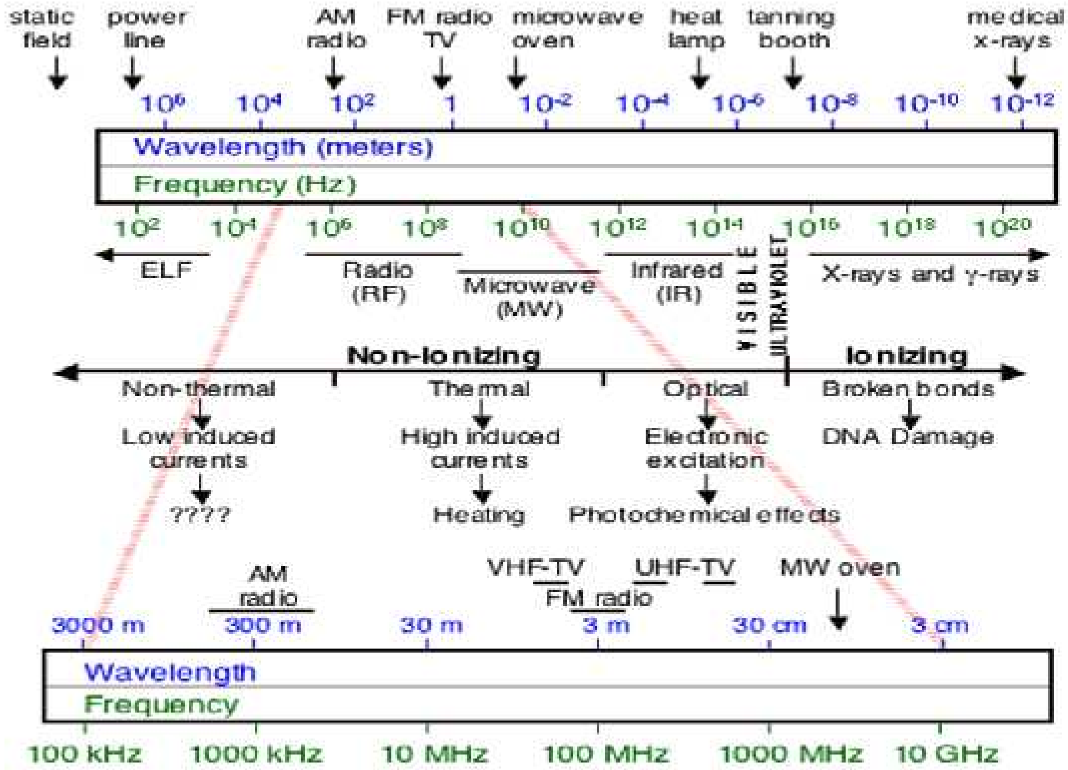


Figure 2.1 :Electromagnetic spectrum.

Between these extremes radio waves and microwaves, infrared radiation, visible light and ultraviolet radiation. The RF part of the electromagnetic spectrum is always defined as that of the spectrum where electromagnetic waves have frequencies in the range from about 3 KHz to 300GHz [44].

We can also divide the spectrum into sections based on wavelength the shortest waves are gamma rays, which have wavelength of 10-6 microns or less and the longest waves are radio waves, which have length of many kilometers.

2.1.5 Ionizing and non-ionizing radiation

All radiation can be divided into two main categories; non-ionizing radiation and ionizing radiation .And they are tow type of non-ionizing radiation, optical (ultraviolet, infrared, and visible, including lasers) and radio frequency (microwaves, radiofrequency, and extremely low frequency) radiation .

We all know when the frequency increase the energy content will be increase .So in ionizing radiation it has high frequency (above 1015 Hz) and enough energy to remove electrons from atoms, to ionize them .So it's called ionizing .For the low-frequencies (under 1015)are not great enough energy to remove electrons from atoms and make ionization .So it's called Non-ionizing radiation.

Therefore, X-rays and gamma rays are examples of ionizing radiation .Because it has enough energy to make ionization, and in the other side microwave and radio frequency are examples of non-ionization radiation .

None-ionizing radiation could be exposed from different sources, may be produced by electronic devices such as microwave oven, laser, ultraviolet lamps, and medical equipment .It includes the high-frequency radiations used in communication and broadcasting; the microwave radiations used in radar, television transmission, and the visible light used in some lasers .

But when you ask yourself; how might I be exposed to ionizing radiation? The answer will be, you are exposed to it from the sun, rocks, soil, natural sources in your body, fallout from past nuclear weapons tests, some consumer products, and radioactive materials released from hospitals and from nuclear and coal power plants .But in the low level .And exposed to more if you work as a pilot, flight attendant, astronaut, industrial and nuclear power plant worker, or x ray or medical personnel [2].

It is important that the terms "ionizing "and "non-ionizing "not be confused when discussing biological effects of electromagnetic radiation or energy; since the mechanisms of interaction with the human body are quite different.

2.2 Types of broadcast towers

Broadcast towers are used for transmitting a range of services including AM and FM radio and UHF, VHF and digital television .The tower will may act as an antenna itself or support one or more antennas on its structure, including microwave dishes.

There are two major types of broadcast towers .The first type is used at medium frequency(MF) (approximately 530 kHz to 1600 kHz) Amplitude Modulated (AM) radio stations .This tower is usually thin, tall structure of triangular cross-section that is supported by guy wires, as shown in Figure 2.2. The tower itself is the radiating antenna .

Figure 2.2: Medium Frequency (MF) broadcast tower.

The second type is used for very-high frequency and ultra-high frequency (VHF/UHF) FM radio and television transmissions (including digital television). These towers may be either a triangular guyed thin structure similar to MF radio towers or, self-supporting structures with four main vertical members and consisting of a tapered structure of large cross-section at the bottom (Figure 2.3).The tower is not the radiating element but a support for the transmitting antennas [6].

Figure 2.3: VHF/UHF broadcast tower.

2.3 Electromagnetic radiation sources

Radiation is a term meaning the transmission of energy in the form of waves through space or through material medium and also radiated energy itself .Sometime electromagnetic radiation is called EMR, while electromagnetic field referred to as EMF .EMR and EMF refer to the entire range of electromagnetic spectrum, from extremely low frequencies to radio waves.

Electromagnetic field can be either man-made or occur naturally, so we have natural sources and human-made sources.

- **Natural sources**

The earth produces EMF, exactly in the form of static fields; similar to the fields generated by DC electricity. Electric fields are produced by air disturbance and other atmospheric activity, when the electric current flowing deep within the earth's core; the magnetic field is produce and it's about 500mG.

Because the fields are static rather than alternating they do not induce currents in stationary objects as do fields associated with alternating current .Such static fields can induce currents in moving and rotating objects [6].

- **Human-made sources**

Any fabrication operated by electricity cases EMF with deferent forms; as example radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays . All electromagnetic radiation travels at the speed of light .The frequency of electromagnetic radiation is what determines its character [39].

These sources caused by human. When we talk about human sources we must mention tow type of sources the first is indoor sources such as televisions, computers, microwave oven, video or audio systems, wireless and mobile phones, electric mixer, vacuum cleaners and many other sets. But the second is outdoor sources including power cables wither underground or overhead power lines, broadcasting transmission stations, mobile base stations…etc.

All alternating electric currents generate electric and magnetic fields which known as EMFs. The electric field is proportional to the voltage, which can be considered as the pressure with which electricity is pushed through the wires [6].

The magnetic field is proportional to the current and depends on the amount of electricity flowing through the wire.

The familiar sources of electromagnetic fields [38]

- Mains power transmission around (50-60) Hz
- TV and VDU emissions around 10^5 MHz
- Medium wave radio broadcast (AM) around10^6 MHz
- TV broadcasting (UHF) around 1 MHz

- VHF radio broadcasts (FM) around 100 MHz
- Microwave ovens around 2.45GHz
- Mobile phones around (800-900 & 1800-1900) MHz
- Microwave communication around $9x10^{10}$ Hz

Some of the most common sources of every day background exposure (Figure.2.4) can be listed as:

- Overhead power line.
- Mobile phone and base stations.
- Microwave ovens.
- TVs, radio and telecommunication transmission.
- Computer, VDUs and other office equipment.
- Large transformer, capacitor…etc.
- Other Local electrical apparatus.

Figure 2.4: Sources of every day exposure.

2.3.1. Mobile communication systems

Communication systems are very importation in our life .It helps us to communicate; it also made the whole world a small village .Technology race occurred in communication technology field, so many companies succeeded to get very small telecommunication set .Which we can put it in the pocket and carry easily from one place to another, these new set be called portable telephones and easily be a mobile phones or cellular phones.

Mobile telephones, sometime called cellular phones or hand phones, are now an integral part of modern telecommunication .It started slowly in use but nowadays it widely used on average large scale all over the world, the users number approaching to 200 million users in the world now and we estimate that the number will be one billion users soon.

That's due to a large-scale integrated circuit technology which reduced the size of mobile phone; another factor was the reduction in price of the mobile phone unit . Technology, feasibility and service affordability cased the transmission from early land to mobile systems to the cellular systems [7].

Mobile phone developed from asset which transmitted audio signal only from one place to another to a set with multiple purposes; it can transmitted audio and image also with sensible sensitivity, transmit data, information, fax image and connecting with the internet network .

2.3.2 GSM Technology

In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) created the Groupe Spécial Mobile (GSM) to develop a standard for a mobile telephone system that could be used across Europe .In 1986, The European Commission initiative proposes to reserve 900MHz spectrum band for GSM, agreed in the EC Telecommunications Council.

In 1989, Groupe Speciale Mobile defines the GSM standard as the internationally accepted digital cellular telephony standard.and a document called "Phones on the Move ". Was produced by the UK's Department of Trade & Industry to use a new technology and operating in the 1800MHz-frequency band.

First GSM call made in 1991 by Radiolinja in Finland and the first GSM network was launched .First SMS sent after one year .By the end of 1993, over a million subscribers were using GSM phone networks being operated by 70 carriers across 48 countries

In 1995, GSM World Congress held in Madrid, Spain and Subscribers of Global GSM exceed 10 million. This number increased to 50 million after one year by using 167 networks in 94 countries, and GSM World Congress moved to Cannes, France .The same year saw the completion of the GSM Phase 2 standardization and a demonstration of fax, video and data communication via GSM.

Global GSM subscribers surpass 100 million by the end of 1998 and the first WAP trials begin in France and Italy in 1999 .But the first commercial GPRS services launched in 2000 .

In 2001, first 3GSM (W-CDMA) network goes live .GSM subscribers exceed 500 million and the first mobile phone color screens launched this **.**One year later**,** first Multimedia Messaging Services go live, first mobile camera phones launched and 95 %of nations worldwide have GSM networks.

GSM subscribers and technology increased rapidly every year .In 2006, GSM surpasses 2 billion subscribers and reaches 3 billion connections in 2008. And it is still increasing until now [28].

GSM network contains several elements :the mobile station (MS), the subscriber identity module (SIM), the base transceiver station (BTS), the base station controller (BSC), the transcoding rate and adaptation unit (TRAU), the mobile services switching center (MSC), the home location register (HLR), the visitor location register (VLR), and the equipment identity register (EIR). Together, they form a public land mobile network (PLMN).

GSM system based on a network of radio base stations, which provides the physical connection of an MS to the network in form of the Air-interface .On the other side, the BTS is connected to the BSC via the Abis-interface .Each of these base stations covers a certain geographical area called a cell and all together provides coverage for a larger area called clusters. Each cluster can be repeated continuously in the covering area so that the cells number in a cluster must be determined carefully. 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 .

Cell horizontal radius varies depending on antenna height, antenna gain and propagation conditions from a few hundred meters to several tens of kilometers .The longest distance the GSM supports in practical use is 35 kilometers .Also, there are several implementations to extend this range by using the concept of an extended cell .

The base stations are connected to the whole network via cable or radio links, which continuously send and receive signals via mobile exchanges the traffic and keep track of where in the network each activated mobile telephone is located. An overview of the GSM subsystems in Figure 2.5.

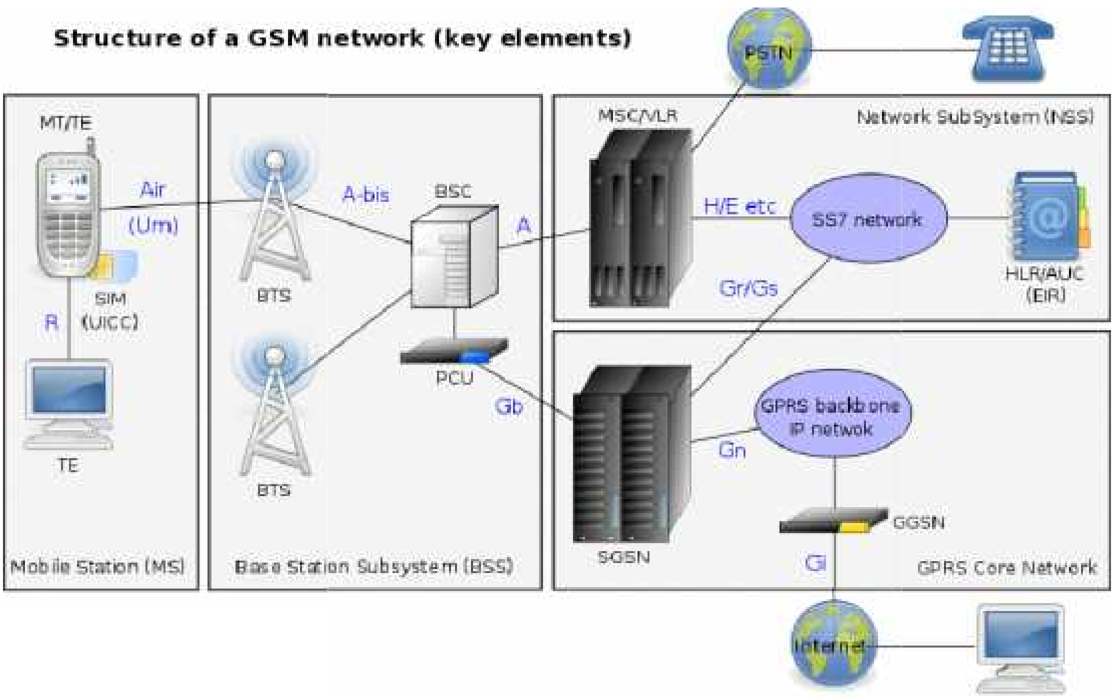


Figure 2.5: The architecture of a mobile network.

In a simple way, when a mobile phone initiates a call, it sends radio signals to the closest base station, which sends the call to the mobile switch .After that the switch routes the call to another base station, whose antenna sends the call as radio signals to the other user's mobile phone .Otherwise, if the destination was an ordinary wired telephone, the mobile switch sends the call to the fixed network .When a call is terminated, the mobile phone goes into idle mode.

By increasing the number of people that uses mobile phones, more base stations are required to handle more calls .Therefore, base stations are being placed closer to mobile phone users, and it uses the frequency reuse technique (Figure 2.6).As towers are being placed closer to homes, universities, hospitals, schools, and other sensitive areas, this is causing anxiety in the community about the effect of these base stations .

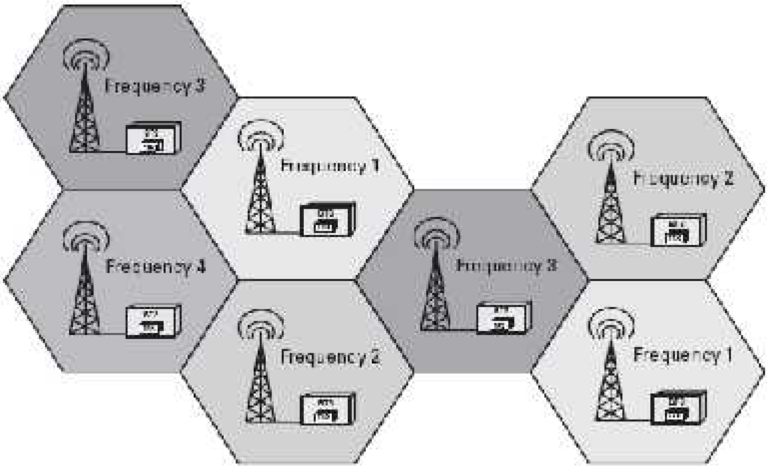


Figure 2.6 :The coverage of an area by single cells and frequency reuse technique.

Some governmental agencies and organizations around the world have but a recommendations and guidelines about exposure to EMF .These organizations study the effect of EMF on the human body, and specify a number of basic restrictions on the amount of electromagnetic energy which can be absorbed by the human body without bad effects [35].

2.3.3 Radio Broadcasting

The radio beginning was in 1888, when Heinrich Hertz produced electromagnetic waves by inducing a spark between two electrodes .These waves were detected by him a few meters away and called Hertzian waves .James Clerk Maxwell worked at Hertz’s experiments and derived his famous equations and predicted that a variable current in a conductor would produce electromagnetic waves in space travels with the velocity of light [19].

Guglielmo Marconi, the first inventor who proved the feasibility of radio communication .In 1895 he sent and received his first radio signal in Italy. After that he broadcasted the first wireless signal across English in 1899 .The first successful transatlantic radiotelegraph message in 1902, when he received the letter "S", telegraphed from England to Newfoundland.

The first person who used the word "radio "was De Forest, who invented AM (amplitude-modulated) radio that allowed for a multitude of radio stations .Radio technology has grown since its early development and the first organized broadcasts taking place in the 1920s.

In 1933, Edwin Howard Armstrong invented FM (frequency-modulated) radio which improved the audio signal of radio by controlling the noise caused by electrical equipment and the earth's atmosphere .After that the transistor was invented by Bell Labs .The first Master FM Antenna system in the world designed to allow individual FM stations to broadcast simultaneously from one source in 1965[34].
Now, there are many radio stations broadcasting all over the world using a variety of different types of transmission .Today, radio broadcast equipment from transmitters and receivers to antennas, studios and relay links are widely available.

Radio broadcasting is a one-way sound broadcasting service, Electromagnetic radiation travels through the air and the vacuum of space from a transmitter to a receiving antenna .Information is carried modulating some property of the radiated waves, such as amplitude, frequency, phase, or pulse width **.**

At the receiver antenna radio waves pass an electrical conductor, the oscillating fields induce an alternating current in the conductor .This can be detected and transformed into sound or other signals that carry information as shown in Figure 2.7[27].

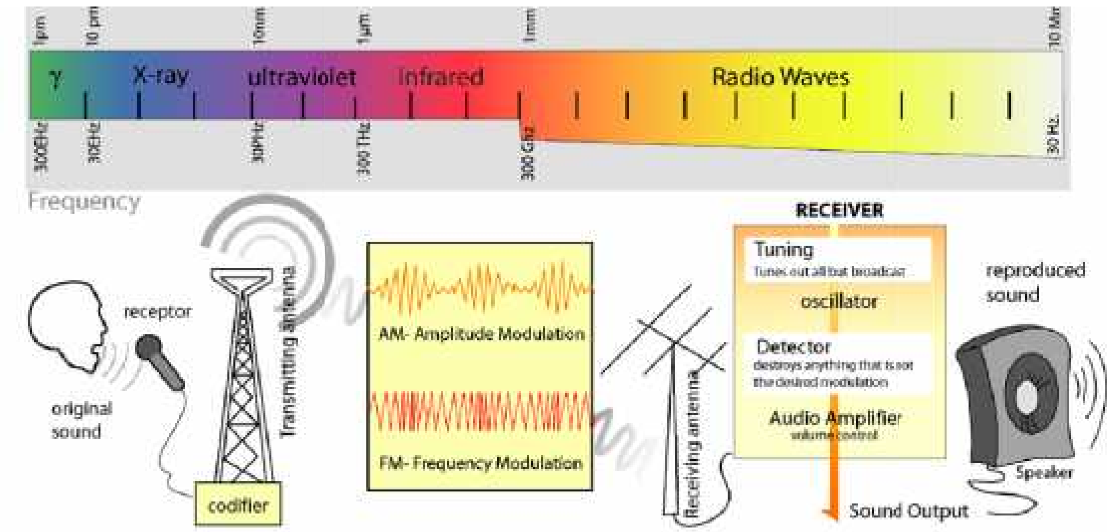


Figure 2.7: Radio transmission and reception schematic.

Radio Broadcasting takes several forms .These include AM and FM stations .The earliest broadcasting stations were AM stations .These stations are using the amplitude modulation technique which varies the amplitude of the carrier signal in response to the amplitude of the signal to be transmitted.

One of the advantages of AM is that its signal can be detected (turned into sound) with simple equipment, but it is subject to interference from electrical storms (lightning) and other Electromagnetic interference .AM radio transmitters can transmit audio frequencies up to 10 kHz, but most receivers are only capable of reproducing frequencies up to 5 kHz or less .

FM station is the other form of radio broadcasting stations and the most widely used around the world .These stations are using frequency modulation in the frequency range of 88 to 108 MHz (except Japan and Russia) .

The popular of FM stations because of the higher sound fidelity and stereo broadcasting .This fidelity was made possible by spacing stations further apart .FM channels are 200 kHz (0.2 MHz) apart .In other countries greater spacing is sometimes mandatory.This 200 kHz bandwidth is not needed to carry an audio signal, just 20 kHz to 30 kHz is enough .But it allowed space for ±75 kHz signal deviation from the assigned frequency, and guard bands to reduce adjacent channel interference [13].

2.3.4 TV Radiation

A television stations broadcasts programs over terrestrial television .A television transmission can be by analog television signals or digital television .The standards of television broadcasting are set by the government, which set many requirements and limitations .For example, define the geographic area that the station is limited to and allocate the broadcast frequency .To broadcast its programs, a television station requires a transmitter or radio antenna, which is located at the highest point available in the transmission area, such as on a summit of a high building, or on a tall radio tower .

TV stations use two kinds of frequencies :Very high frequency(VHF)which has the radio frequency range from 30 MHz to 300 MHz, and Ultra high frequency (UHF) with frequencies between 300 MHz and 3 GHz (3,000 MHz).

VHF stations often have very tall antennas because of their long wavelength, but require much less effective radiated power (ERP), and therefore use much less transmitter power output, .Full-power stations on band I (channels 2 to 6) are generally limited to 100 kW analog video (VSB) and 10 kW analog audio (FM), or 45 kW digital (8VSB) ERP .Stations on band III (channels 7 to 13) can go up by 5dB (W)to 316 kW video, 31.6 kW audio, or 160 kW digital .Low-VHF stations are often subject to long-distance reception just as with FM .

UHF has a much shorter wavelength, and requires a shorter antenna, but also higher power .Stations can go up to 5000 kW ERP for video and 500 kW audio, or 1000 kW digital .Low channels travel further than high ones at the same power, but UHF does not suffer from as much electromagnetic interference and background "noise "as VHF, making it much more efficient for TV[17] .

2.3.5 Microwave Radiation

Microwave radiation is a form of a high frequency RF radiation, microwave frequencies occupy upper part of electromagnetic spectrum, usually defined as the frequency range from 300MHz to 300GHz with corresponding wavelengths ranging from 1m to 0.1cm.

Microwave frequencies include three bands :the ultrahigh frequency band (UHF) of 300MHz to 3GHz the super high frequency band (SHF) of 3 or 300GHz and the extremely high frequency band (EHF) of 30 to 300GHz [22].

There are several sources of microwave radiation; some of them are normal sources like microwave radiation emitted from the sun and stars .Others are industrial sources in some microwave applications.

These applications containing some of our daily usage as microwave oven; dry machine and others. The most popular and well known use of microwave energy is the cooking and heating of food at home, restaurants and cafe's .

The microwave oven is based on the idea that substance absorbs radiofrequency radiation which leads to vibrate molecules and produced heat .So, water molecules lose its absorbed energy by fraction with the other molecules, which leads to rise the temperature of food.

Most microwave heating devices operate at the frequency of 2.450 MHz but in some countries 915 MHz is also used. Because of the large power, most systems are well shielded meeting the requirements of the product performance standards for microwave ovens .

Exposure to high frequency electromagnetic fields causes biological effects .So that safety in microwave oven achieved with two independent safety switches which switch off the microwave power when the door is open and prevents excessive leakage of microwave radiation [39].

2.3.6 Compare between the transmitter powers

There are three categories of transmitter powered systems (Figure 2.8):

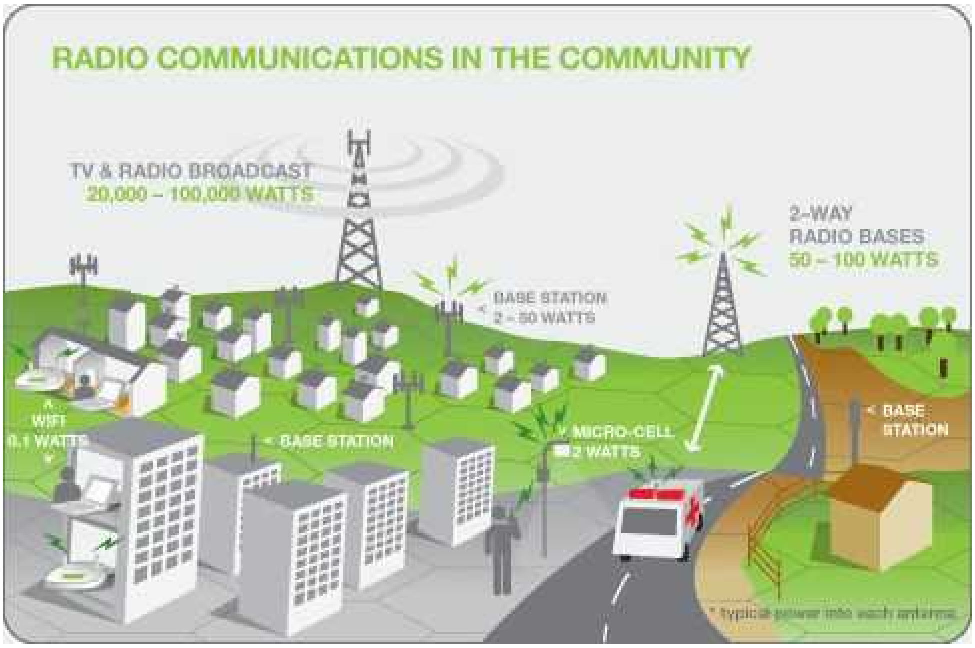


Figure 2.8: communication systems in the community and its typical power

1. High powered systems are used for television and radio broadcast, usually from a single transmitting tower in an elevated location.
2. Medium powered systems are used for two-way communications typically from a repeater tower to vehicle radio systems like emergency services.
3. Low powered systems are used for mobile communications and rely on a network of transmitting sites like mobile phone base stations.

Table 2.1: Typical power into antenna

Radio Systems	Typical Transmitter Power (Watts)
TV & Radio broadcast	5,000 – 100,000
Air traffic control radars	5000 – 20,000
Radio paging services	50 – 100
Emergency communications	50 – 100
Government radio systems	50 – 100
Mobile phone base station	2 – 50
Wireless Broadband base station	2 – 50
Radio Devices	
Walkie Talkies	0.1 – 5
Mobile phones	0.002 – 0.2
Wi-Fi Modem	0.1
Cordless phones	0.01 – 0.2
Baby monitors	0.01 – 0.1
Car remote control	0.001 – 0.1

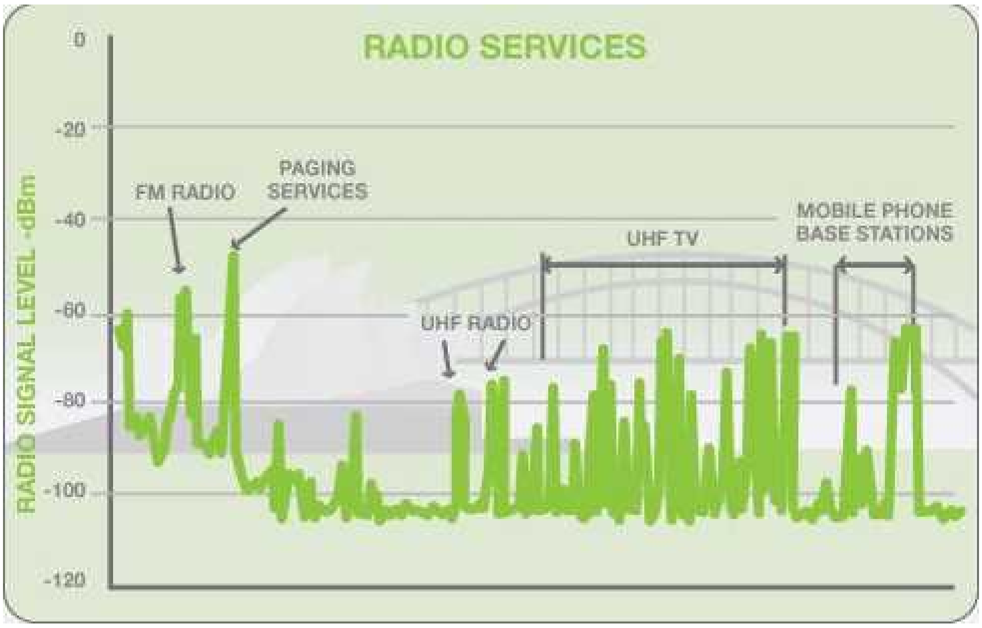


Figure 2.9: typical radio communications signals in a community

This figure (Figure 2.9) is a plot from a spectrum analyzer (specialized radio measurement equipment) showing the various radio communications signals measured in a typical community. The plot is taken at one location to illustrate typical radio communication signals present, and to make a comparison of signal level.

The type of radio service is indicated on the plot along horizontal axis and signal level in dBm (level relative to 1 milli-watt) on the left hand axis. The units are not really important here except to show relative levels. The figure also shows how many radio services are used in a typical community [20].

2.4 Specific Absorption Rate (SAR)

Exposure to communication electromagnetic fields has raised public concern about possible effects to people exposed to these radiations. Concerns for potential health impacts caused by operation of communication Means are becoming an issue for individuals, researchers and governments. Many studies have been done and other are ongoing regarding potential biological, thermal non-thermal and behavioral effects to humans exposed to electromagnetic fields.

Interaction of electromagnetic fields with a human is a multidimensional issue that depends on the electromagnetic properties of human biological tissues. The most important parameter used to estimate human exposure to electromagnetic fields is SAR (Specific Absorption Rate).

For this reason almost all national and international safety guidelines and recommended limits on human exposure to electromagnetic fields are given in terms of SAR [31] .

SAR is defined as a measure of the rate at which electromagnetic energy is absorbed in the body during exposure to electromagnetic radiations .The unit of SAR is watts per kilogram (W/kg).

The international guidelines of Electromagnetic Fields (EMF) exposure are based on deep analysis and are designed to offer protection for all persons, including children, against known health effects of EMF with a large safety consideration.

MF exposure guidelines for radio communications transmitting antennas specify the maximum level of radio frequency energy (SAR) that can be safely absorbed by the whole body .This is because exposure from a radio communications transmitting antenna is typically over the whole body .And we can also test base station antennas exposure using a similar procedure to the SAR test for wireless devices [9] .

SAR can be calculated using three methods .The first method is Electric Field distribution measurement method which represents the correlation between the electric intensity of the body E and SAR with the following formula:

$$SAR = \frac{\sigma \, |E|^2}{\rho} \quad W/kg \qquad \ldots\ldots\ldots\ldots..(2.2)$$

Where :
σ - Conductivity of body tissue (S/m).
E - Root mean square of intensity of electrical field at considered point (V/m).
ρ- Mass density of tissue at that point (kg/m^3).

In the previous formula. The electric field strength is measured using the Spectrum Analyzer and using the average values of σ and ρ for the human body in specific frequencies to calculate SAR .which is the easiest and most practical method.

The second method is Temperature Distribution Measurement Method .Since SAR and the temperature rise due to the electric absorption are proportional, SAR is measured by the distribution of the temperature rise. The following formula represents the correlation between the rise in the phantom temperature and SAR.

$$SAR = c\ T/t \qquad \ldots\ldots\ldots\ldots..(2.3)$$

Where:
T -Temperature rise (K) .
c -The specific heat of various body tissues (J/kg K).
t -The exposure duration (sec).

Temperature can be measured using a thermal sensor or infrared camera (referred to as thermo graphic camera, infrared ray thermal picture device or temperature distribution analyze).But this method is hard and not practical for our project.

Third method is Magnetic Field Measurement Method .It has been reported that SAR of the body surface and inside can be sought by measuring the injection magnetic field on the body surface under similar installation conditions as when measuring electric field distributions [8] .

2.5 Effect of radiation source on humans body

For many years in the science community the Electromagnetic radiation has been a hot topic .It can be found everywhere, coming from every electronic device and every source of energy .These controversial waves have many beneficial, but also it has many detrimental effects on the human body .

However, rapid development of man industry, constantly oscillating electromagnetic fields (EMFs) from new technologies is expected to continue and even accelerate, as we adopt an increasing number of systems and devises emitting such fields .This development one of humans need, so that it cannot and should not be stopped as most of these devices are extremely helpful and provide improved quality of life to millions of consumers.

On other hand, the daily exposure to electromagnetic fields (EMFs) maybe cause some bad effect so that this situation become one of the important issues of health policies, both at the level of individual countries and internationally .Thus, international scientific organizations around the world are trying to respond to those concerns with establishment of the health and safety standards.

2.5.1 Potential health effect of EMFs

There is some possible effect on human body where this health effects based on heating .So that, the recommended limits necessary to have safe exposure from RF energy. This heating effect varies with the frequency of the electromagnetic energy. For example, the eyes are particularly vulnerable to RF energy in the microwave range, and prolonged exposure to microwaves can lead to cataracts [45].

The Specific Absorption Rate (SAR) founded to measure this heating effect. The IEEE and many international organizations have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR.

2.5.1.1 Thermal and Non thermal effect

High Frequency (HF) electromagnetic fields are absorbed depending on the frequency and polarization of the fields on the one hand and the dimensions and material characteristics of the biological system on the other hand .

The thermal effects result from the fact that electromagnetic fields with frequencies above approximately 100 kHz may be partly absorbed by materials containing water such as biological tissues and be converted into heat .Biological or health effects maybe occur if there is excessive heating .Exposures in everyday life generally do not involve tissue heating .Therefore, this will not lead to thermal effects .But people still fear that such exposures might result health effects, for example non-specific symptoms such as headache and sleeplessness or even life threatening effects like the induction of cancer .Because heating is not likely to occur, such effects are called non-thermal.

Non-thermal effects are those occurring when the energy deposited in the sample is less than that associated with normal temperature fluctuations of the biological system being studied. In many studies a non-thermal biological effects have been demonstrated, but adverse health effects on the basis of such effects have not been established .Therefore they cannot serve as a basis for exposure guidelines[25].

2.5.1.2 Short term and Long term

Short or long-term effects depending on when effects can be measured or observed . Short-term effects occur during or shortly after exposure .But long-term effects may not appear until months or years later .Of course every long-term effect is always the result of a short-term effect .At some point in time there should have been an interaction between the electromagnetic fields and biological tissue [25].

The heating of tissues is the only scientifically established effect associated with exposure to radiofrequency (RF) electromagnetic fields .At the frequencies used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organs of the body.

Many of studies present the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers. To date, research does not suggest any consistent evidence of adverse health effects from exposure to radiofrequency fields a t levels below those that cause tissue heating . Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or “electromagnetic hypersensitivity” [1].

2.5.1.3 Direct and Indirect effect

The interaction between the electromagnetic field and biological tissues_causes the direct effects, but when the interaction between the electromagnetic field and medical devices that contain electronics then the indirect effects will occur.

The indirect effects happen because the electromagnetic fields may interfere with electronic circuits of exposed equipment .This may lead to situations where these devices malfunction and the health of people using them may be afflicted [25].

2.5.1.4 Effect of far-field and near-field

The volume of space surrounding an antenna consists of two or three distinct regions depending on the nature of the electromagnetic field produced by the antenna.

The far field region of a radiating antenna is the region far enough from the source that only the radiating field components are significant .The electric and magnetic fields decay inversely with distance from the source, the energy is equally distributed between the electric and magnetic fields and the field components are orthogonal . Power density decays with the inverse square of the distance from the source .Angular field distribution is independent of distance from the antenna .

The radiating field predominates, but the non-radiating fields are not insignificant . The outer boundary is approximated by $R \sim D/\lambda$, where D is the largest dimension of the antenna .Interference between different parts the antenna is significant .The angular field distribution is dependent on distance from the antenna.

The non-radiating electric and magnetic fields dominate. For electrically small antennas, the region is either predominately electric or predominately magnetic. $R \sim \lambda/2\pi$.

Near-field sources are operating in the close vicinity of the human body for example self-usage of a mobile phone and can cause temporarily high local exposure but in case of far-field it usually lead to lower but rather continuous exposure levels like exposure to base stations .Total personal exposure consists of contributions from near-field (NF) and far-field (FF) [46].

2.5.2 Electromagnetic exposures indoors

There are many electric devices that can be as a source of electromagnetic fields (EMF) for example the video display terminal and the personal computers themselves produce very little EMF .Also there is another source which is cathode-ray tube screen where many studies talked about this subject.

2.5.3 Electromagnetic exposures out-doors

2.5.3.1 Effects from GSM base station

In recent times, the GSM communications network in the world has expanded rapidly, and most countries use this technology .But daily exposure to GSM electromagnetic fields has raised public concern of possible adverse health effects to people living near base station antennas.

The base station has a common concern which is relates to the possible long-term health effects where whole-body may exposure to the RF signals .To date, the only health effect from RF fields was determined in many researches related to an increase in body temperature more than (1 °C).

The recent surveys have indicated that RF exposures from base stations are normally thousands of times below international standards and due to their lower frequency when we make comparing at similar RF exposure levels the body absorbs up to five times in case of the signal from FM radio and television than from base stations [49].

Many studies take the effect of base station on human body one of these studies result said that for GSM 900 MHz base station antenna even in the peak-time of usage, in different sites, different heights from ground level, indoors and outdoors, with and without usage of few mobile phones, in the vicinity of base station antennas, the practical measurements of field strength and power density levels were below safety guidelines.

Another study was in Germany the results of this study show that the GSM cellular phone tower radiation is the dominating HF source in residential areas in Germany. The median power density is found in the range of 200 $\mu W/m^2$ and the maximum value exceeding 100,000 $\mu W/m^2$. No location reached or exceeded the official standard values for the USA or Germany which is10,000,000 $\mu W/m^2$ [47].

2.5.3.2 Effect from radio and television transmitters

Radio and television broadcasting stations use electromagnetic waves to transmit their signals with various RF frequencies, depending on the channel, ranging from about 550 KHz for AM radio up to about 800 MHz for some UHF television station. For FM radio and VHF television frequencies it is lie in between these two extremes.

The body absorbs more energy at radio and television frequencies which are lower than those employed in mobile telephony and because a person's height makes the body an efficient receiving antenna [49].

Several factors control the amount of RF energy to which the public or workers might be exposed as a result of broadcast antennas. One of these factors is the type of station also the design characteristic of antennas being used, the amounts of power transmitted to the antenna, height of the antenna and the distance from the antenna. The absorbed energy by the human body is different from some frequencies to other frequencies.

For workers who make antenna maintenance they require to climb antenna structures for repairs purpose or beacon replacement. So, in these cases it is possible that the workers exposed to high levels of RF energy when they interact with an active tower or in areas immediately surrounding a radiating antenna and this can be founded in some reports done by EPA and OSHA [15].

But if we say that RF radiation maybe cause the cancer, the relevant exposure may will be years or even decades before the disease becomes manifest. Thus while the balance of evidence from such studies does not indicate a hazard, and where increased rates of disease have been found they could have occurred by chance or as a consequence of unrecognized confounding factors, the findings do not provide strong evidence again a hazard.

2.5.3.3 Wireless antennas and RF exposure levels

Power density is known as the rate at which the energy flows through a defined area and the RF exposure levels are described in terms of this power density .The levels produced by wireless communication measured with ($\mu w/cm^2$) where power density measured with (w/cm^2).

When we move away from antenna the power density from a Wireless antenna start decrease rabidly with the square of the distance which we move. Because all evidence present no adverse short -or long-term health effects occur from the RF signals produced by base stations .Since wireless networks produce generally lower RF signals than base stations so that no adverse health effects are expected from exposure to them.

As we said before, there are many factors that control the intensity of RF energy, also RF exposures differ according to weather is a stand-alone tower or on the rooftop of a building. But the most common exposure situation for us occurs with antennas placed on towers [49].

2.6 Antennas

2.6.1 Definition

As defined by the IEEE standards that the antenna or aerial is "a means for radiating or receiving radio waves ."In other words we can define it that the antenna is an electric device that sends or receives radio and television signals, antennas convert electromagnetic waves into electrical currents and vice versa[11].

2.6.2 Radiation Mechanisms [11]

First of all we will examine some basic sources of radiation in order to show how the electromagnetic fields are generated by the sources .

Single wire

If the electric charge moves the current flow is created .Equation (2.3)shows the basic relationship between the current and charge .It simply states that to create a radiation, there must be a time varying current or an acceleration of charge .To create a charge the wire must be curved, bent or terminated

$$l\,\frac{dI_z}{dt} = lq_l\frac{dv_z}{dt} = lq_l a_z \qquad \ldots\ldots\ldots\ldots..(2.4)$$

Where l (m) is the length of wire, $\frac{dI_z}{dt}$ if the current is time varying, q_l (coulomb/m) is the charge per unit length and $\frac{dv_z}{dt} = a_z$ (meters/sec^2) is the acceleration.

If a charge is not moving, current is not created and there is no radiation .If charge is moving with uniform velocity; there are two cases .First, there is no radiation if the wire is straight and infinite in extent .Second, there is no radiation if the wire is curved, bent, discontinuous, terminated, or truncated .But, it radiates if charge is oscillating in a time-motion, even if the wire is straight. Figure 2.10 shows the wire configuration for a radiation.

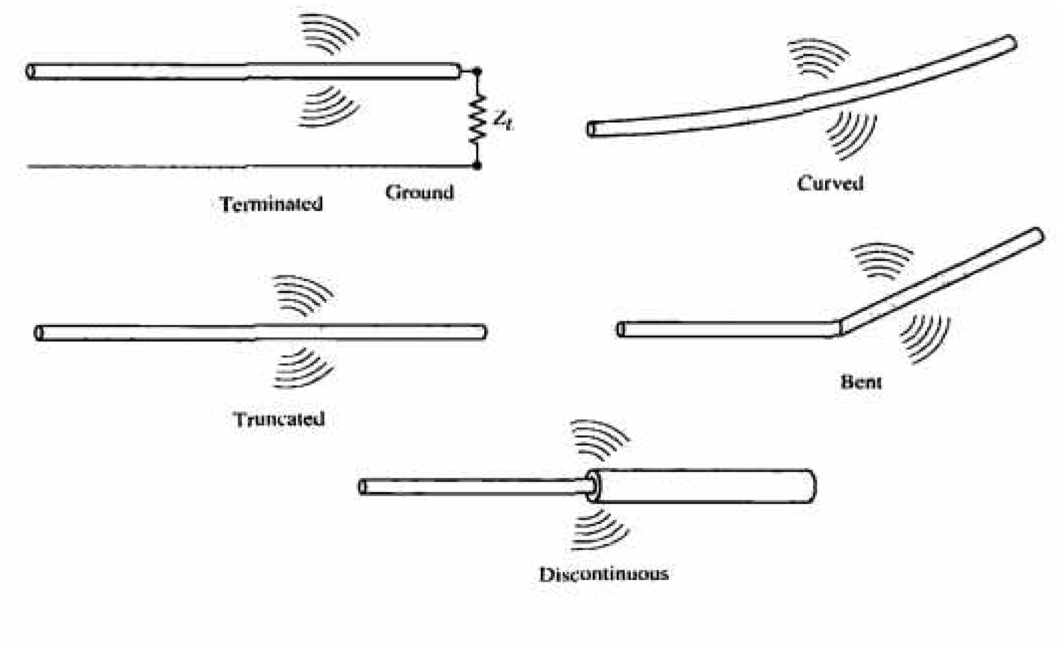


Figure 2.10 :wire configuration for a radiation.

Two wires

In two wire radiation mechanism the two conductor transmission line creates an electric field between the conductors by applying a voltage as shown in Figure 2.11 . The movement of the charges creates a current that in turn creates magnetic field intensity .Associated with the magnetic field intensity are magnetic lines of force which are tangent to the magnetic field.

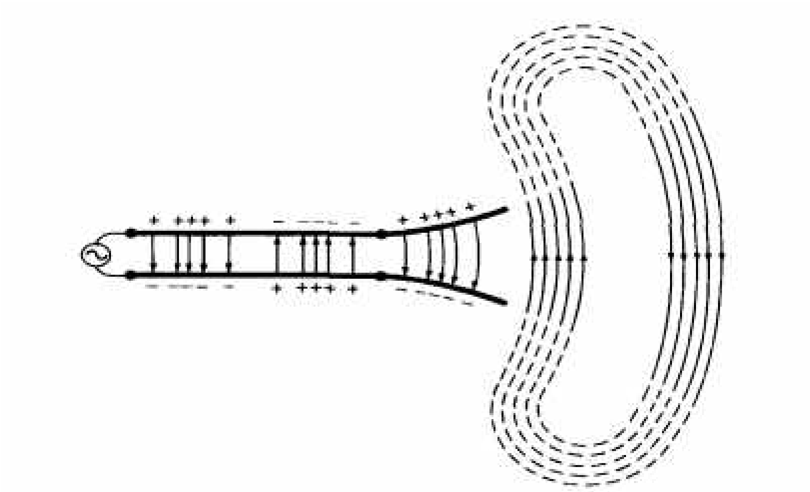


Figure 2.11 :Two wires antenna, free-space wave and electric field lines.

We know that the electric field lines start on positive charge and end on negative or infinity, or still moving on closed loop .Because there are no magnetic charges, magnetic field lines always from closed loops encircling current-carrying conductors.

The creation of time–varying electric and magnetic fields between the conductors forms electromagnetic waves which travel along the transmission line .The free space waves are periodic but constant phase moves with the speed of light and travels a distance of λ/2 in the time of one-half of period .

The electromagnetic waves created by an electric disturbance .If the initial electric disturbance by the source is a short duration, the created electromagnetic waves travel inside the transmission line, then into antenna, and finally are radiated as free-space waves.

Dipole

The lines of force created between the arms of small center-fed dipole in the first quarter of the period during which time the charge has reached its maximum value and the lines have traveled outwardly a radial distance λ/4.

During the next quarter of the period, the original lines travel an additional λ/4)a total of λ/2 from initial point (and the charge density on the conductors begins to become weaker .The lines of force created by the opposite charge and travel distance λ/4 as shown in Figure 2.12.

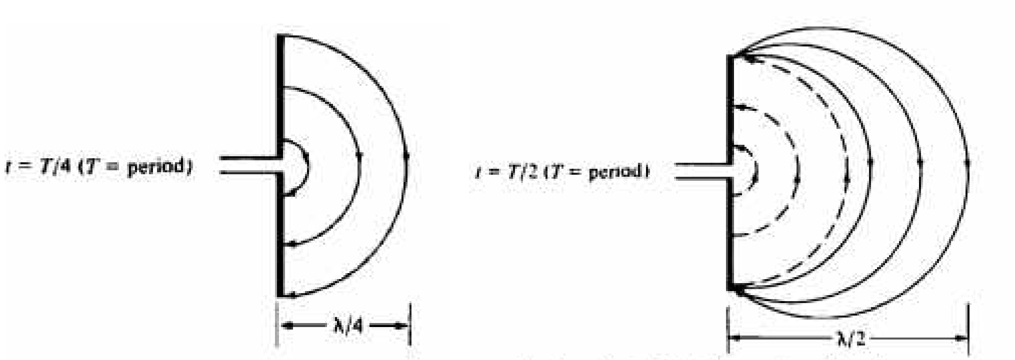


Figure 2.12 :Formation of electric field lines for dipole.

Isotropy

The antenna that radiates its energy equally in all directions called isotropic antenna, often this concept used as a useful reference to describe real antennas, and its radiation pattern is represented by a sphere whose center related with the location of the isotropic radiator .But the non-isotropic antenna radiates most of the energy fed into part of the space on specific direction it's represent the real antenna .

$$\overline{E}\ \ r,\theta,\emptyset\ \ = \frac{e^{-jkr}}{4\pi r}\hat{u}(\theta,\emptyset) \qquad \dots\dots\dots\dots..(2.5)$$

2.6.3 Some antenna parameters

Impedance matching

These techniques can be used for efficient transfer of energy to achieve maximum power transfer, designed to be effective for a specific frequency of operation in narrow band techniques, or for a given frequency spectrum in broadband techniques, the impedance of the radio, the antenna, and the transmission line connecting the radio to the antenna must be the same, usually the amount of impedance used in radios is 50 ohm [48].

VSWR and Reflected Power

VSWR stands for Voltage Standing Wave Ratio it is an indication of how good the impedance match is. When VSWR is high then that gives an indication that the signal is reflected before to being radiated by the antenna .But VSWR and reflected power are different ways of measuring and expressing the same thing .2.0:1 or less from VSWR is consideration good .Often VSWR abbreviated as SWR [48].

Bandwidth

From range of frequencies over which the antenna can operate correctly.

Directivity and Gain

Directivity can be defined as "the ratio of the radiation intensity in given direction from the antenna to the radiation intensity averaged over all directions .The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified .The direction of maximum radiation intensity is implied [11].

Mathematically it can be written as this equation:

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \qquad \ldots\ldots\ldots\ldots..(2.6)$$

WhereD is directivity (dimensionless). U is radiation intensity(W/solid angle), $U_0$is radiation intensity of isotropic source (W/solid angle) and P_{rad} is total radiated power(W).

Any real antenna is radiates energy in a specific direction so that the antenna cannot create energy it just radiate .In some directions is radiates more or less energy than the isotopic antenna, so that the gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy an isotropic antenna would radiate in the same direction on the same input power.

The gain of the antenna is closely related to the directivity .The difference between the two quantities is that the total power accepted by the antenna over 4π for gain rather than total radiated power over 4π , taking into consideration the losses in the antenna as well as its directional capabilities .So that, if the antenna is 100 % efficient the two quantities are the same [5].

Antenna Placement

Always, to get a good performance must be careful to place of antenna and chose the correct placement .

Radiation pattern

The radiation pattern of antenna is representation of the distribution of the power radiated(out flowing) from the antenna in the case of transmitting antenna, or received (inflowing)to the antenna in the case of receiving antenna, as a function of direction angles centered on the antenna .The radiation pattern is three-dimensional, but it is difficult to display the three dimensional radiation patterns in a meaningful manner, so we use two-dimensional radiation pattern which can be displayed easily on a screen or piece of paper [48].

Polarization

The process that causes neutral parties to take sides in a conflict is called polarization . It also causes individuals on either side of the conflict to take increasingly extreme positions that are more and more opposed to each other .As parties move toward these opposite "poles, "they define themselves in terms of their opposition to a common enemy .Trust and respect diminish, and "distorted perceptions and simplified stereotypes emerge".

The plane of polarization is best described in terms of the direction of the electric field vector E, in the direction of maximum radiation .The electric field vector E will map out an ellipse in the plane perpendicular to the direction of propagation .In general, this is called elliptical polarization [10].

Linear Polarization

If we have two linearly polarized waves, E1 and E2 of the same frequency, each of these have either the X or Y component of the electric field vector E .the X component of the electric field vector would be represented as:

$EX = E1\sin(\omega t - \beta z)$.

And the Y component would be represented as :

$EY = E2\sin(\omega t - \beta z + \delta)$.

Resulting electric field vector would take the following form:

$E = iE1\sin(\omega t - \beta z) + jE2\sin(\omega t - \beta z + \delta)$.

Where i and j are unit vectors along the x -and y-axis, respectively.

In this case can be investigated assumes that E2 is either exactly in phase or 180° out of phase with E1 .With this condition, it is observed that there are four different cases of linear polarization that can be obtained.

Elliptical Polarization
Another case that can be presented assumes that EY and EX are in time phase quadrature, meaning that they have exactly a 90° phase difference between them.

Circular Polarization
A third case that can be presented sees the components EY and EX in time phase quadrature, as in the previous case, but with the values of E1 and E2 being equal [10].

2.6.4 Mathematical calculations

Assume that there are *n* antennas as illustrated in Figure 3. The *i*th one may be characterized by its power (*Pi*), gain relative to the isotropic antenna in a given direction (*Gi*), and coordinates relative to a certain origin (*xi*,*yi*,*zi*), where $i \in \{1, 2, .., n\}$.

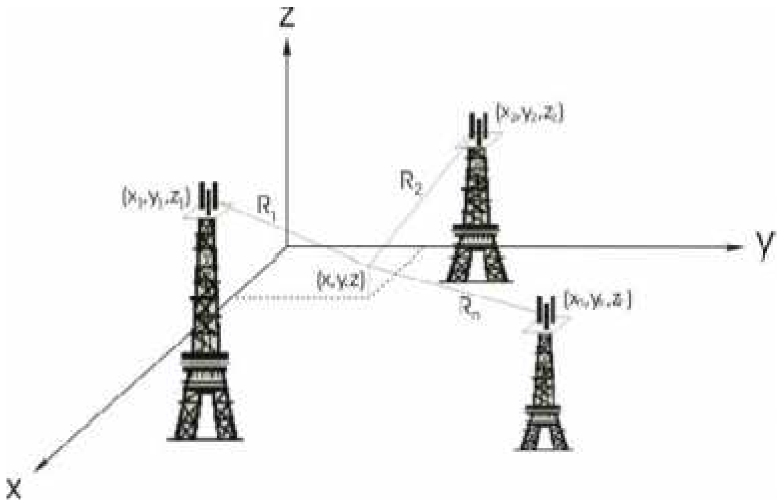


Figure 2.13: Antennas contributing to RF field at point of interest.

Although the quantity *Gi* is generally a function of coordinate variables, it may be safely treated as a constant to simplify calculations. The electromagnetic power density (*Si*) due to the *i*th radiating antenna at point (x,y,z) located in the far field free space is given by the general equation

$$S_i = \frac{EIRP_i}{4\pi R_i^2} \qquad \dots\dots\dots\dots..(2.7)$$

where R_i is the distance to the antenna and $EIRP_i$ is the Equivalent Isotropic Radiated Power of the antenna. It is given by the product of the antenna power and its gain, i.e.

$$R_i^2 = (x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2 \qquad \dots\dots\dots\dots..(2.8)$$

and

$$EIRP_i = P_i * G_i \qquad \dots\dots\dots\dots..(2.9)$$

The total power density due to all antennas is given by super position as:

$$S = \sum_{i=1}^{n} S_i = \sum_{i=1}^{n} \frac{P_i G_i}{4\pi[(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2]} \qquad \dots\dots\dots\dots..(2.10)$$

The magnitude of the electric field strength (*E*) and magnetic field strength (*H*) are related to the power density as follows[35]:

$$S = \frac{E^2}{377} = 377H^2 \qquad \dots\dots\dots\dots..(2.11)$$

2.7 Standards and limits for human exposure

There are different national and international organizations which determined limits as guidelines for exposure of humans to electromagnetic field radiations. These exposure limits be determined due to different approaches and precautions of each country.

Standards and guidelines which determine the exposure limits which be accepted for electromagnetic field radiations vary from country to another, according to its scientific rules be used and its precautions to protect its population.

In addition to the thermal effects, there are indirect effects that can arise, for example, those involving interaction with an object at different electrical potential from the body.

Guideline to these possible health effects are normally in two levels of protection depending on whether the subjects are the general public and not controlled by health checks, protective clothing , or procedures, or subjects are workers in controlled environments or controlled working practices.

Guidelines often differentiate between occupational exposure and general public exposure, these can be defined as occupational or controlled exposure that is appropriate when person who are fully aware of the potential for exposure system or the levels in their environment.

For the general population one uses the term “uncontrolled exposure”, which applies when the person who are exposed may not be aware either of the levels of fields that exist or of the possible consequences of their exposure .

There are many organization have established limits for human exposure to RF fields. The most widely accepted guidelines are:

1- International commission for Non-ionizing Radiation Protection (ICNIRP).
2- National Radiation Protection Board (NRPB).
3- American National Standards Institute; Institute of Electric and Electronic Engineers (ANSI/IEEE).

2.7.1 International commission for Non-ionizing Radiation Protection (ICNIRP)

ICNIRP standards is used in most European countries, since the publication of ICNIRP; guidelines for limiting EMF exposure up to 300GHz several institutions have criticized the guidelines as lacking clear interpretation on exposure safety or direct application to equipment in existence. Concerns have also been expressed about the use of safety factors, precautionary aspects and long-term exposure as well as points not included in ICNIRP guideline.

The starting point is the behavioral changes founded when experimental animals were exposed to RRF radiation at levels that produced a rise in whole-body temperature in excess of 1ºC. SAR of (1-4) W/Kg or higher is needed to cause these changes.

ICNIRP guidelines feature a two-tier system, which lower limits for exposure of the public than occupational or workers exposure.

In the controlled environment (workers), the basic restriction SAR is 0.4 W/Kg for the whole body exposure and 10W/Kg for partial body exposure (head and trunk) with a permissible time of 6 minutes. In the uncontrolled environment (general public), the basic restriction SAR is 0.08W/Kg for the whole body exposure with a permissible time of 6 minutes.

It is obvious that the guidelines for the general public and five times lower than for occupational (workers) exposure. This difference was intended to allow for the following circumstances:

1- Exposure under extreme environmental conditions increases the thermal effect from RF exposure.
2- Worker are normally adults exposed under controlled conditions, who are trained to be aware of potential risks and to take appropriate precautions to avoid unnecessary exposure, the general public cannot reasonably be expected to take the same precautions.
3- Worker are exposed only during the working day, usually 8 hours per day, on the other hand, the general public can be exposed for 24 hours per day, this total weekly exposure duration is approximately five times that of workers
4- In general, children are normally considered to be more sensitive to exposure to physical, chemical and biological agent. At higher frequencies, children absorbed more energy from external electromagnetic fields than adults.

INCIRP standard has exposure limits for electric and magnetic fields that are whole body and time averaged. Exposure limits for the magnetic fields (H) are relaxed below 100MHz since the exposure limits at lower frequencies are based more on electro stimulation than body heating and both induced and contact currents are related to the strength of the electric fields.

INCIRP guidelines are set out in two levels of protection for the public and the healthy worker under the following condition [22]:

1- All SAR values are averaged over any 6 min period and localized SAR values are averaged over 10g tissues in a single mass
2- For palsies of duration T the equivalent frequency is determined by 0.5T
3- For pulsed exposure in the range of (0.3-10) GHz and for localized exposure of the head, the specific absorption should not exceed 10mJ/kg averaged over 10g.

The frequency dependence of the reference field levels is consistent with data on biological effects and coupling of the fields. INCIRP recommends the use of the reference levels as general guidance for EMF limits for workers and the general public.

The following tables summarize INCIRP Standards and limits for human exposure[23]:

Table 2.2: Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.

Exposure characteristics	Frequency range	Current density for head and trunk (mA m^{-2}) (rms)	Whole-body average SAR (W kg^{-1})	Localized SAR (head and trunk)(W kg^{-1})	Localized SAR (limbs) (W kg^{-1})
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/*f*	—	—	—
	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 exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/*f*	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	*f*/500	0.08	2	4
	10 MHz–10 GHz	—	0.08	2	4

Table 2.3: Basic restrictions for power density for frequencies between 10 and 300 GHz.

Exposure characteristics	Power density (W m^{-2})
Occupational exposure	50
General public	10

Table 2.4: Reference levels for occupational exposure to time-varying electric and magnetic fields (unperturbed rms values)

Frequency range	**E-field strength (V m^{-1})**	**H-field strength (A m^{-1})**	**B-field (μT)**	**Equivalent plane wave power density *S*eq (W m^{-2})**
up to 1 Hz	—	1.63×10^5	2×10^5	—
1–8 Hz	20,000	$1.63\times10^5/f^2$	$2\times10^5/f^2$	—
8–25 Hz	20,000	$2\times10^4/f$	$2.5\times10^4/f$	—
0.025–0.82 kHz	500/*f*	20/*f*	25/*f*	—
0.82–65 kHz	610	24.4	30.7	—
0.065–1 MHz	610	1.6/*f*	2.0/*f*	—
1–10 MHz	610/*f*	1.6/*f*	2.0/*f*	—
10–400 MHz	61	0.16	0.2	10
400–2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	*f*/40
2–300 GHz	137	0.36	0.45	50

Table 2.5: Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values)

Frequency range	**E-field strength ($V\ m^{-1}$)**	**H-field strength ($A\ m^{-1}$)**	**B-field (μT)**	**Equivalent plane wave power density *S*eq ($W\ m^{-2}$)**
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2\times10^4/f^2$	$4\times10^4/f^2$	—
8–25 Hz	10,000	4,000/*f*	5,000/*f*	—
0.025–0.8 kHz	250/*f*	4/*f*	5/*f*	—
0.8–3 kHz	250/*f*	5	6.25	—
3–150 kHz	87	5	6.25	—
0.15–1 MHz	87	0.73/*f*	0.92/*f*	—
1–10 MHz	$87/f^{1/2}$	0.73/*f*	0.92/*f*	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	*f*/200
2–300 GHz	61	0.16	0.20	10

Table 2.6: ICNRIP reference levels at specific frequencies

	Frequency (MHz)	**Power Density (W/m^2)**	**Electric field Strength(V/m)**	**Magnetic field Strength(A/m)**
General public exposure	900	4.5	41	0.11
	1800	9	58	0.15
	1900	9.5	60	0.16
	2100	10	61	0.16
Occupational exposer	900	22.5	90	0.24
	1800	45	127	0.34
	1900	47.5	131	0.35
	2100	50	137	0.36

2.7.2 NRPB

NRPB exposure guidelines incorporate basic restrictions on the specific absorption rate. To verify that the exposure of an individual is within NRPB guidelines, it necessary to demonstrate that none of the basic restrictions is exceeded.

SAR is averaged over an exposure time and a specified mass of tissue, depending in the tissue region. Averaging times are specified because of the time taken for the temperature of the tissues to equilibrate when they are exposed to the radiation. These restrictions apply equally to workers and to members of the general public.

NRPB guidelines also specify reference levels for external electromagnetic field strengths, at or below which the basic restriction on whole body SAR will not be exceeded. The reference levels in the frequency range 800-900MHz is from 26 to $33W/m^2$ and for 1800-1900MHz the level is $100W/m^2$.

Experimental studies on animals and man indicate that a thermal load from inside or outside the body in addition to the basal metabolism results in a 1°C body temperature rise, after which the thermoregulatory mechanisms control and lower temperature. The external thermal load to create this rise over about 4W/kg; RF energy is no different, so using suggested safety of ten result in whole body exposure limit of 0.4W/kg[5].

2.7.3 IEEE standard exposure limits

The present IEEE exposure gridlines have lineage that extends back for nearly half a century. While the C95.1 standards are voluntary, they have had a major influence on government policy in United States and in the development of exposure limits in many places around the world.

Determination of exposure standards and safety levels of radio frequency radiation has been a research area of significant interest for over decades and, in particular, since 1966 with the publication of a safety standard by United State of America standards Association, currently known as the American National Standards Institute (ANSI) [40].

An exposure condition can be considered to be acceptable if it can be shown that it produces SARs below 0.08W/kg as averaged over the whole body, and spatial peak SAR value not exceeding 1.6W/kg as average over any 1g of tissue. "This is a safety standard of ANSI"

Another safety standard is set in Europe for the use of mobile telecommunication equipment by the public. The European standard is set at 2W/kg averaged over a volume equivalent to 10g and period of 6 min [29].

A committee of ANSI, confirmed a $10mW/cm^2$ as the safe level for such industries as radar and radio others whose employees would be exposed to electric equipment [41]. ANSI standard for safe human exposure to radio frequency fields provides guidelines for maximum permissible exposure limits. In frequency range of wireless communication, the metric is derived from SAR in tissue and the incident power density that case it.

In the controlled environment, basic restriction SAR is 0.4W/kg for the whole body exposure in any 6 minutes of time. In uncontrolled environment, restriction SAR is 0.08W/kg (is reduced by a factor of five) for whole body exposure averaged over any 30 minutes of exposure [30].

Table 2.7: Summary of Exposure Guideline[43]

	European power frequency		Mobile phone (GSM) frequency		Microwave oven frequency
Frequency	**50 Hz**	**50 Hz**	**900 MHz**	**1.8 GHz**	**2.45 GHz**
EM Field	Electric field (V/m)	Magnetic field (μT)	Power density (W/m^2)	Power density (W/m^2)	Power density (W/m^2)
Public exposure limits	5000	100	4.5	9	10
Occupational exposure limits	10000	500	22.5	45	-

Comparison between ICNIRP&NRPB and ANSI/IEEE

The standards that limit microwave exposure set at 0.4 w/Kg, SAR for occupational 0.08 W/Kg for public exposure (ANSI 1992). The averaging time for determination of SAR was 6minutes (NRPB 1993).

Table 2.7: AR limits.

Document	**SAR limit(w/kg)** Workers	general public	time(min)
NRPB	0.4	-	15
ICNIRP	0.4	0.08	6
ANSI/IEEE	0.4	0.08	6(30)

2.7.4 World health organization (WHO)

WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standard, providing technical support to countries and monitoring and assessing. WHO stated safety regulations, which illustrated at Table 2.8.

Table 2.8: safety limits for MF and EF in WHO.

Values	At Work		Public Areas	
	MF(μ T)	EF (KV/m)	MF(μ T)	EF (KV/m)
High value	7500 (1-8) hr/day	30 (1 hr only)	1000 (limited hours)	12 (limited hours)
Low value	424 Whole Day	20(for 2 hrs) 5(Whole day)	100 (whole day)	1 (whole day)

MW oven standard

The Food and Drug Administration (FDAs) microwave oven standard is an emission standard that allows leakage which measured at 5cm from the oven surface of (1mW/cm^2) at the time of manufacture and a maximum level of(5mW/cm^2) during the lifetime of the oven.

The standard also requires ovens to have two independent interlock systems that prevent the oven from generating microwaves the moment that latch is released or the door of the oven is opened[41].

2.7.5 FCC Limits for Maximum Prermissible Exposure (MPE)

The Federal Communications Commission (FCC) is an independent United States government agency. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite and cable. The FCC's jurisdiction covers the 50 states, the District of Columbia, and U.S. possessions.

The FCC is directed by five Commissioners appointed by the President and confirmed by the Senate for 5-year terms, except when filling an unexpired term. The President designates one of the Commissioners to serve as Chairperson. Only three Commissioners may be members of the same political party. None of them can have a financial interest in any Commission-related business.

Over the past years, the Federal Communications Commission (FCC) and its Local and State Government Advisory Committee (LSGAC) have been working together to prepare a voluntary guide to assist state and local governments in devising efficient procedures for ensuring that the antenna facilities located in their communities comply with the FCC’s limits for human exposure to radiofrequency (RF) electromagnetic fields.

The exposure limits adopted by the FCC expressed in terms of electric and magnetic field strength and power density for transmitters operating at frequencies from 300 kHz to 100 GHz are shown in Table 2.9 and Table 2.10. The FCC also adopted limits for localized ("partial body") absorption in terms of SAR that apply to certain portable transmitting devices such as hand-held cellular telephones[52].

(A) Limits for Occupational/Controlled Exposure

Tabel 2.9: FCC Limits for Occupational/Controlled Exposure.

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	100	6
3.0-30	1842/f	4.89/f	$900/f^2$	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

(B) Limits for General Population/Uncontrolled Exposure

Tabel 2.10: FCC Limits for General Population/Uncontrolled Exposure.

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	100	30
3.0-30	824/f	2.19/f	$180/f^2$	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

Chapter Three

Methodology

Contents

3.3 Methodology

3.1.1 Mobile Phone Base Stations (MPBS)

Mobile phone base stations (MPBS) have been selected randomly from Hebron district. The selection included those in the density populated areas as well as less density populated areas. Locations of MPBS also will be noted and divided into two categories, i.e. those situated within and > 200 meters from dwellings (schools and houses and public buildings). The study covered a Comprehensive sample of MPBS in Hebron district, which exceeds 50 MPBS.

The measurements are repeated several times, and power density, electric field, magnetic field and power level are measured. Measurements performed starting at the foot of the base station, in the direction of the main beam of the antennas.

The Field Meter (EMR-21C) and spectrum analyzer model 2650 are used to take the desired measurements. Spectrum analyzer was adjustrd at the frequencies that used by the base stations, and the band of GSM operators, and choose the suitable span that separate the measured value from the adjacent frequencies. Field meter measures power density, electric field and magnetic field at frequency range from 100 kHz up to 3 GHz by using isotropic antenna.

The GSM system operates in either the 900 MHz or 1800 MHz band. The 900 MHz band is utilized in Palestine. 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 reason. Time Division Multiple Access (TDMA) is employed to allow each channel to be used by eight simultaneous sessions.

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 towers 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 spectrum analyzer is connected via interface with high specifications laptop that displays and stores the desired data from the spectrum analyzer by using specific software called AK2640.

AK2640 Software, which is a soft program designed to capture measurements of the radiated power from the spectrum analyzer automatically at certain or individual interval times according to our requirements.

The distances between the base station and the measuring point are determined by using Global Positioning System (GPS) and Laser Meter.

At spectrum analyzer measurement points two values are recorded and two pictures are set, the first one is the value and spectrum of the signal power that radiated from the base station, and the other one is the value and spectrum of the maximum radiated electric field. Each value will take 6 minutes of time for accuracy and assurance of global standards.

Consideration for GSM900:

1- Building height at which antennas is to be installed.

2- Height of the macro cell antennas.

3- The distance between the measured point and the base station.

4- The horizontal distances between the macro cells (base stations).

5- The frequency assigned to macro cells.

6- The distance between sectored antennas in the same macro cell.

3.1.2 Mobile stations

The spectrum analyzer has been adjusted to measure GSM JAWWAL uplink. Measurements are taken at the first case for a low power indoor antenna which was 1cm far away from the mobile at different distances form the antenna. The second case was outdoor macro cell antenna, and the measurements are also taken at the same steps as in the first case. In a special case, an experiment is performed to highlight the variation of the radiation levels during the call progress In order to measure the EME Exposure from the mobile.

3.1.3 Radio and TV stations

Almost, the same steps are applied to the Radio and TV broadcasting towers, but the spectrum analyzer is adjusted at the frequencies that used by the radio stations (for FM 88 MHz–108 MHz, for AM 535 KHz – 1700 KHz,for VHF 30 MHz -300 MHz, , for UHF 300 MHz - 3 GHz), and adjusted the appropriate span and band.

Consideration for Radio and Television towers:

1- The towers height.

2- Building height at which tower is to be installed.

3- The type of antennas that used in the tower.

4-The frequency used by the Radio or TV stations.

5- The band of frequencies that must be adjusted by the frequency analyzer.

3.1.4 Microwave Ovens

The measurements are taken at close and different distances (nearly some centimeters) for the power density, electric field, magnetic field and power level. Different kinds, of different manufacture companies and of different age, of microwave ovens will be tested. The same conditions must be considered for all measurements. We will use the appropriate antenna for the spectrum analyzer that can detect the frequencies of microwave ovens. And make sure of the measurements accuracy based on the use of microwave oven data sheet, taking into consideration the manufactured company.

Consideration for microwave oven:

1- The distance between the microwave oven and the measured point.

2- Kind of the microwave oven.

3- The frequency used by the microwave oven.

3.2 Cell Description and Antenna Dimensions

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

The antennas produce a beam that is narrow in the vertical direction but quite wide in the horizontal direction.While most of the energy is contained in the narrow beam. As the beam progresses, a small amount of energy is directed towards the ground to provide coverage as one moves away from the antenna, the signal in this narrow beam decreases in strength as the inverse square of the distance from the antenna.

Because of the narrow beam pattern, RF fields are much weaker outside of the main beam than within it. RF exposure a person receives from a base station thus depends on both the distance from the antenna, and on the angle below the direction of the main beam. At ground level, the signal is relatively weak near the base of an antenna lower. For most base stations, the signal strength at ground level increases gradually with distance from the tower, reaches a maximum between 40-200 m from the base of the tower, and then decreases.

The radio signals developed by base stations are fed to the antennas, which produce beams that are radiated into the cell around the base station. The profile of the beams is carefully chosen by the network planners in order to produce optimal coverage of the cell, the general principle of beam formation is illustrated in Figure 3.2

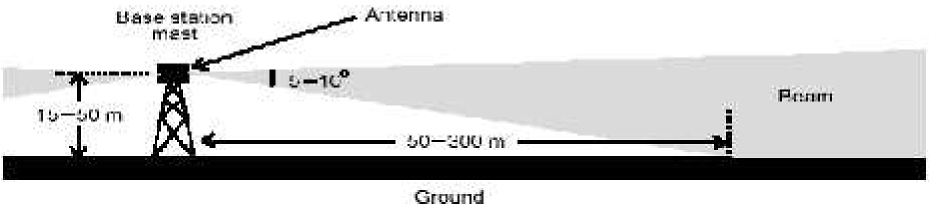


Figure 3.1: Heights showing the shape of the beam formed by a typical antenna used with a macro-cellular base station

Base station traffic is a parameter that cannot be negligible when measuring human's exposures to base station emissions. The traffic that flows through a mobile communication base station depends on human activity, and hence the activity of electromagnetic fields in the environment is expected to be higher during day than at night due to business jobs.

Chapter Four
Practical Field Measurements

Contents

4.1 Introduction

Rapid growth in electric power and utilization in several applications to make life easier leads to appearance for several aspects of relations with diseases which weren't known its relation with electromagnetic fields previously.

Cellular technologies represent the most usage source of electromagnetic radiation (EMR) due to its wide spread on various communities and different ages; it also spread for children without any restrictions or regulations. So, due to these relations we had to discuss the effects of wide spread usage for electromagnetic radiation sources, especially mobile phone usage.

Practical measurements of the power density are very important to insure that the field levels of different electromagnetic radiation sources within the safe limits in public areas.

This chapter presents the results and analysis of field practical measurements that were individually done among different types of electromagnetic radiation sources located in different areas in Hebron district.

This research depends on a real assessment of possible health hazards effects by measuring the actual and real EMRs and its power densities over selected areas in Hebron district. These selected areas represent different attitudes. Measurements were taken at different days and different times (day and night; working and off days).

4.2 Practical Electromagnetic Radiation Measurements

The overall radiation power was measured within the band width 900 MHz up to 3GHz; which is limited by the bandwidth of the spectrum analyzer and field meter used. The experiment equipments are shown in Figure 4.1 (a, b) including the isotropic antenna.

The instruments were together with a soft program designed to capture measurements of the radiated power from the spectrum analyzer automatically at certain or individual interval times according to our requirements.

For the experiments to be done; global positioning system (GPS) is used to capture the location at the same time of the radiated power measurement process. Also, a car was used to carry the measurement sets and to move around the selected and different locations.

Figure 4.1: a) Field Meter (EMR21-C)

Figure 4.1: b) Spectrum Analyzer (2650 3.3GHz)

4.3 GSM radiation measurements

To perform this section; the measurements is divided into two categories. The first category concentrated mainly on the transmission from the base stations. The second category of measuring the GSM radiation is to study the mobile radiation itself.

4.3.1 RF EME exposure levels from JAWWAL Base stations

Base stations transmit power levels typically from a few watts to less than 100 watts, depending on the size of the region or "cell" that they are designed to service. Base station antennas are mounted on buildings or towers at a height that vary from 10 to 50 meters above ground, these antennas emit RF beams that are typically very narrow in the vertical direction but quite broad in the horizontal direction.

Base station traffic is a parameter that cannot be negligible when measuring human's exposures to base station emissions. The traffic that flows through a mobile communication base station depends on human activity, and hence the activity of electromagnetic fields (EMFs) in the environment is expected to be higher during day than at night due to business jobs.

Accordingly, the emitted power from a base station may vary over the day and weak from a minimal power during times with low to modest traffic, to perhaps up to 5 times that level at peak traffic [36].

To measure the exposure levels from the base stations we have chosen a sample of JAWWAL base stations in Hebron district. This sample included ten base stations with different types micro and macro, and different categories green field, roof top and indoor antennas.The distribution of these base stations shown in Figure 4.2.

According to JAWWAL planning method, adjacent cells have different frequencies to prevent interference and power levels are kept to a minimum to ensure no interference with nonadjacent cells, which use the same frequency, so that the spectrum analyzer adjusted to measure GSM downlink at the center frequency that assigned to each antenna by JAWWAL network and 10 MHz bandwidth.

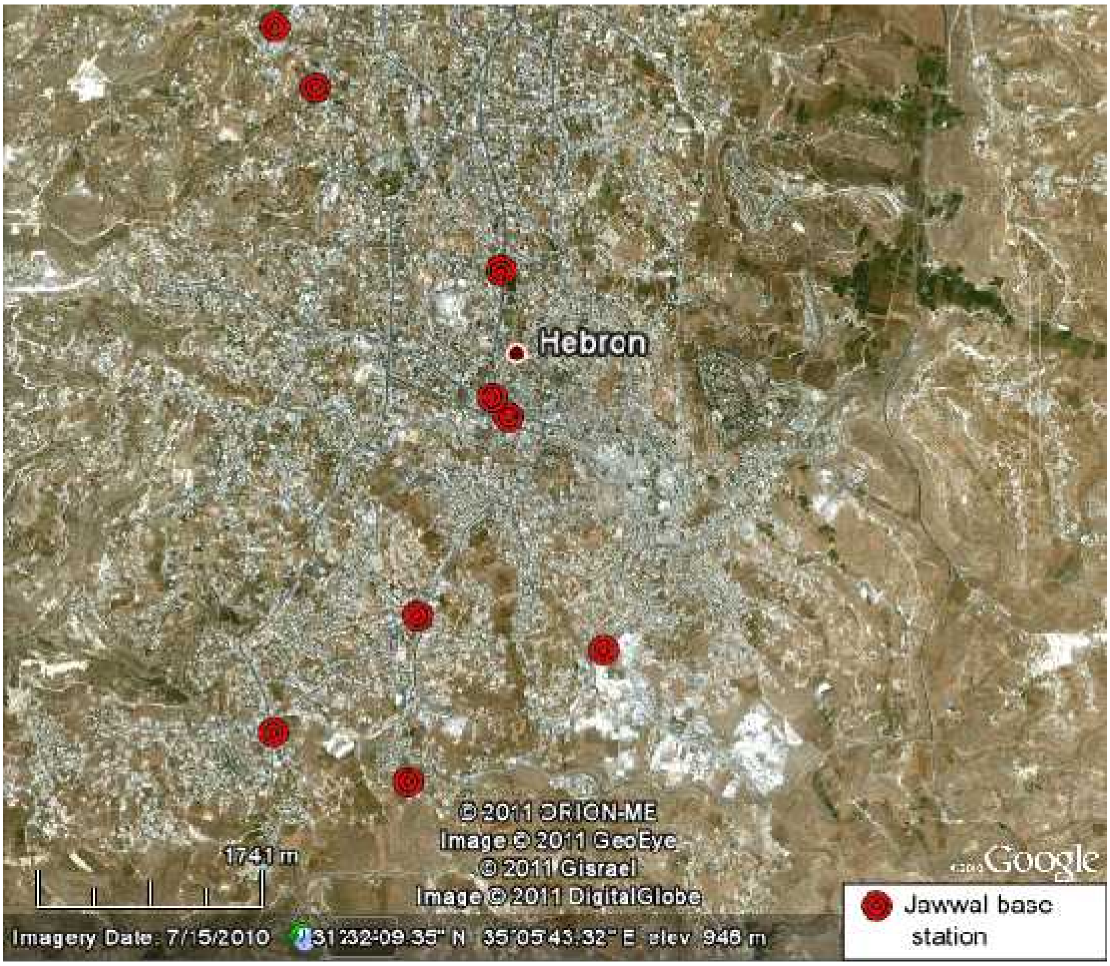


Figure 4.2: Jawwal base station map that included in the project in Hebron district.

The results for the measurements of the chosen base stations as shown below:

1. JAWWAL micro/roof top cell (HMIC11) in Wad AL-Hareya region at 31°30'10.66''N ; 35° 5'23.21''E Figure 4.3:

Figure 4.3: JAWWAL micro cell in Wad Al-Hareya region.

The following tables show the measurements which taken by using the field meter at different distances and the cell height was 3 meter from the roof top.

Table 4.1: Measurements at Wad Al-Hareya base station by field meter.

Distance (m)	**Power density W/m^2**	**Electric field V/m**	**Magnetic field A/m**
3	0.0040	1.34	0.0035
6	0.0055	1.3	0.0035
10	0.0092	1.87	0.0050

Table 4.2: Measurements at Wad Al-Hareya base station by spectrum analyzer.

Distance (m)	**Electric Field (mV/m)**	**Power (nW)**
3	31.69	36.3
6	50.12	91.20
10	60.26	131.8

Table 4.3: Measurements between the antennas (cell A & cell B) by field meter.

Distance (m)	**Power density W/m^2**	**Electric field V/m**	**Magnetic field A/m**
3	0.0016	0.78	0.0022
6	0.0014	0.73	0.0019

Table 4.4: Measurements under the cell, which is 12 m height and non-line of site places.

Distance (m)	**Power density W/m^2**	**Electric field V/m**	**Magnetic field A/m**
10	0.0005	0.42	0.0011
15	0.0003	0.32	0.0008
20	0.0008	0.54	0.0014
25	0.0007	0.53	0.0014

2. JAWWAL macro/roof top cell (HEBR65) in Mafraq AL-a’jori region at 31°30'52.43"N ; 35° 5'27.53"E , Figure 4.3:

Figure 4.4: JAWWAL macro cell in Mafraq AL-a'jori region.

The following table shows the measurements which taken by using the field meter at different distances and the cell height was 9 meters from the roof top.

Table 4.5: Measurements at Mafraq AL-A'jori by field meter.

Distance (m)	Power density W/m^2	Electric field V/m	Magnetic field A/m
3	0.0323	3.49	0.0093
6	0.0032	1.11	0.0029
9	0.0024	0.96	0.0025
15	0.0042	1.26	0.0033
35	0.0012	0.68	0.0018

3. JAWWAL macro/roof top cell (HEBR64) in AL-Haouz Althani region at 31°30'23.80"N; 35° 4'43.90"E, which was 22 height from the ground as shown in Figure 4.5:

Figure 4.5: JAWWAL macro cell in AL-Haouz Althani.

The following table shows the measurements which are taken by using the field meter at different distances to cell A and cell B in the base station:

Table 4.6: Measurements at AL-Haouz Althani by field meter.

Distance (m)	Power density W/m^2	Electric field V/m	Magnetic field A/m
Cell A			
3	0.0061	1.49	0.0041
6	0.0016	0.78	0.0021
Cell B			
3	0.0071	1.64	0.0044
6	0.0020	0.88	0.0023
10	0.0007	0.51	0.0014
15	0.0010	0.64	0.0017
30	N/A	N/A	N/A

And the following table shows the measurements which taken by using the spectrum analyzer to the same base station.

Table 4.7: measurements at AL-haouz Althani by spectrum analyzer.

Distance (m)	Electric Field (mV/m)	Power (dBm)
Cell A		
3	44.67	-38.3
6	64.57	-34.9
10	85	-33.5
20	93.3	-32.8
30	195	-27.3
50	234.4	-25.5
60	269.2	-24
70	323.6	-23
80	407	-20.7
90	269	-24.2
100	169.8	-28.4
Cell B		
2	7.762	-42.2
6	56.23	-35.9
15	147.9	-29.5
50	275	-24.4
70	309	-22.3
100	512.9	-18.8
120	537.0	-18.5
150	426.6	-20.3
200	309	-22.8

4. JAWWAL macro/roof top cell (HEBR16) in Abu ktelah region at 31°33'5.01"N; 35° 5'3.42"E, which was 25 height from the ground, Figure 4.6.

Figure 4.6: JAWWAL macro cell in Abu ktelah region.

The following table shows the measurements which taken by using the field meter at different distances to cell B and cell C in the base station.

Table 4.8: Measurements at Abu Ktelah by field meter.

Distance (m)	**Power density W/m^2**	**Electric field V/m**	**Magnetic field A/m**
Cell B			
3	0.0176	2.1	0.0056
10	0.0371	3.74	0.0099
Cell C			
3	0.0175	2.57	0.0068
6	0.0164	2.49	0.0066
10	0.0124	2.43	0.0065
15	0.0335	3.56	0.0094
20	0.0112	2.06	0.0055

And the measurements by using spectrum analyzer for the same cells at the next table

Table 4.9: measurements at Abu Ktelah by spectrum analyzer.

Distance (m)	Electric Field (mV/m)	Power (dBm)
Cell B		
3	478	-18.8
10	524	-17
15	912	-12.4
Cell C		
3	66.7	-32.1
6	120	-27.6
10	114.5	-29.5
15	125	-29.4
20	199.5	--25.3

5. JAWWAL macro/roof top cell (HEBR95) in Ein Sarah Street at 31°32'17.92"N ; 35° 5'55.64"E, which was 12 meter height from the ground and 2 meter from the roof top, Figure 4.7.

Figure 4.7: JAWWAL macro cell in Ein Sarah Street.

Spectrum analyzer measurements are taken at different distances on the roof top and on the main street. It was a line of site to the cells C and A.

Table 4.10: Measurements in Ein Sarah street by spectrum analyzer.

Distance (m)	Electric Field (mV/m)	Power (dBm)
Cell C		
3	6457	3.2
5	3715	-1.7
6	3090	-3
40	309	-21.9
60	741	-15.3
80	707	-15.5
100	588	-17.11
120	446.7	-19.5
200	323.6	-22.7
300	281	-23.4
Cell A		
3	3.388 V/m	-1.1
6	3.236	0.7
10	3.89	0.0
15	3.715	0.1
60	1.023	-11.6
70	645 mV/m	-14.3

While, the measurements that taken by Field Meter for a base station 12 m height in Ein Sarah , for cell C are shown in Table 4.11.

Table 4.11: Measurements in Ein Sarah street by spectrum analyzer.

Distance (m) Horizontal	Power density W/m^2	Electric field V/m	Magnetic field A/m
3 (North)	0.4757	13.39	0.0355
6	0.0642	4.92	0.0157
3 (South)	0.2311	9.33	0.0253
10 (West)	0.0069	1.75	0.0046

6. JAWWAL macro/indoor cell (HEBR60) in Hebron Center at 31°31'41.24"N; 35° 5'56.55"E, Figure 4.8.

Figure 4.8: JAWWAL indoor antenna in Hebron Center.

This base station uses indoor antennas that fixed at some floors in the mall to achieve the indoor solution technique. In this technique, GSM companies uses low power radiation antennas, so we have measured the radiation from these antennas and record them in the following Tables:

Table 4.12: Measurements in Hebron center at ground floor by spectrum analyzer.

Distance (m)	**Electric Field (mV/m)**	**Power (dBm)**
3	309	-22.1
6	213.8	-25.3
10	112	-30.9
15	93.3	-32.5
20	64	-35.6
30	32	-41.3

Table 4.13: Measurements in Hebron center at ground floor by field meter.

Distance (m)	**Power density W/m^2**	**Electric Field V/m**	**Magnetic field A/m**
3	0.0019	0.84	0.0023
6	0.0006	0.47	0.0013
10	0.0009	0.58	0.0015
15	0.0012	0.69	0.0018
20	0.0004	0.38	0.0010
30	0.0002	0.17	0.0005

Table 4.14: Measurements in Hebron center at third floor by spectrum analyzer.

Distance (m)	**Electric Field (mV/m)**	**Power (dBm)**
2 (under the antenna)	363.1	-21.8
4 (left the antenna)	125.9	-29
10 (left the antenna)	83.1	-33.7
4 (right the antenna)	120	-31.4
10 (right the antenna)	79.4	-33.7
10 (at the other side)	182	-27.8

Table 4.15: Measurements in Hebron center at fifth floor by spectrum analyzer.

Distance (m)	**Electric Field (mV/m)**	**Power (dBm)**
1 (under the antenna)	1047	-12.4
3 (right the antenna)	436	-19
6 (right the antenna)	501	-17.9
3 (left the antenna)	190.5	-25.5
6 (left the antenna)	138.5	-27.9

7. JAWWAL macro/roof top cell (HEBR50) in AL-fahs region at 31°30'42.05"N; 35° 6'22.06"E, which was 20 meter height from the ground and 2 meter from the roof top.

Table 4.16: Measurements in AL-fahs base station by field meter.

Distance (cm)	Power density W/m^2	Electric field V/m	Magnetic field A/m
Cell A			
3	0.0102	1.96	0.0052
6	0.0029	1.06	0.0028
10	0.0022	0.9	0.0024
15	0.0031	1.09	0.0029
20	0.0027	1.00	0.0027
Cell C			
3	0.0029	1.04	0.0028
6	0.0032	1.09	0.0029
10	N/A	N/A	N/A
15	0.0021	0.88	0.0023
20	0.0065	1.57	0.0041

8. JAWWAL macro/green field cell (HEBR07) in Bani Nae’em region at 31°30'52.71"N; 35° 9'37.81"E, which was 24 meter height from the ground, Figure4.9.

Figure 4.9: JAWWAL Green Field antenna in Bani Nae’em region.

Measurements taken by Field Meter for a tower 24 m height in Bani Nae'em For cell C. In Table 4.17 the measurements taken horizontally from the base of the tower. While, in Table 4.18 the measurements taken on a building near the site which height 22m.

Table 4.17: Measurements in Bani Nae'em base station by field meter.

Distance (m) Horizontal	Power density W/m^2	Electric field V/m	Magnetic field A/m
3	0.0016	0.78	0.0021
15	0.0004	0.41	0.0009
20	0.0012	0.66	0.001
25	0.0001	0.15	0.0004
40	0.00011	0.10	0.0006

Table 4.18: Measurements in Bani Nae'em base station by field meter.

Distance (m)		Measured		
Vertical	Horizontal	Power density W/m^2	Electric field V/m	Magnetic field A/m
6	6	0.0001	0.2	0.005
6	9	0.0002	0.3	0.0008
12	30	0.0016	0.77	0.0021
16	30	0.0028	1.02	0.0027
16	20	0.0041	1.88	0.0051
22	40 (West)	0.0389	3.09	0.0106
22	50 (West)	0.0437	4.34	0.115
22	30 (ES)	0.0802	5.52	0.0147
22	40 (ES)	0.0465	4.19	0.0111

We have shown in Chapter 2 that the exposure limits to the JAWWAL GSM network radiation, which is around 0.9 GHz, is 4.5 W/m^2 including IEEE and ICNIRP standard exposure limits. And 6 W/m2 for FCC guidelines. This standard limit, although international, is not universally adopted. In UK the limit is 4 W/m^2, Australia 2 W/m^2, Switzerland 0.042 W/m^2 and Italy 0. 1 W/m^2. The Salzburg Resolution recommended an outdoor exposure level of less than 0.1 $\mu W/cm^2$ in publicly accessible areas around a base station. This is 4500 times lower than the FCC guideline value for 900MHz emissions. The Salzburg Resolution is the intensity below which no health effects have been published.

Due to our measurements by field meter we found that the average value of the power density was about 0.0226W/m^2 for all values measured and 0.0103 W/m^2. while the maximum values was about 0.475 W/m^2 which was measured from Ein Sarh site at distance 3 m away from the cell C antenna of the base station and found that the minimum measured value was 0.0002 W/m^{2}, this value was measured in ground floor of Hebron center at 30 m away from indoor low power antenna shown in Figure 4.10.

Figure 4.10: Indoor antenna at ground floor in Hebron center

By comparing the last results with the international standard and guidelines we found that the maximum measured value is lower than the allowed value by 9 times. But the average measured value is lower by 200 times.

However the average channel power that measured from the spectrum analyzer at 10 MHz band was -21.4 dBm. While the maximum power level was 3.2 dBm at 3m away from cell C antenna in Ein Sarh site as shown in the Figure 4.10. And the minimum value was for non line of site measurement and it was about -42.2 dBm as shown in Figure 4.11. This value measured at 2 m away from AL-hauoz althani base station which height was 22 m.

But the average electric field that measured from the spectrum analyzer at center frequency that assigned to each base station individually was about 720 mV/m which equal 0.00137 W/m^2. While the maximum electric field level was 6.457 V/m as shown in the Figure 4.12 which equal to 0.112 W/m^2 as shown in Figure 4.13. This value measured at 3m away from cell C antenna in Ein Sarh site. And the minimum value was for non line of site measurement and it was about 7.762 mV/m^2 at 2 m away from AL-hauoz Althani base station which height was 22 m. By comparing the last results with the international standard we found that the maximum measured value is lower than the allowed value by 40 times.

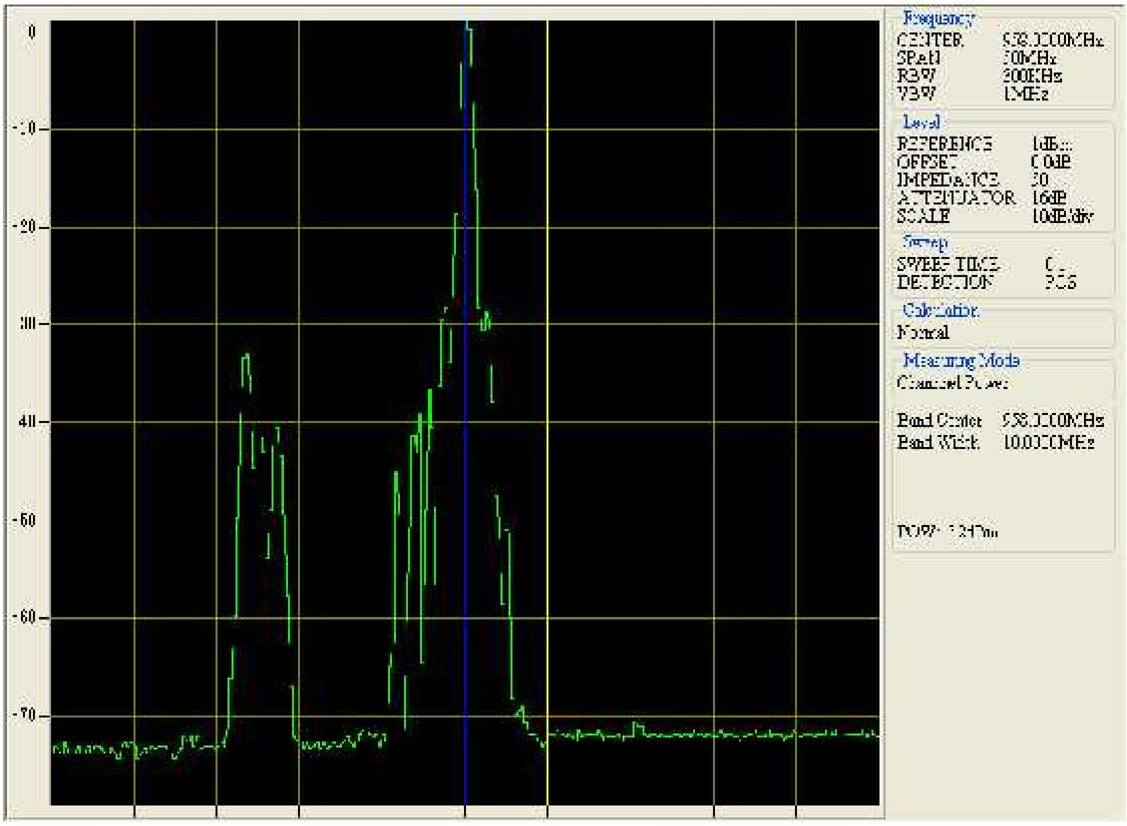


Figure 4.10: Power measurements at distance 3m away from Ein Sarah base station (cell C).

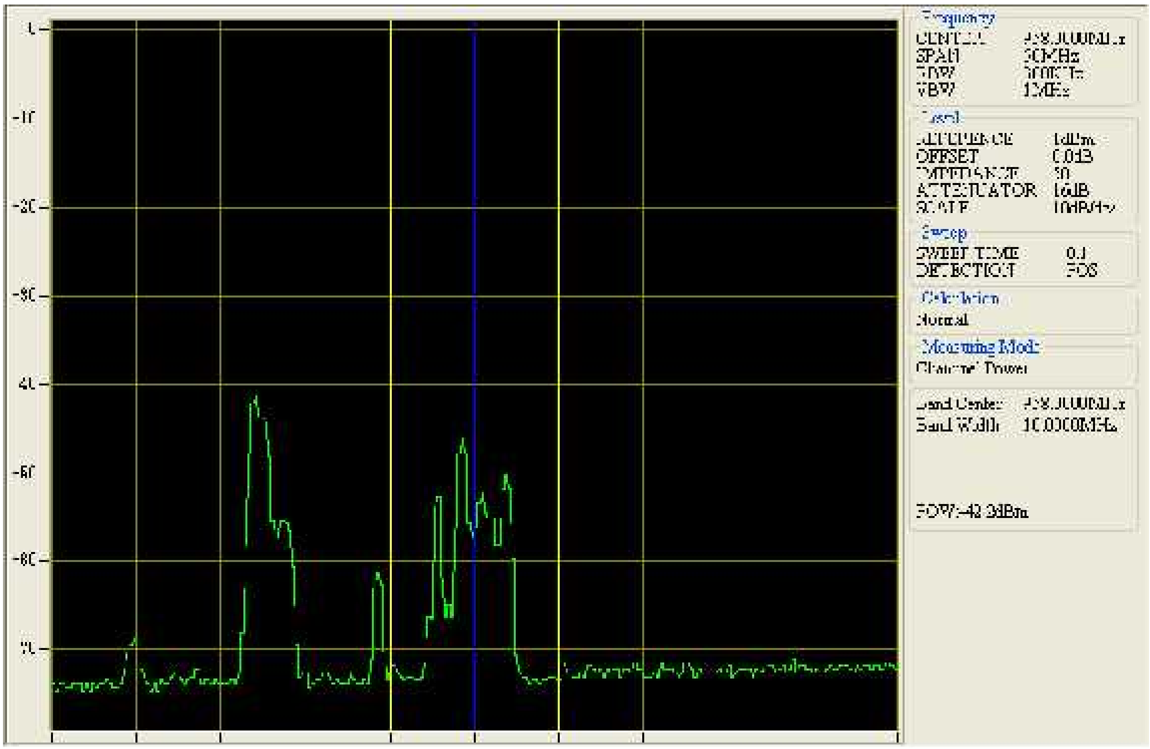


Figure 4.11: Power measurements at distance 2 m away from AL-hauoz althani base station (cell A) (under the building).

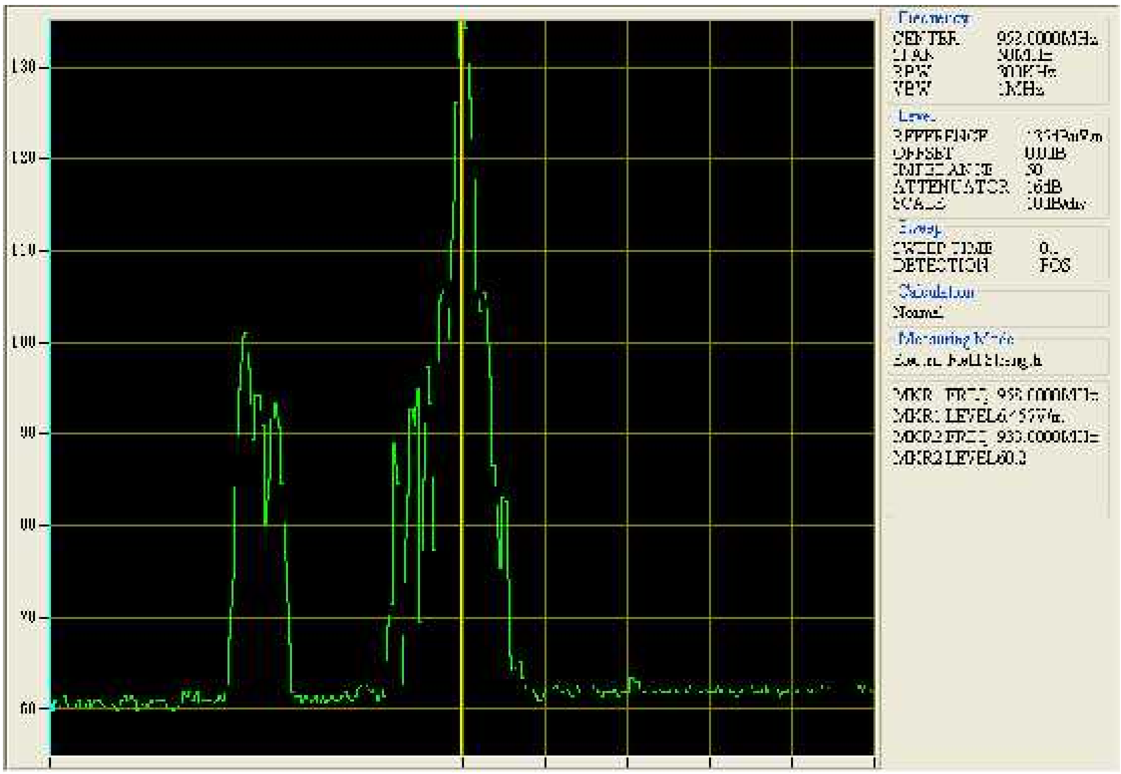


Figure 4.12: Electric field measurements at distance 3m away from Ein Sarah base station (cell C).

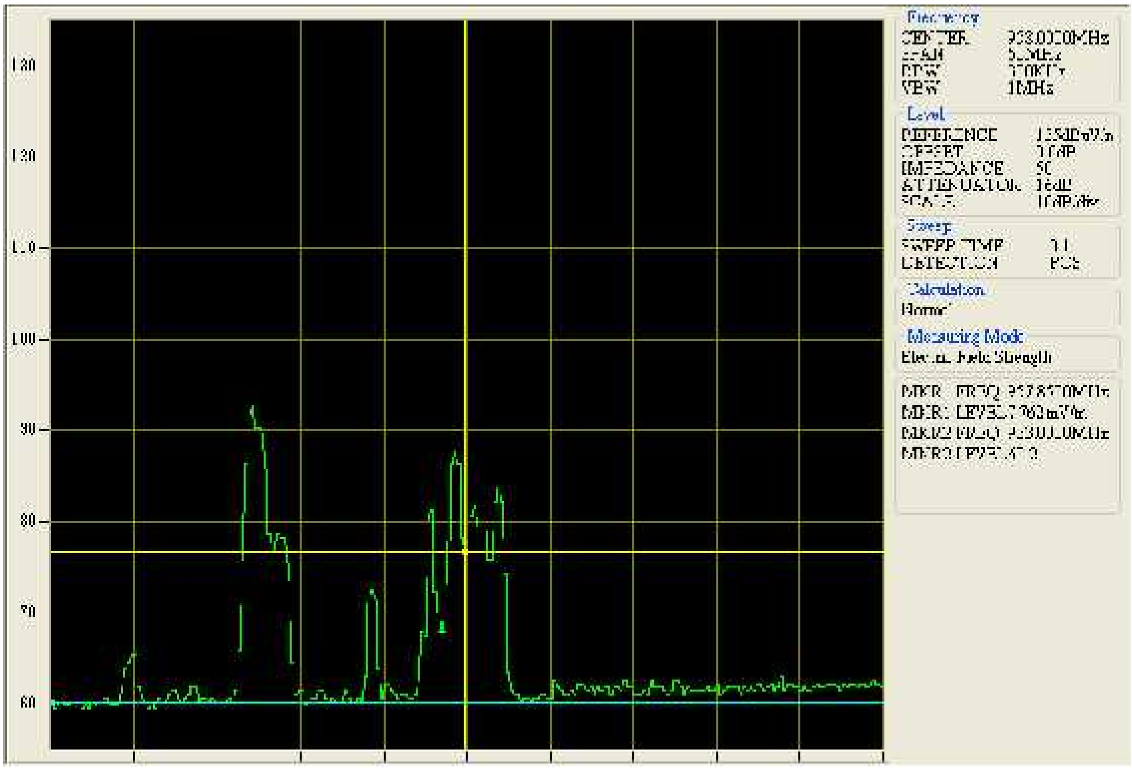


Figure 4.13: Electric field measurements at distance 2 m away from AL-Hauoz althani base station (under the building)

4.3.2 RF EME Exposure from a typical GSM phone

The second category of measuring the GSM radiation is to study the mobile radiation itself. So, the analyzer has been adjusted to measure GSM JAWWAL uplink; the considerations in this subsection are restricted to the fields produced by GSM mobile phones.

The maximum powers that 900 MHz GSM mobile phones are permitted to transmit by the present standards are 2W. However, because TDMA is used, the average powers transmitted by the phone are never more than one-eighth of this maximum value (0.25W) and are usually further reduced by a significant amount due to the effects of adaptive power control and discontinuous transmission.

Adaptive power control means that the phone continually adjusts the power it transmits to the minimum needed for the base station to receive a clear signal. Discontinuous transmission refers to the fact that the power is switched off when a user stops speaking.

The power levels from the mobile are measured from two different base station antennas to get two different cases in measuring the mobile radiation.

The first case was a low power indoor antenna as shown in Figure 4.10. The measurements are taken by using the analyzer, which was 1cm far away from the mobile at different distances as shown in Table 4.19. And it was measured from JAWWAL base station (HEBR60) in Hebron Center at 31°31'41.24"N; 35° 5'56.55"E.

Table 4.19: measurements for mobile station radiation at different distances from an low power indoor antenna.

Distance (m)	Electric Field (V/m)	Power (dBm)
3	3.802	-2.00
10	10.00	8.70
15	13.80	9.40
25	18.20	11.3
50	21.88	13.4
100	33.11	17.0

According to the previous table it has been shown that the power control signal of the GSM system controls the radiated power from the mobile and increases it as long as the mobile gets away from the base station in other words by increasing the distance between the mobile phone and the base station the radiation from the mobile will increase.

The maximum measured value at uplink frequency of 913MHz for the electric field was about 33.11 V/m as shown in Figure 4.14 which is about approximately equal to 2.9 W/m^2 of the power density. And the maximum power level at the same point was about 17.0 dBm as shown in Figure 4.15 which equal to 50 mW. This value measured at 100 m far away from the low power antenna.

For IEEE and ICNIRP the maximum allowed value of power density at 900 MHz frequency is 4.5 W/m^2 and 6 W/m^2 for FCC guidelines. Although the maximum measured value is high according to the base station measurements but it still less than the allowed values of IEEE and ICNIRP by 1.5 times and 2 times less than the FCC guideline. But this level of signal is the most worrying one since it is too high and also too close to the brain.

The second case was outdoor macro cell antenna as shown in Figure 4.16. The measurements are also taken by using the spectrum analyzer which was 1cm far away from the mobile at different distances as shown in Table 4.20. And it was measured from JAWWAL macro/roof top cell (HEBR95) in Ein Sarah Street at 31°32'17.92"N; 35° 5'55.64"E.

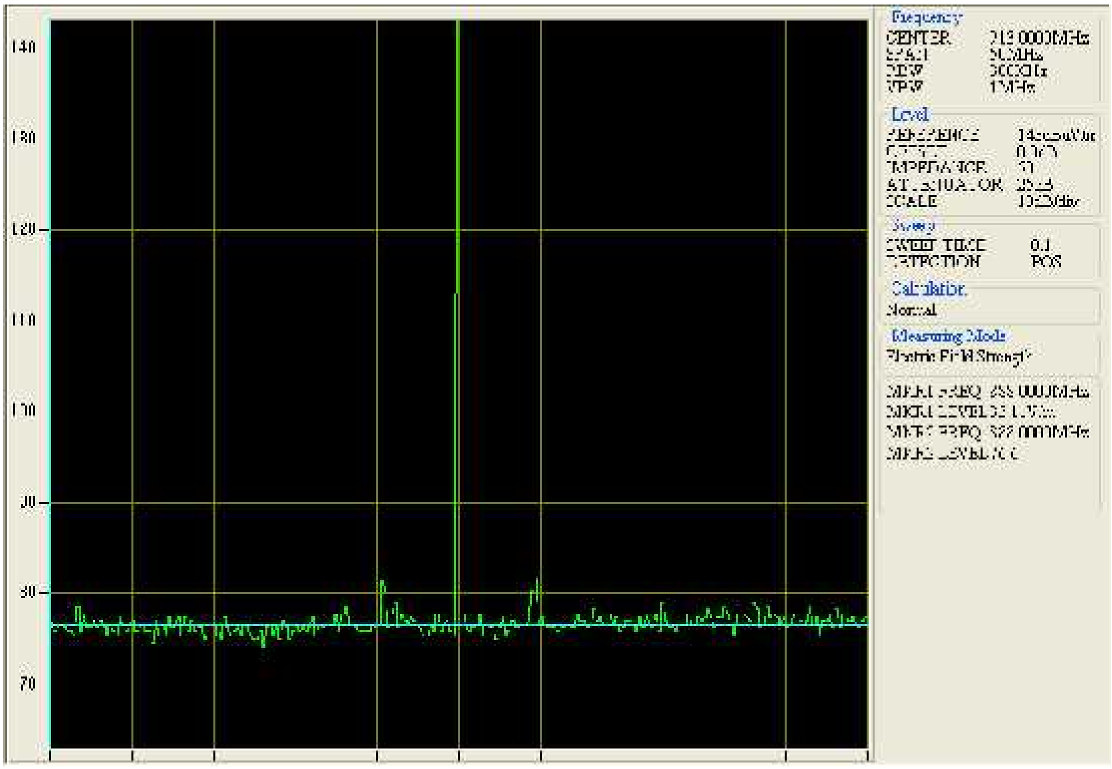


Figure 4.14: Electric field measurements at distance 100m away from the low power antenna

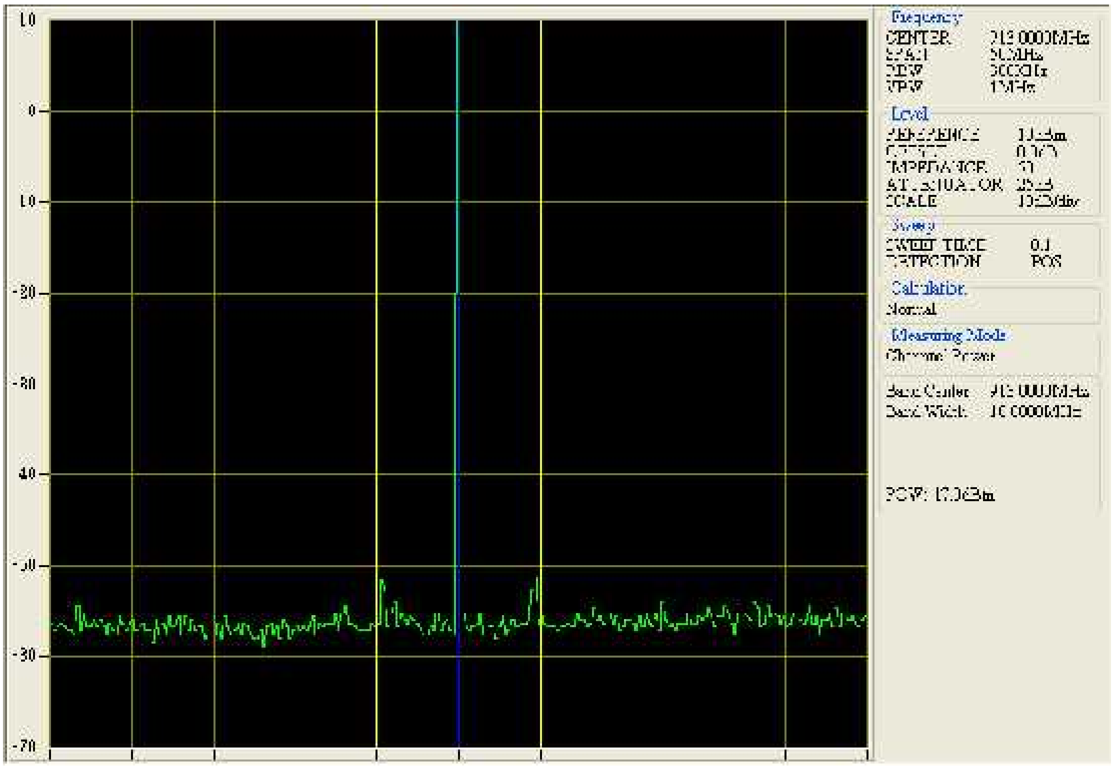


Figure 4.15: Power measurements at distance 100 m away from the low power antenna.

Table 4.20: Measurements for mobile station radiation at different distances from outdoor macro antenna.

Distance (m)	Electric Field (V/m)	Power (dBm)
10	2.754	0.4
20	3.631	0.5
40	5.012	9.0
60	16.00	11.3
80	20.89	15.3
100	26.30	17.5

Figure 4.16: JAWWAL outdoor macro cell antenna.

As shown in the previous table the values of electric field and power level for the measurements of mobile radiation from the outdoor macro cell antenna is less than those from the low power indoor antenna. This is due to the higher power that radiated from the micro cell antennas which makes the mobile phone to radiate less power in order to connect to the base station.

By comparing the measurements from the mobile phone we conclude that this level of signals is also lower than the allowed international values of ICNIRP, IEEE and FCC. However, it still higher than the radiation levels from the base station itself.

In order to measure the EME exposure from the mobile; an experiment is performed to highlight the variation of the radiation levels during the call progress. Four different measurements are recorded in one minute for the electric field at a point of 1 cm away from a mobile phone is measured.

These measurements are taken during call setup as shown in Figure 4.17, conversation silence as shown in Figure 4.18, conversation speaking as shown in Figure 4.19, and call termination as shown in Figure 4.20. The result is shown in Figure 4.21.

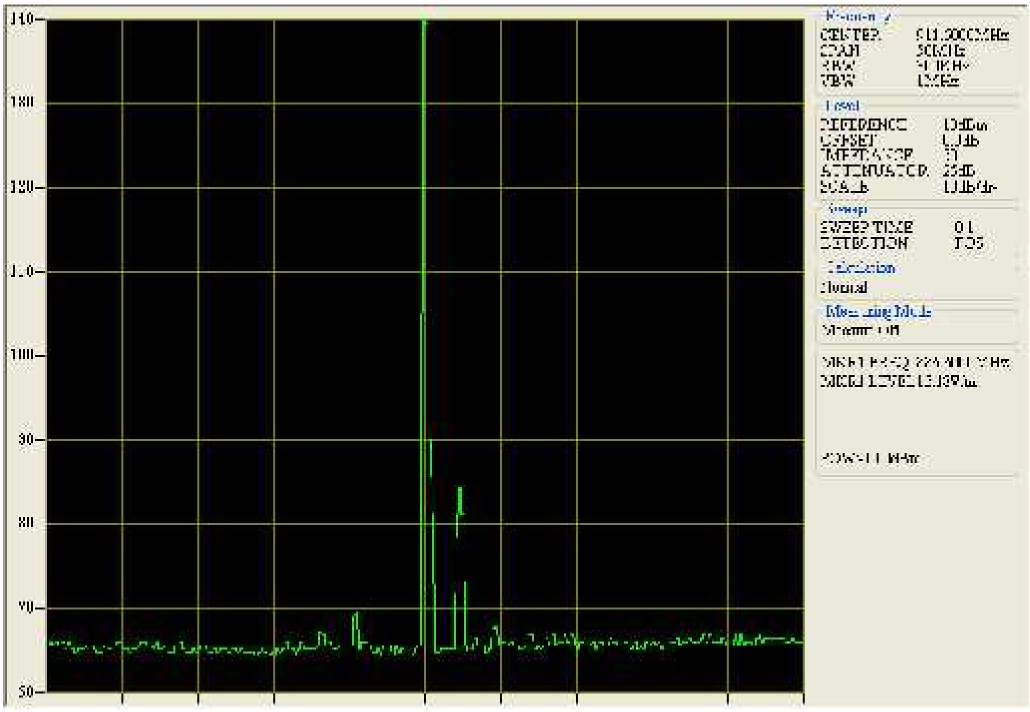


Figure 4.17 : Measurment of electric field and power during call setup.

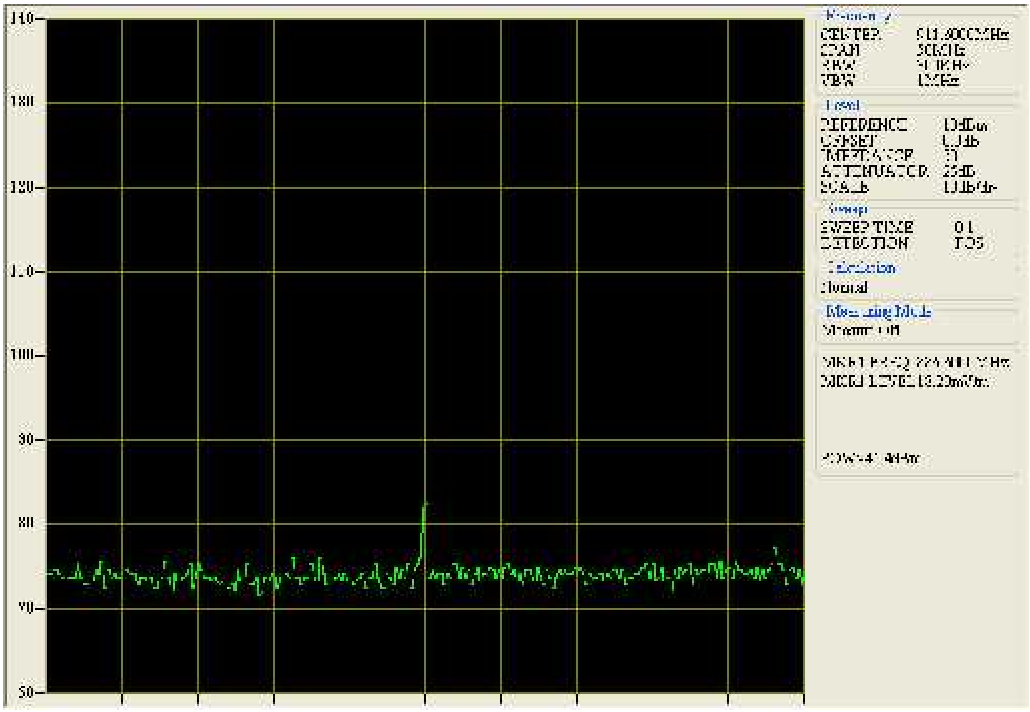


Figure 4.18 : Measurment of electric field and power during silence.

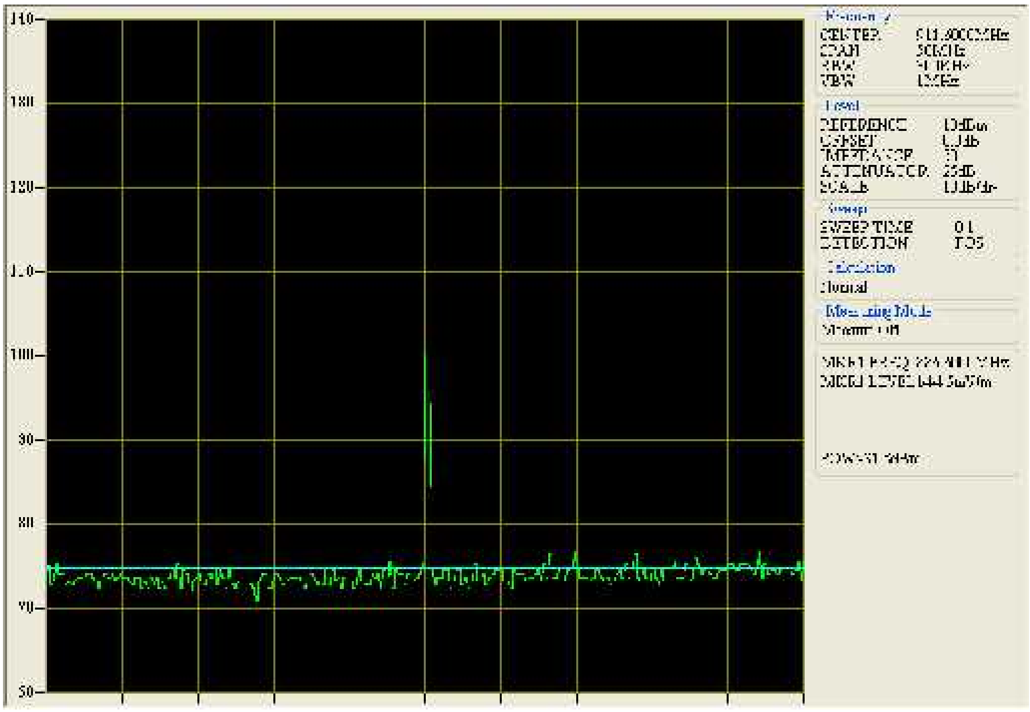


Figure 4.19 : Measurment of electric field and power during speaking.

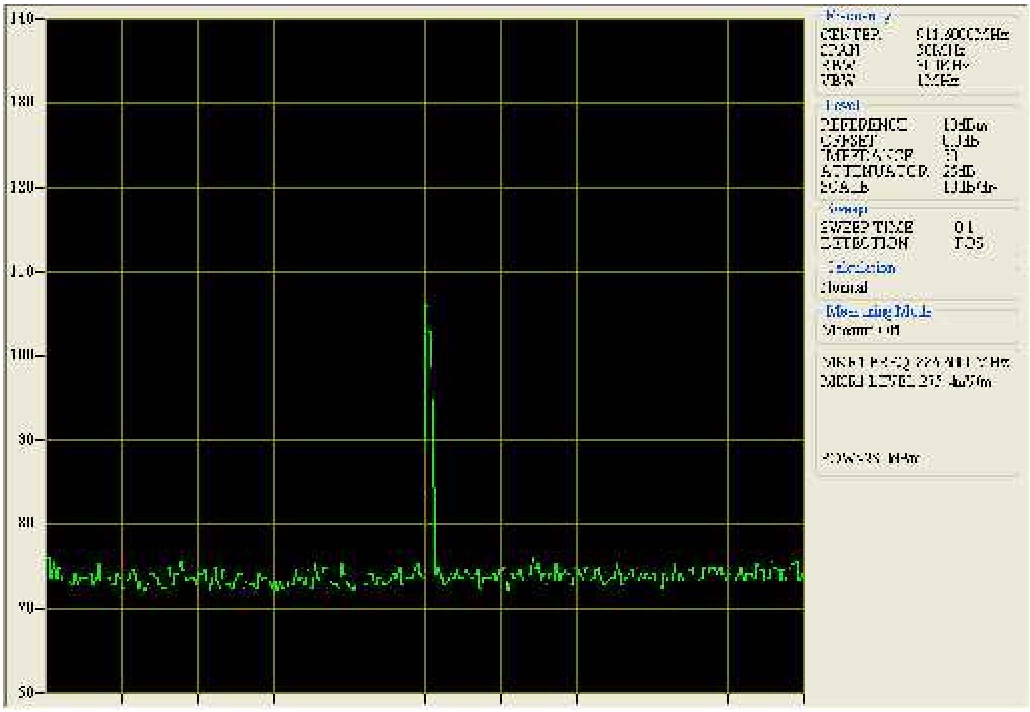


Figure 4.20 : Measurment of electric field and power during call termination .

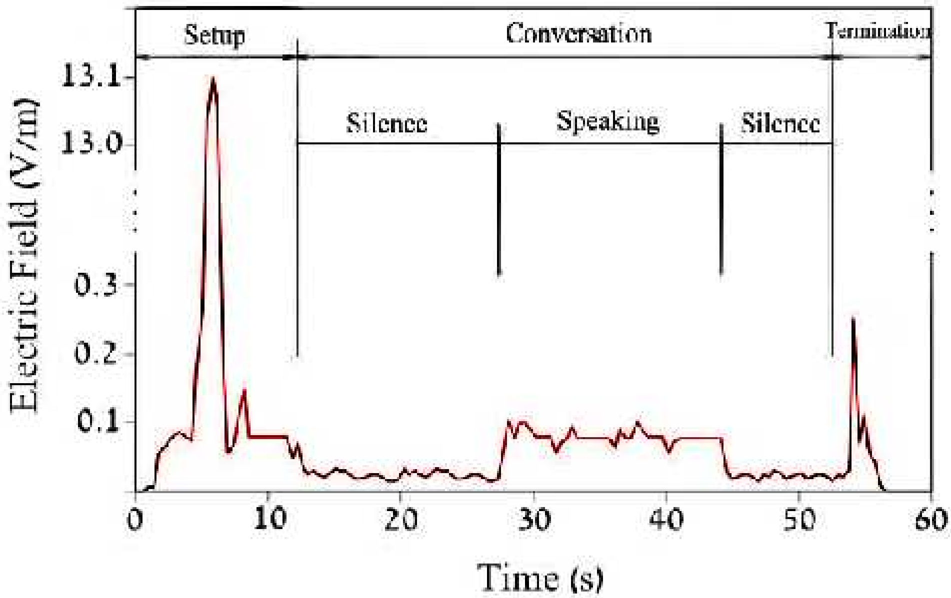


Figure 4.21: Electric field levels emitted from a typical GSM phone during a call progress.

As shown in the previous figure the maximum electric field is measured during call setup period which equal to 13.18 V/m and the minimum was during the silence period which equal to18.2 mV/m. The magnitude of the signal may vary depending on the phone model and its location relative to the base stations. However, this experiment provides deeper insight knowledge and concludes with some advice of keeping the phone away from our head during call setup.

4.4 Measurement of broadcasting stations

4.4.1 RF EME Exposure from FM Radio stations

There are several areas of concern related to the broadcast towers; the physical design, how it looks like, as shown in Figure 4.22; and the safety of the people living or working in the path of the broadcast electromagnetic radiation.

The design and construction of a broadcast towers is not new, so this is not a big concern. The concern now is how much real level of radiation is below the broadcast towers where there are big possibilities of existing of people living there.

Figure 4.22: Broadcasting towers view at N 31°33'26.41"; E 35° 5'43.41".

There are hundreds of thousands of radio operators worldwide. Radio service provides its members (operators) with the opportunity to communicate with persons all over the world and to provide valuable public service functions, such as making communications services available during disasters and emergencies.

FCC's rules limited the transmission between amateur operators with power levels of up to 1500 watts. However, most operators use considerably less power than this. Studies by FCC and others have shown that most radio stations transmitters would not normally expose persons to RF levels in excess safety limits.

If there were any opportunity for significant RF exposure, it would most likely apply to the amateur operator and his or her immediate household. To help ensure compliance of amateur radio facilities with RF exposure guidelines, both FCC and ARRL have developed technical publications to assist operators in evaluating compliance of their stations [35].

In our project, two different scenarios are used during the measurement process of radio stations. The first scenario depends on measuring the whole electromagnetic radiation from all radio stations which operate with frequency band (88-108) MHz, so the spectrum analyzer was adjusted to measure this band frequency. The second takes only one station called AL-Horia radio station, which operates at 92.7 MHz Also, the field meter was used to measure electric field, magnetic field and power density at all of the band.

In the first scenario, in order to measure the exposure from the radio broadcasting towers, the spectrum analyzer was adjusted at 98 MHz center frequency and band of 20 MHz So that the all band from 88 MHz to 108 MHz was included in the range of measurement.

The measurements has been taken in Ras AL-Jora region at different locations from towers group as shown in Figurer 4.23, these locations are distributed randomly as shown in Figure 4.24. The measurements recorded as shown in Table 4.21.

Table 4.21: Measurements for FM radio stations in Ras AL-Jora region by spectrum analyzer at different locations.

GPS Position	Power (dBm)
Latitude: 31°33'25.96"N Longitude: 35° 5'45.65"E	-17.4
Latitude: 31°33'24.53"N Longitude: 35° 5'45.40"E	-20.7
Latitude: 31°33'23.55"N Longitude: 35° 5'45.08"E	-19.3
Latitude: 31°33'22.18"N Longitude: 35° 5'45.02"E	-24.9
Latitude: 31°33'21.00"N Longitude: 35° 5'45.37"E	-21.7
Latitude: 31°33'19.64"N Longitude: 35° 5'45.98"E	-28.3

Figure 4.23: FM radio stations at Ras AL-Jora in Hebron district.

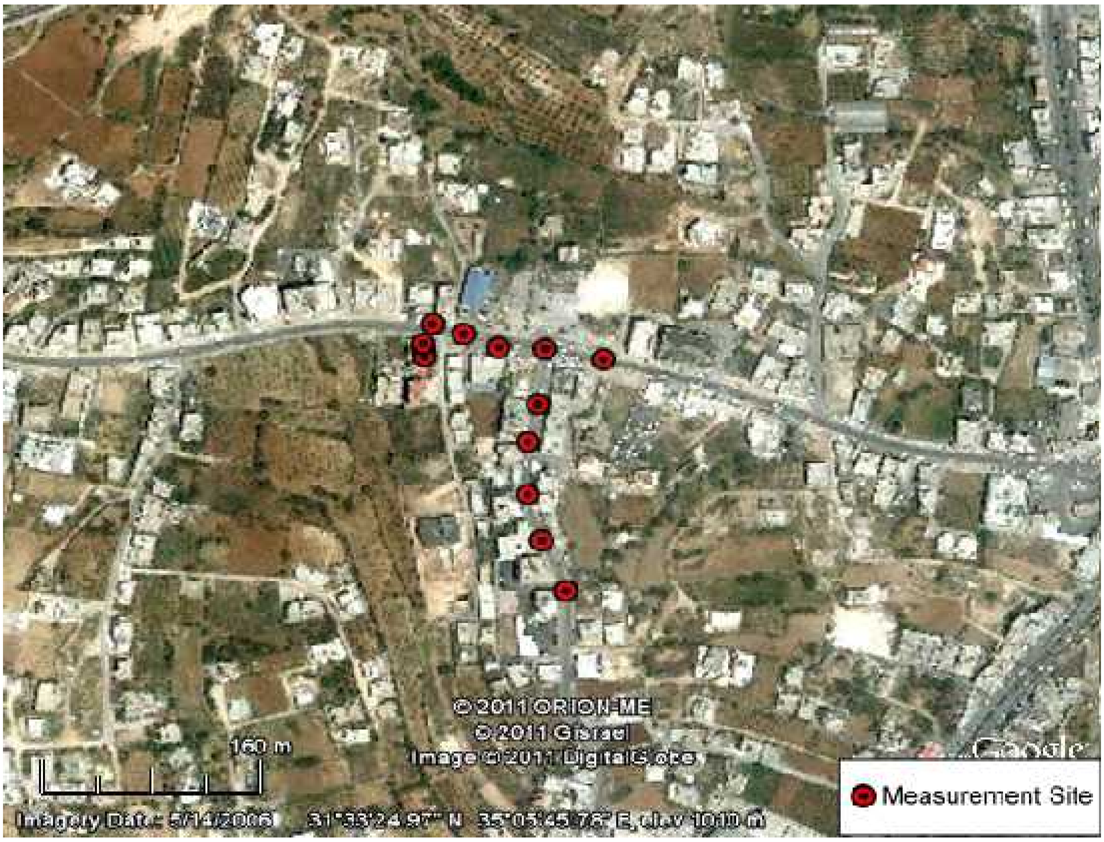


Figure 4.24: Measurements map at Ras AL-Jora for radio stations.

The field meter is also used to measure the electric field, magnetic field and power density at same locations at the same region as shown previously in the measurements map. The results are shown in Table 4.22.

Table 4.22: Measurements for FM radio stations in Ras AL-Jora region by field meter at different locations.

GPS Position	Power density W/m^2	Electric field V/m	Magnetic field A/m
Latitude: 31°33'25.96"N Longitude: 35° 5'45.65"E	0.0794	5.49	0.0146
Latitude: 31°33'24.53"N Longitude: 35° 5'45.40"E	0.0330	4.06	0.0108
Latitude: 31°33'23.55"N Longitude: 35° 5'45.08"E	0.0677	5.05	0.0134
Latitude: 31°33'22.18"N Longitude: 35° 5'45.02"E	0.0417	3.95	0.0105
Latitude: 31°33'21.00"N Longitude: 35° 5'45.37"E	0.0151	2.39	0.0063
Latitude: 31°33'19.64"N Longitude: 35° 5'45.98"E	0.0182	2.62	0.0070
Latitude: 31°33'26.03"N Longitude: 35° 5'44.37"E	0.0218	2.87	0.0076
Latitude: 31°33'26.41"N Longitude: 35° 5'43.41"E	0.0346	3.61	0.01
Latitude: 31°33'26.69"N Longitude: 35° 5'42.57"E	0.0654	4.97	0.0132
Latitude: 31°33'25.64"N Longitude: 35° 5'47.25"E	0.0346	3.61	0.0096

Samples of measurements are also taken above a building near the towers of FM stations by field meter and spectrum analyzer Figure 4.25. The building height was 9 meters above the ground and the measurements were at two different cases.

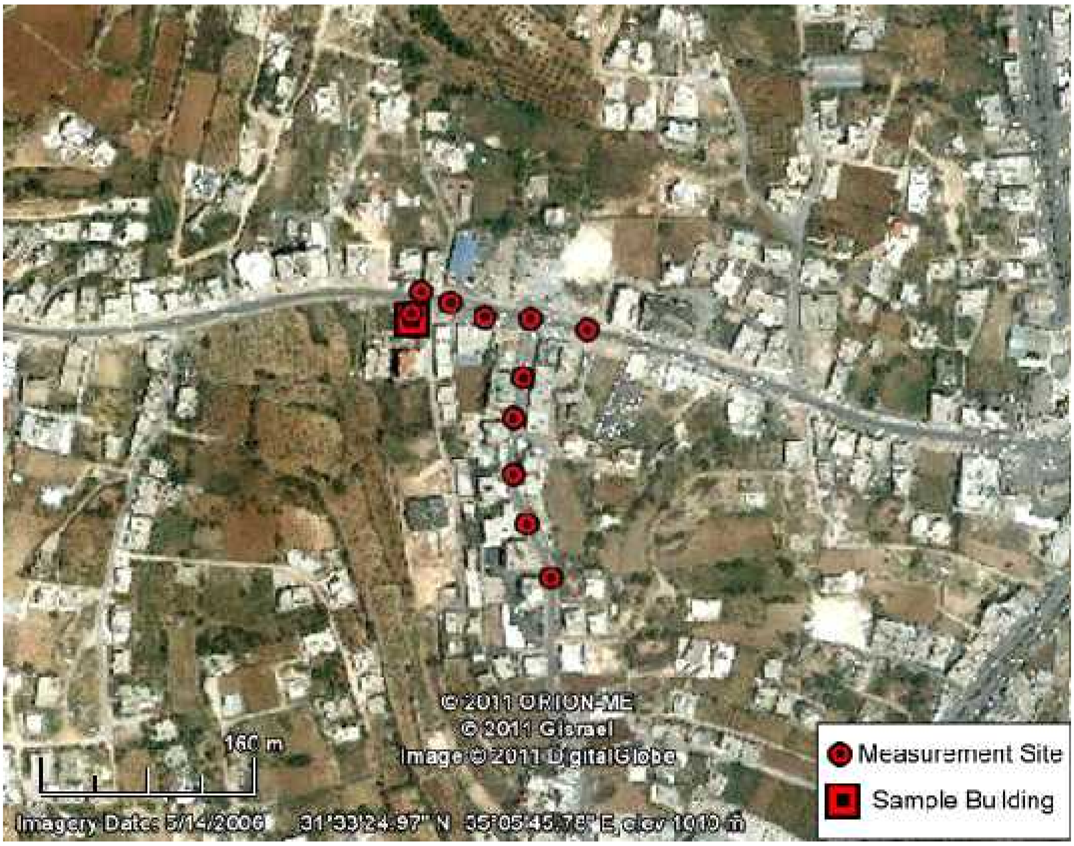


Figure 4.25: Position of the sample building.

The first case was on the building rooftop at the center, east and west of the roof, then the measurements are recorded in the following Tables:

Table 4.23: Measurements for FM radio stations in Ras AL-Jora region by spectrum analyzer at rooftop of the sample building.

Site on roof	Power (dBm)
Center	-14.9
East	-16.7
West	-22.7

Table 4.24: Measurements for FM radio stations in Ras AL-Jora region by field meter at rooftop of the sample building.

Site on roof	Power density W/m^2	Electric field V/m	Magnetic field A/m
Center	0.1321	7.06	0.0188
East	0.0455	4.14	0.0110
West	0.0491	4.30	0.0114

The second case was inside the building at the first floor and second floor and the results were as following:

Table 4.25: Measurements for FM radio stations by spectrum analyzer inside the sample building.

Floor	Power density W/m^2	Electric field V/m	Magnetic field A/m	Power (dBm)
First	0.0035	1.17	0.0031	-33.7
Second	0.0064	1.55	0.0051	-26.9

According to the first scenario results, the average power measurements that taken by the spectrum analyzer was -20.7 dBm. However, the maximum power level was about -14.9 dBm as shown in Figure 4.26, this value was measured at the roof top of the building that lies in the vicinity of the towers group.

As will as, the measurements of Field Meter also shows that the maximum power density was measured at the same point that measured by spectrum analyzer which equal to 0.1321 W/m^2, and the average power density of the all measurements was about 0.05 W/m^2.

According to the international standards and limits for human exposure of the radio frequencies; the maximum allowed value of power density of this range of frequencies that used by the radio stations is 2 W/m^2. By comparing the last results with these international regulations we note that the maximum measured values are lower than the stranded by 15 times, and the average is lower by 40 times.

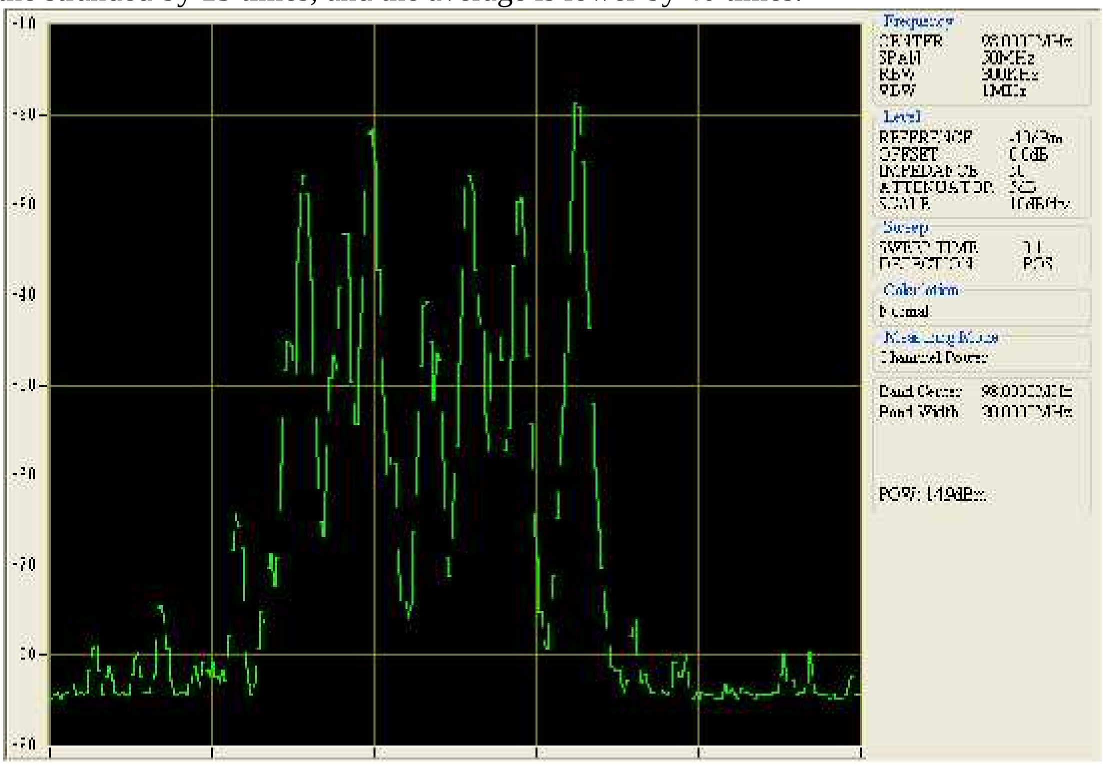


Figure 4.26: Power measurements above the building in Ras AL-Jora.

In the second scenario; to measure the exposure from single radio station; the spectrum analyzer was adjusted at the frequency that used by Al-Horia radio station, Figure 4.27, which was 92.7 MHz center frequency and band of 1MHz. In this way, the exposure measurements will be for one radio station. The measurements were at different distances from the radio tower as shown in Table 4.26.

Figure.4.27: Alhoria FM radio station.

Table 4.26: Measurements for Al-Horia FM radio stations by spectrum analyzer.

Distance (m)	Power (dBm)
5	-41.6
10	-32.4
20	-35
30	-35.9
50	-33.2
60	-28.7
70	-28.9
80	-24.5
100	-22.8

The second scenario results show that the average measured power value was about -31.4 dBm. While the maximum power level was -22.8 dBm as shown in Figure 4.28, which equal to 0.0045 W/m^2. This value is lower than the allowed international value (2 W/m^2) by 44.4 times.

From the results of the previous two scenarios, we note that, the measured power values from the towers grope are more than the values of power that radiated from single tower. But it remains lower than the maximum allowed international value.

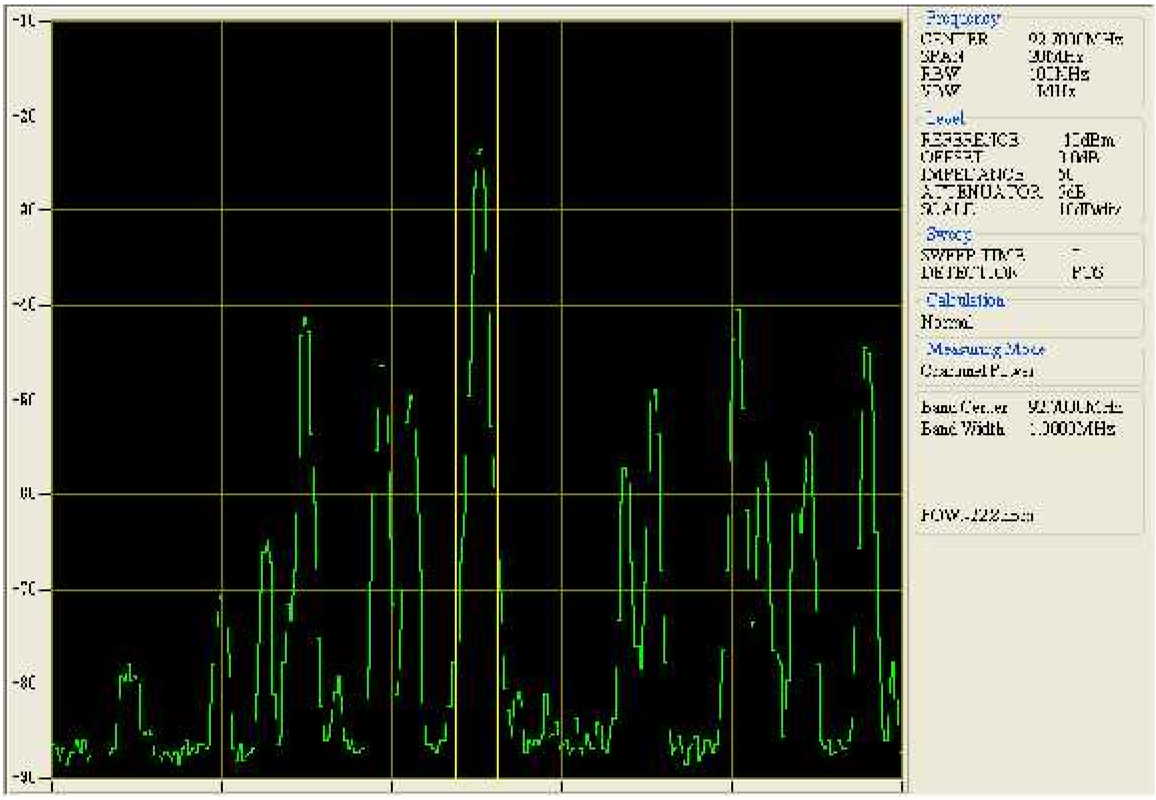


Figure 4.28: Power measurements at distance 100m from Al-Horia tower in Ras AL-Jora

4.4.2 Radio frequency emissions from TV broadcasting towers

VHF/UHF TV towers are placed on the highest point in an area, so the transmitted signal has a clear path to receiving antennas. The transmitted antenna pattern is designed and produced to let the radiating beam is projected away from the tower almost horizontally, so that as much area as possible is covered; this minimizes the signal strength at ground level near the tower. The higher level fields therefore occur at a height accessible to the general public. Sample measurements of typical transmitter sites show that the signal levels on the ground near the towers are smaller than the general public exposure limits.

To measure the radiation from TV broadcasting stations, a location has been chosen near the transmission towers of a TV stations. For the measurements to be accurate, the spectrum analyzer is adjusted to measure the radiation in the frequency band up to 800 MHz only by using suitable isotropic antenna. This will help to reject global system for mobile communications, GSM transmission and other radiations over the broadcasting bandwidth. Also, the field meter is used to measure the power density, electric filed and magnetic field at different locations near to broadcasting towers.

The radiation was measured from two TV broadcasting stations. The first station is Al-Wattan TV station, which operate at 43 UHF (647.25 MHz video carrier, 652.75 MHz audio carrier) as shown in Figure 4.29. The second station is Al-Nwras TV station, which operate at 41 UHF (631.25 MHz video carrier, 636.75 MHz audio carrier) as shown in Figure 4.30. The measurements for these two stations are shown in the tables below.

Figure 4.29: Alwattan TV station.

Table 4.27: Al-Wattan TV broadcast tower measurements by spectrum analyzer.

Distance (m)	Power (dBm)	GPS position
5	-47.7	Latitude: 31°33'7.27"N Longitude: 35° 6'12.72"E
10	-36.7	Latitude: 31°33'7.90"N Longitude: 35° 6'12.86"E
40	-33.8	Latitude: 31°33'8.57"N Longitude: 35° 6'12.78"E
60	-29.0	Latitude: 31°33'9.27"N Longitude: 35° 6'12.64"E
80	-37.0	Latitude: 31°33'9.97"N Longitude: 35° 6'12.43"E
100	-36.7	Latitude: 31°33'10.95"N Longitude: 35° 6'11.29"E
130	-35.6	Latitude: 31°33'12.19"N Longitude: 35° 6'10.47"E
160	-44.9	Latitude: 31°33'13.48"N Longitude: 35° 6'9.22"E
200	-37.7	Latitude: 31°33'14.47"N Longitude: 35° 6'6.36"E
250	-36.7	Latitude: 31°33'15.48"N Longitude: 35° 6'5.43"E
300	-33.3	Latitude: 31°33'16.61"N Longitude: 35° 6'4.59"E
350	-29.6	Latitude: 31°33'17.89"N Longitude: 35° 6'3.82"E
400	-26.3	Latitude: 31°33'19.88"N Longitude: 35° 6'2.09"E
450	-34.3	Latitude: 31°33'20.77"N Longitude: 35° 6'1.82"E
500	-40.3	Latitude: 31°33'21.44"N Longitude: 35° 6'1.76"E

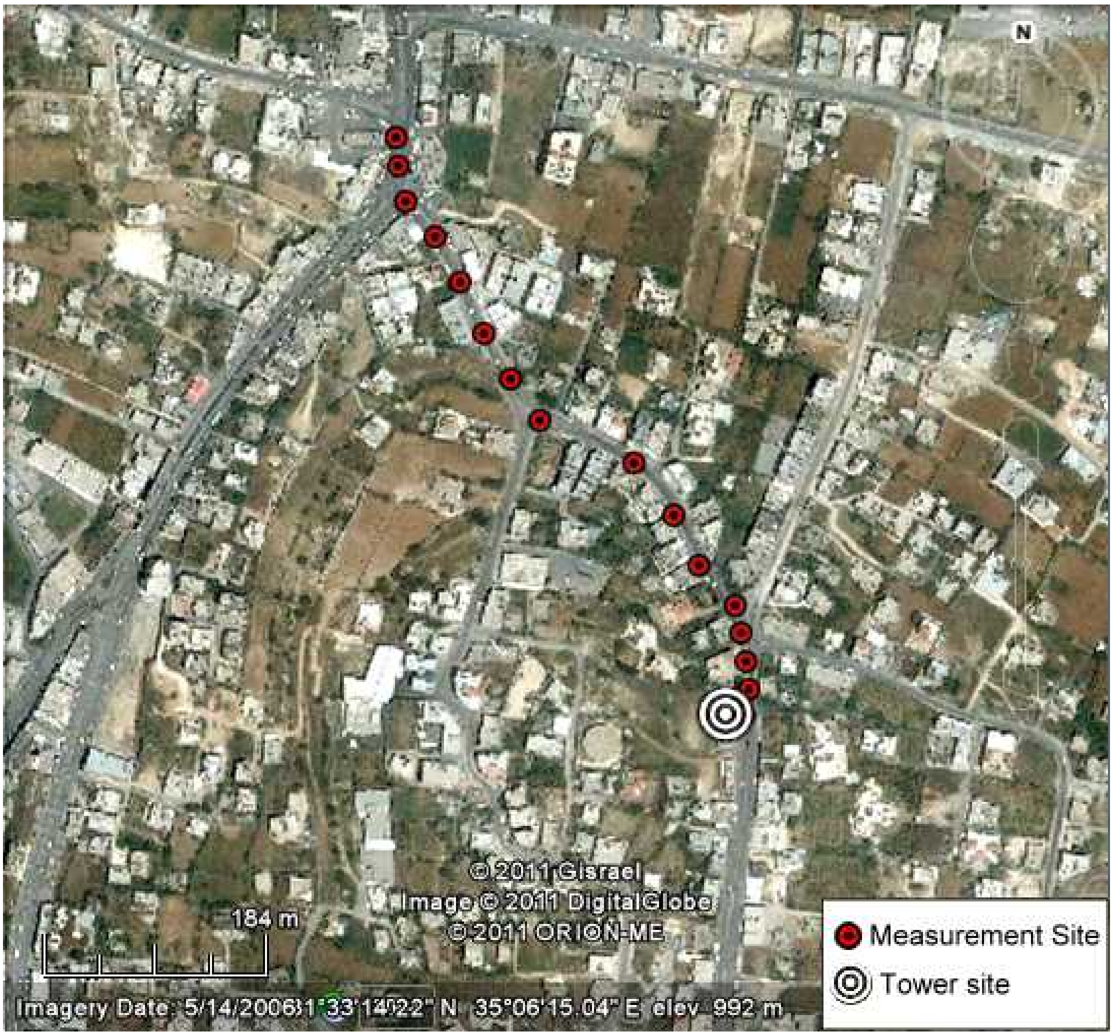


Figure 4.31: Map of Al-Wattan TV tower site and measurements locations.

Table 4.28: Al-Wattan TV broadcast tower measurements by field meter

Distance (m)	Power density W/m^2	Electric field V/m	Magnetic field A/m
3	0.0003	0.31	0.0011
20	0.0006	0.47	0.0013
40	0.0009	0.60	0.0016
60	0.0011	0.63	0.0017
100	0.0018	0.82	0.0022
200	0.0025	0.96	0.0026

Figuer 4.30: Al- Nwras TV station.

Table 4.29: Al-Nwras TV broadcast tower measurements by spectrum analyzer.

Distance (m)	Power (dBm)	GPS position
10	-50.4	Latitude: 31°33'26.54"N Longitude: 35° 5'43.06"E
50	-42.4	Latitude: 31°33'26.06"N Longitude: 35° 5'45.07"E
100	-41.8	Latitude: 31°33'25.62"N Longitude: 35° 5'47.30"E
150	-39.1	Latitude: 31°33'25.14"N Longitude: 35° 5'49.23"E
250	-34.7	Latitude: 31°33'24.49"N Longitude: 35° 5'51.32"E
300	-34.0	Latitude: 31°33'23.77"N Longitude: 35° 5'53.28"E
350	-37.0	Latitude: 31°33'23.22"N Longitude: 35° 5'55.12"E
400	-29.4	Latitude: 31°33'22.81"N Longitude: 35° 5'56.98"E
450	-31.8	Latitude: 31°33'22.50"N Longitude: 35° 5'59.27"E
500	-35.8	Latitude: 31°33'22.04"N Longitude: 35° 6'1.42"E

Figure 4.32: Map of Al-Nwras TV tower site and measurements locations.

Table 4.30: Al-Nwras TV broadcast tower measurements by field meter.

Distance (m)	Power density W/m^2	Electric field V/m	Magnetic field A/m
20	0.0014	0.72	0.0019
40	0.0016	0.79	0.0021
60	0.0020	0.90	0.0026
120	0.0035	1.15	0.0030

The previous tables shows that the two stations have the same values approximately; the measurements at the base of the towers have the minimum values and the values start increase until it reaches a certain distance. Then it begins to decrease gradually while the distance increasing.

According to the values that measured by the spectrum analyzer; the maximum value of power for Al-Nawrs broadcasting station was measured at distance of 400 m away from the base of the tower which was about -29.4dBm as shown in Figure 4.33. And the maximum measured value for Al-Wattan broadcasting station was also measured at distance 400 m away from the base of the tower which was about -26.3dBm as shown in Figure 4.34.

Also, the values that measured by the field meter show that the maximum power density for Al- Wattan broadcasting station was measured at distance of 200 m away from its tower which was equal to 0.0025 W/m^2, and 0.0035 W/m^2 for Al-Nawrs broadcasting station at distance of 120 m away from the tower.

For the TV stations that use the 41 UHF and 43 UHF frequencies; the allowed and acceptable power density level for ICNIRP standards and limits for human exposure is nearly 3.2 W/m^2. But, due to FCC regulations the allowed value of the power density reaches 4.2 W/m^2. Therefore; the measured levels of power, electric field and magnetic field that radiated from the TV broadcasting stations are very low and show acceptable levels of exposure comparing with allowed international values.

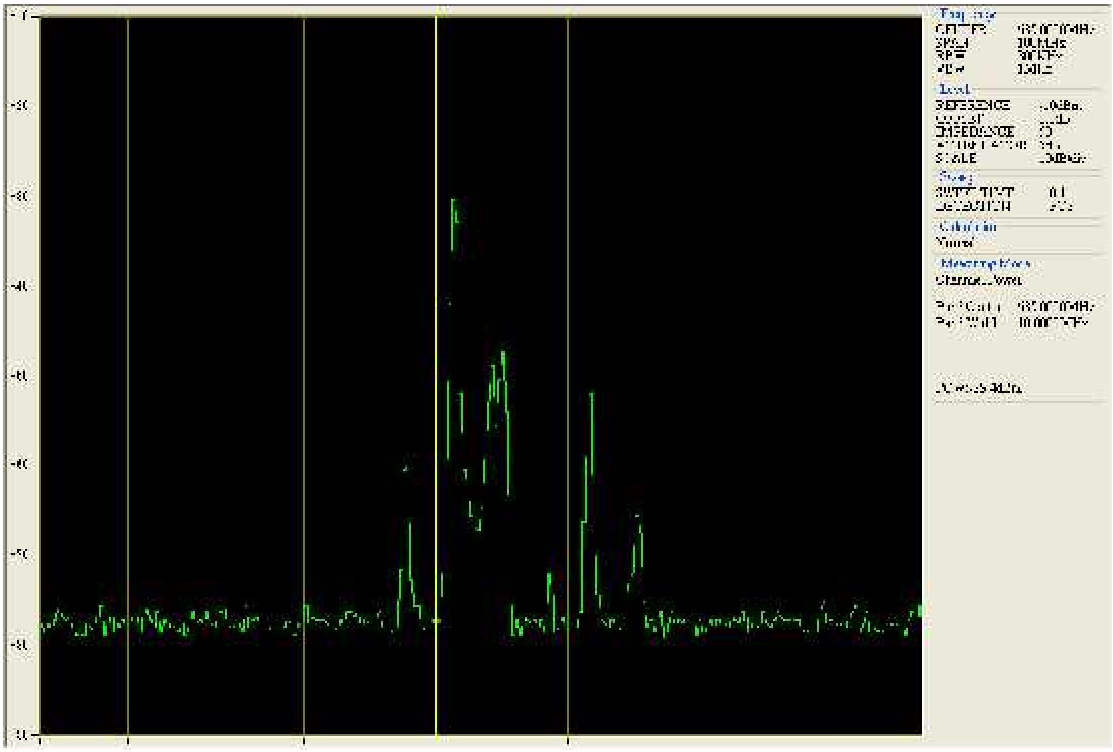


Figure 4.33: Power measurement for Al-Nawrs TV station at distance 400 m.

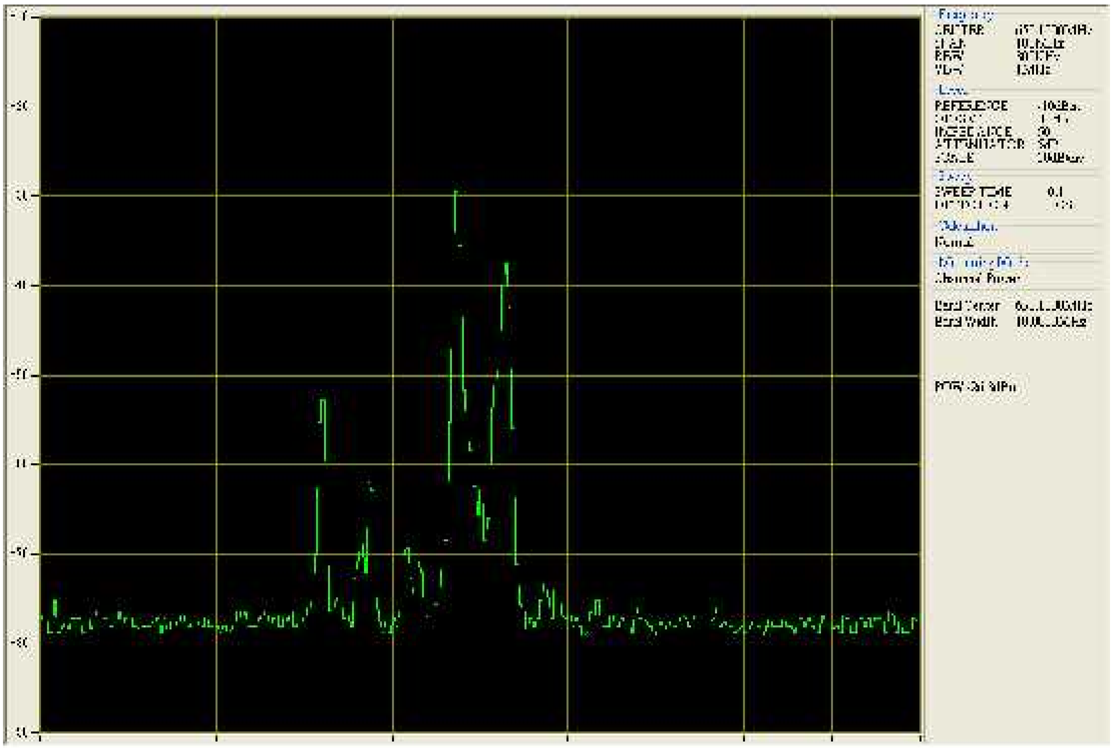


Figure 4.34: Power measurement for Al-Wattan TV station at distance 400 m.

4.5 Measurements of Microwave Oven radiation

Microwave ovens are used daily in restaurants, cafeterias, kitchens, and homes. Microwave oven users are often concerned about potential health hazards from the exposure to microwave radiation leakage. With the latest technological advances in door seal design and with proper maintenance, microwave oven leakage has been greatly minimized or eliminated.

The radiated power from the microwave oven is differ from one type to another due to the manufacturing companies and lifetime. So that two samples are taken for two kinds of microwave ovens. The first one is Universal microwave oven as shown in Figure 4.35, the second is TOKYO microwave oven as shown in Figure 4.36.

Figure 4.35: Universal microwave oven.

Figure 4.36: TOKYO microwave oven.

To measure the radiation that emitted from the microwave oven, the two instruments are used; spectrum analyzer and field meter. The center frequency was adjusted to 2.45 GHz at the analyzer which is the frequency that used by the oven. So, the measurements that we got give an idea about the overall effect of radiation over this frequency band. The results of measurements at different distances of the two kinds are shown in the following Tables :

Table.4.31: Universal microwave oven measurements by field meter.

Distance (cm)	Power density W/m^2	Electric field V/m	Magnetic field A/m
1	1.988	27.37	0.0726
10	0.7983	17.35	0.0460
20	0.409	12.42	0.0337
30	0.4254	12.66	0.0336
50	0.1866	8.39	0.0222

Table.4.32: Universal microwave oven measurements by spectrum analyzer.

Distance (cm)	Electric Field (V/m)	Power (dBm)
1	11.75	3.0
10	9.33	0.3
20	8.511	-1.0
30	5.88	-5.4
50	1.75	-15.1

Table.4.33: TOKYO microwave oven measurements by field meter.

Distance (cm)	Power density W/m^2	Electric field V/m	Magnetic field A/m
1	1.651	24.95	0.0652
10	0.808	17.45	0.0463
20	0.409	12.82	0.0336
30	0.2856	10.38	0.0275
50	0.1481	7.35	0.0195
150	0.0361	3.69	0.0098

Table.4.34: TOKYO microwave oven measurements by spectrum analyzer.

Distance (cm)	Electric Field (V/m)	Power (dBm)
1	7.7	0
10	5.6	-3.7
20	3.09	-4.1
30	2.57	-11.3
50	1.02	-17.1

The allowed limit of the power density for human exposure to the all guidelines including The Food and Drug Administration (FDAs), NRPB, WHO, IEEE, FCC and ICNIRP at the operation frequency of the microwave (2.45 GHz) is 10 W/m^2.

From the previous measurement tables, we note that as we go away from the microwave Surface the electric field and the power values decrease rapidly. The maximum electric field was measured by the analyzer was about 11.75 V/m for the first microwave oven (Universal microwave oven) as shown in Figure 4.37 at 1 cm away from the door of the oven. And it was 7.7 V/m for the second microwave oven (TOKYO microwave oven) as shown in Figure 4.38 at the same distance of the previous measurement.

However, due to the field meter measurements, the maximum values that measured for the two samples have also been at 1 cm far away from the oven door. The first microwave radiates a power density equal to 1.988 W/m^2, while the second microwave oven radiates 1.651W/m^2 of the power.

By comparing the measurements of the microwave and the international standards and guidelines we note that the maximum measured levels of exposure is lower than allowed level by 5 times for the first microwave and by 6 times for the other on.

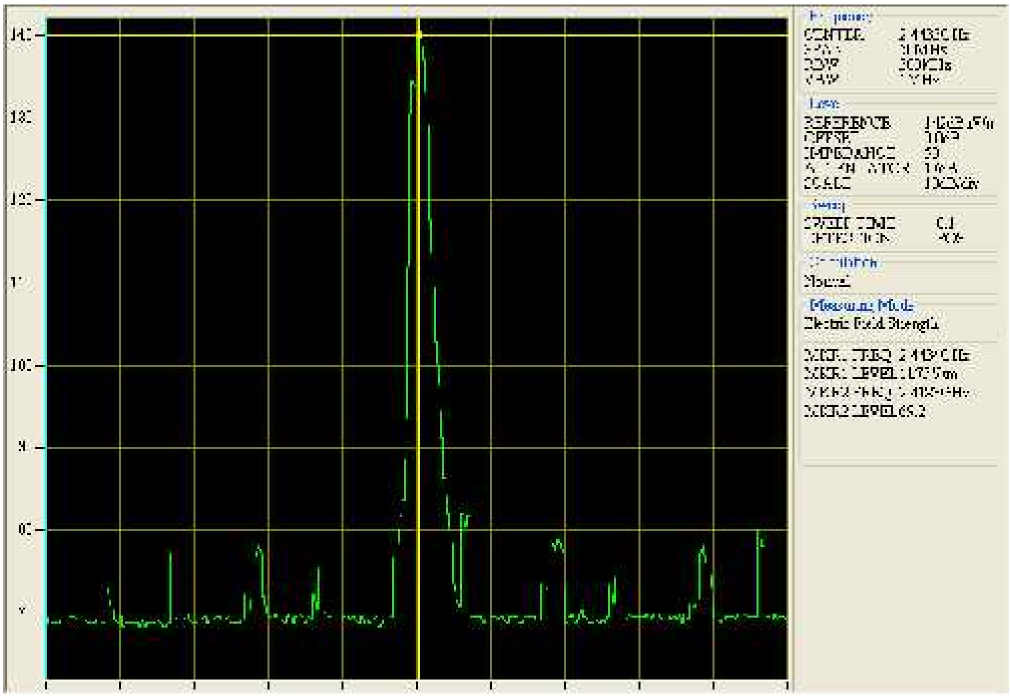


Figure 4.37: Electric field measurements at distance 1cm away from Universal microwave oven.

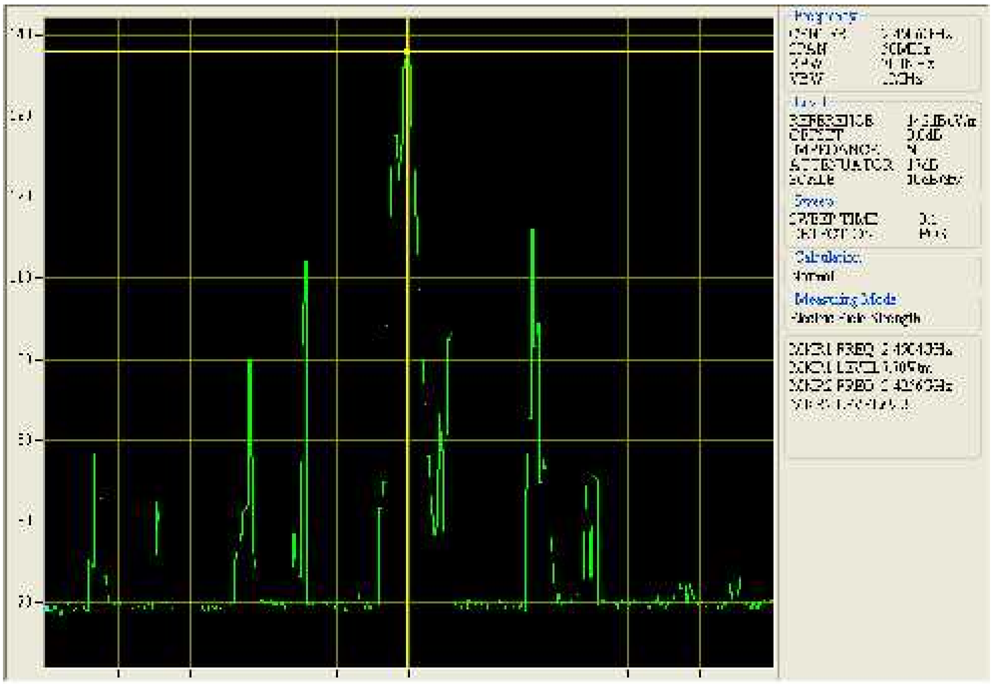


Figure 4.38: Electric field measurements at distance 1cm away from TOKYO microwave oven.

Chapter Five
Conclusion, Recommendations and Further studies

Contents

5.1 Conclusion

In our introduction, we listed the motivations for exploring this work. Measurements were carried out for different common electromagnetic radiation sources in Hebron district. These sources included; Mobile Phone Base Stations (MPBS), Mobile phones (MPs), FM radio stations, TV broadcast stations, and microwave ovens. In evaluating the results of our tests and measurements, we conclude that:

1- Most of electromagnetic radiation (EMRs) sources are safe for human individually, but we have to take care about exposure to more than one EMR source at the same time.

2- Our conjecture that JAWWAL Communication Company follows the regulations set by the international organizations such as ICNIRP, IEEE, WHO and FCC standard exposure limits up held. Due to the low power that radiated from its cells.

3- Base station antennas emitted very narrow beam of radio waves and operated spread parallel to earth direction, so approach to that antennas at (1-2) m distance may be dangers especially in front of antenna. However most of human exposure to base stations happens in the far field of the antenna.

4- Mobile phone radiation levels showed a high-emitted power during the call setup duration. This level of signal is the most worrying one since it is too high and also too close to the brain.

5- Signal level for broadcasting is small within the transmission tower dead zone but it will be greater in the surrounding areas around the transmission antenna itself.

6- The signal strength at ground level increases gradually with distance from the tower or base station, reaches a maximum value at specific distance, and then decreases.

7- It is founded that microwave ovens have high radiation values at short distances comparing with GSM and broadcasting stations. So, it is advised to be away from the microwave oven while using it.

8- Radiation levels from the microwave ovens at close distances and mobile phones at call setup duration are high in compare with the broadcasting towers and base stations radiation. But, it still under the international allowed level of exposure.

9- Power levels fluctuate during day due to the number of users and there are times for high densities or not, also the distance from the base station and the mobile activity.

10- it is impossible to remove all EMF exposure and remain a modern technologically advanced society.

These results represent an invitation to the decision makers to put in consideration the importance of creation a new agency to be in charge of the electromagnetic radiation potential in Palestine and make the EM potential measurement and environmental impact assessment before giving any approval for projects that may be emit electromagnetic radiation during its operations. Moreover, it gives the ordinary people perception about the amount of EM radiation that they are exposed to, and increase their awareness of this kind of technology and how to deal with. This recommendation provides an idea to reduce the concerns about the electromagnetic waves (EMWs) effect for the both sides.

General Recommendations:

1- In order to establish the required call with minimum radiated power from the mobile phone, it is preferred to be near the base station

2- It is restricted recommended for mobile phone companies to use shielding panting for the building that facing the main beam of antenna base station at close distance to reduce and limit the radiation. For example uses RF shielding fabric.

3- Radiation reduction shielding material can be chosen according to selected frequency band.

4- Mobile phone accessories such as Tecno AO, ADR Protect and Bluetooth kit can be used to reduce the effect of radiation on brain especially thermal and a thermal radiation.

5- In order to decrease the electromagnetic fields emitted, it is needed to develop the design of the electric devices in general and the mobile phones in specific.

6- It is advised and recommended to keep the mobile phone away from our head at call setup during the call progress.

7- Choose the most suitable and highest location for installing the base stations and take into consideration the architectural development of the area around it.

8- Because of people concern about base station sites, we advice to change its look and choose something close to nature to look like a tree for example.

9- To reduce aesthetic impact of their systems on communities; it is generally preferred for GSM companies to install their antennas on existing structures and to co-locate where possible, i.e. locate base stations from different companies on the same structure.

10- To decrease the emitted power radiated from the base stations and to prevent the adverse effects of electromagnetic fields, it is necessary to increase the number of base station.

11- It is recommended to reduce the number of broadcast towers at small limited area by rearrange and distribute them far apart from each other to reduce the people concern whom living in the vicinity of these towers.

12- Because of the high radiation level of microwave ovens at close distances, it is advised to keep away at safe distance to avoid the exposure of EM radiation while using these devices.

13- Never tamper with, inactivate the interlocking devices, or operate it with a broken door.

5.2 Further Studies

This study represents a trail to have a global look for different kinds of electromagnetic sources which human were exposed during their daily life indoors and outdoors in Hebron district; and they deal with it without any precautions or restrictions the study aim to indicate the biggest threat EM source based on real and practical measurements.

So, we suggest for the future work to make an electromagnetic radiation map for West Bank and Gaza strip; in order to support decision maker to take action against random activities, which be careless about the adverse effects of EMF on humans, so it have to put in consideration the environmental impact assessment of projects that produces electromagnetic radiations.

Therefore, we need to use fixed or mobile monitoring station to records electromagnetic radiation periodically at the important areas during the day for long time around the year, after that we can transfer it to other locations to get other records. Moreover, we can extend the map to include other cities such as Ramallah, Nablus and Gaza.

Finally, we may get an electromagnetic radiation risk map, which will explain the electromagnetic radiation potential to support decision maker to put its healthy hazarded effect on human in consideration. It will improve the evaluation of the environmental assessment of the projects produces electromagnetic field.

Appendix-A

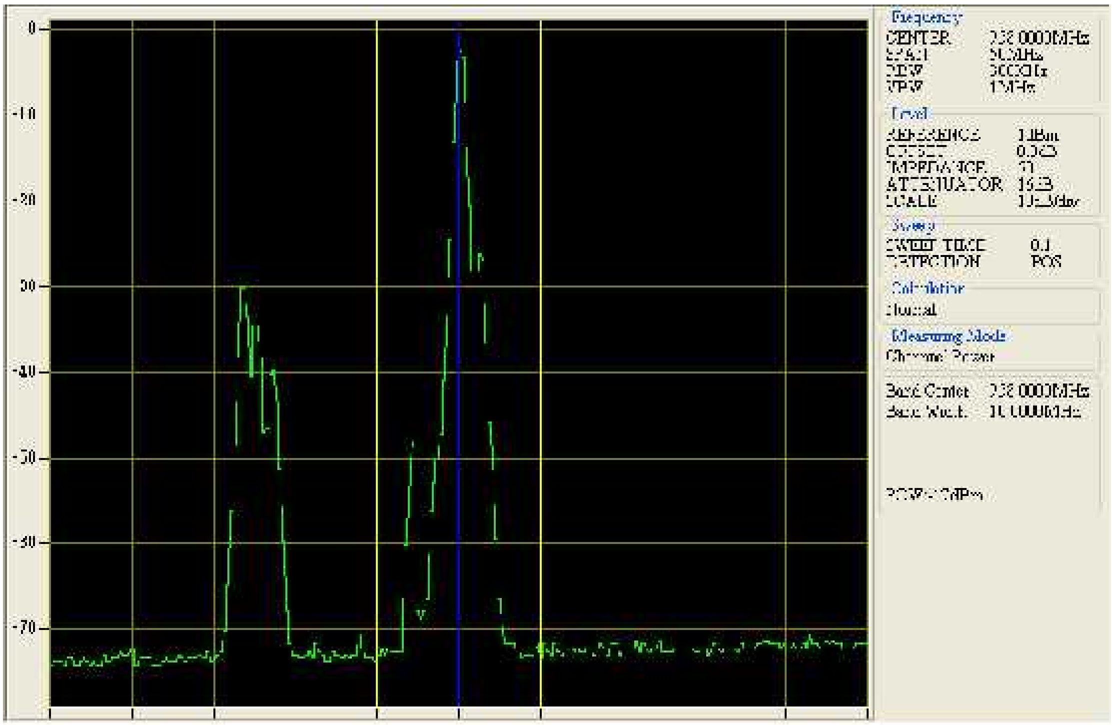
<u>Some Spectrum Analyzer measurements</u>

Ein Sarah base station:

Electric field measurement at distance 3m away from Ein Sarah base station (Cell C).

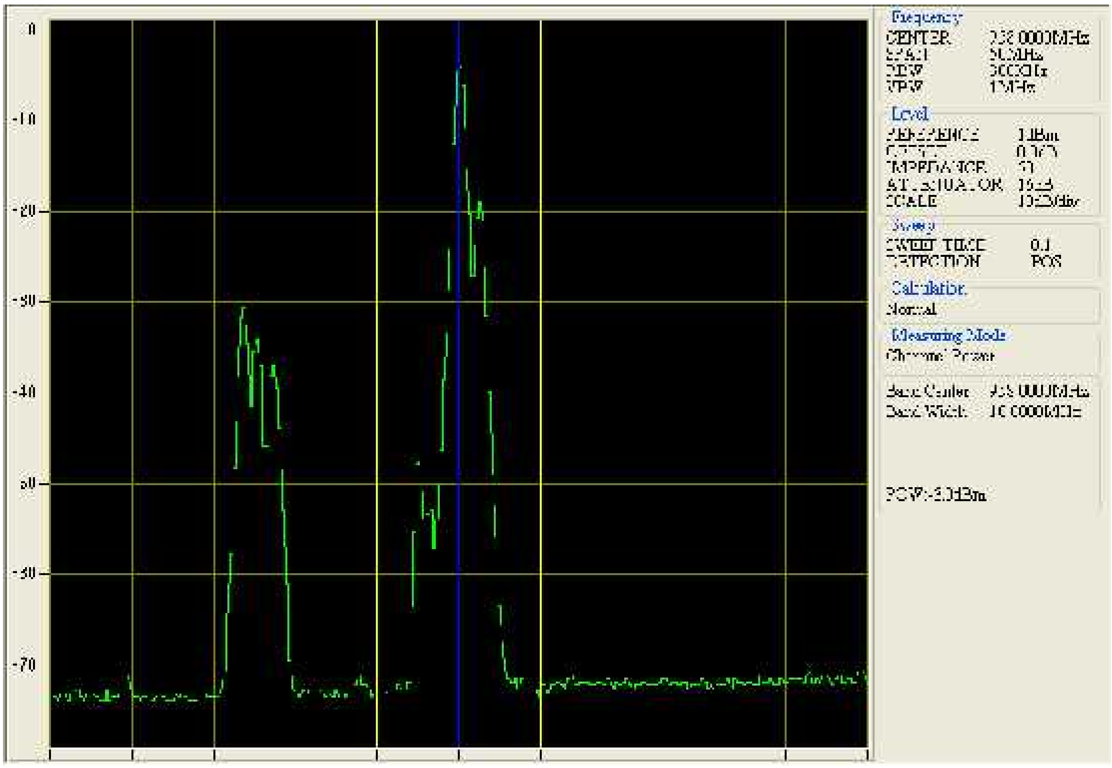
Power measurement at distance 3m away from Ein Sarah base station (cell C).

Electric field measurement at distance 5m away from Ein Sarah base station (Cell C).

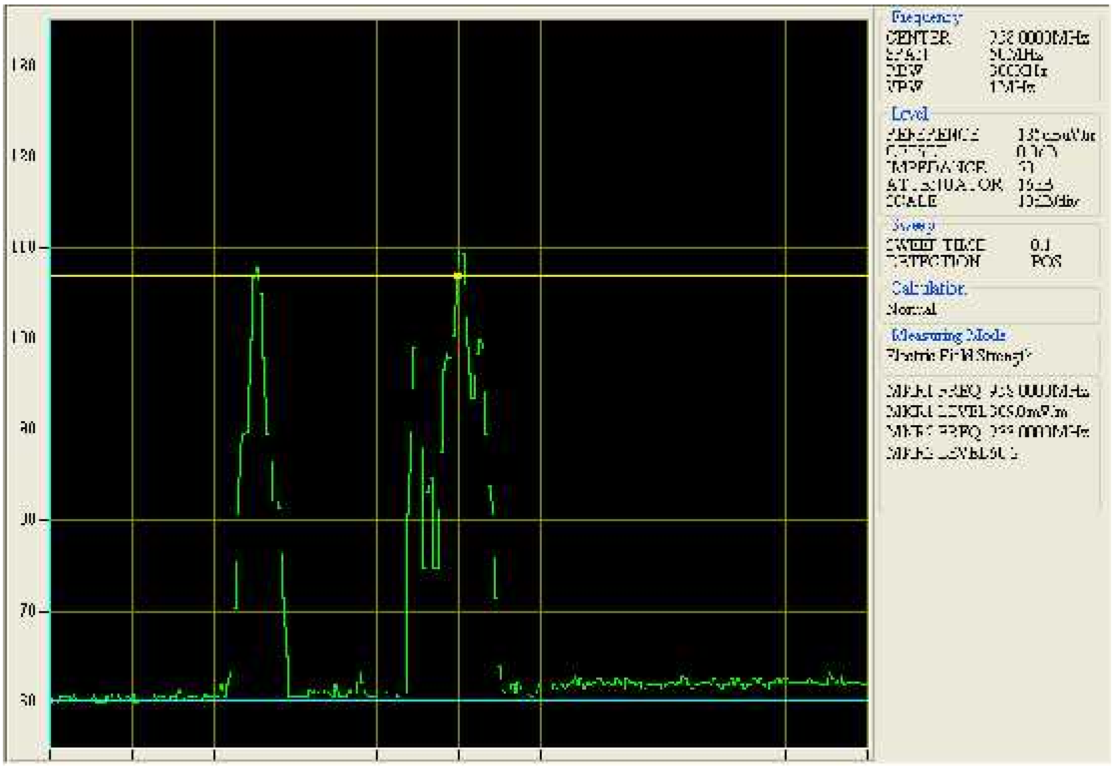


Power measurement at distance 5m away from Ein Sarah base station (cell C).

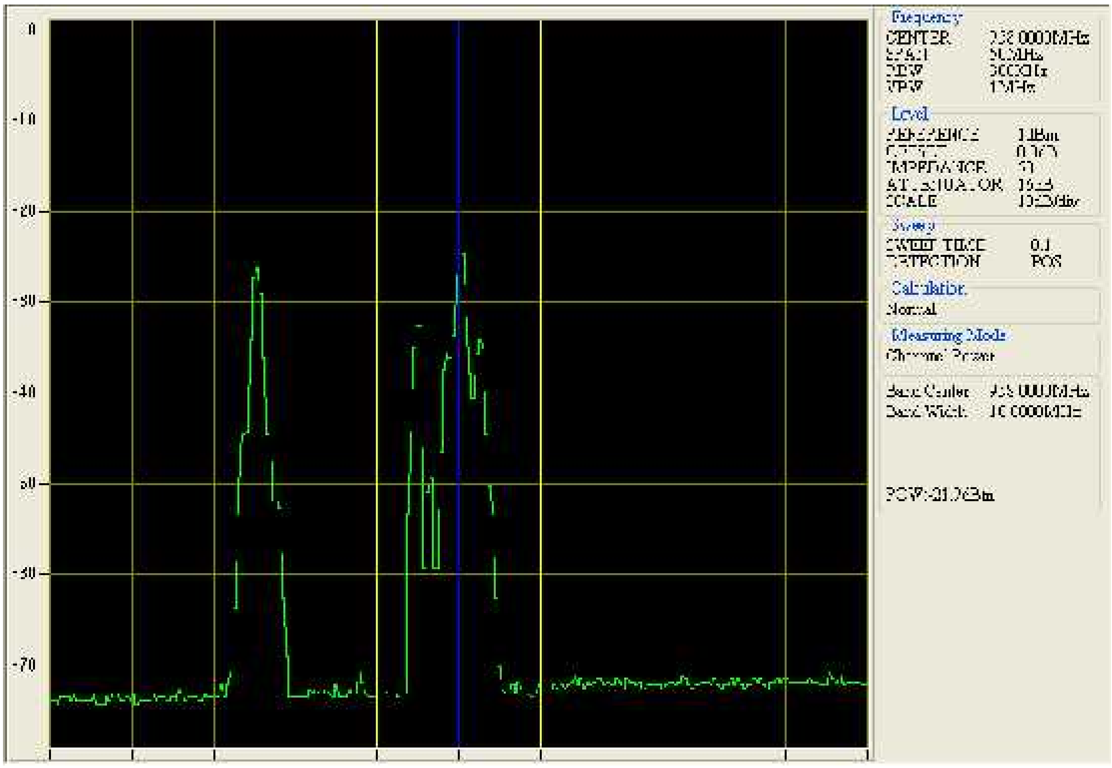
Electric field measurement at distance 6m away from Ein Sarah base station (Cell C).



Power measurement at distance 6m away from Ein Sarah base station (cell C).

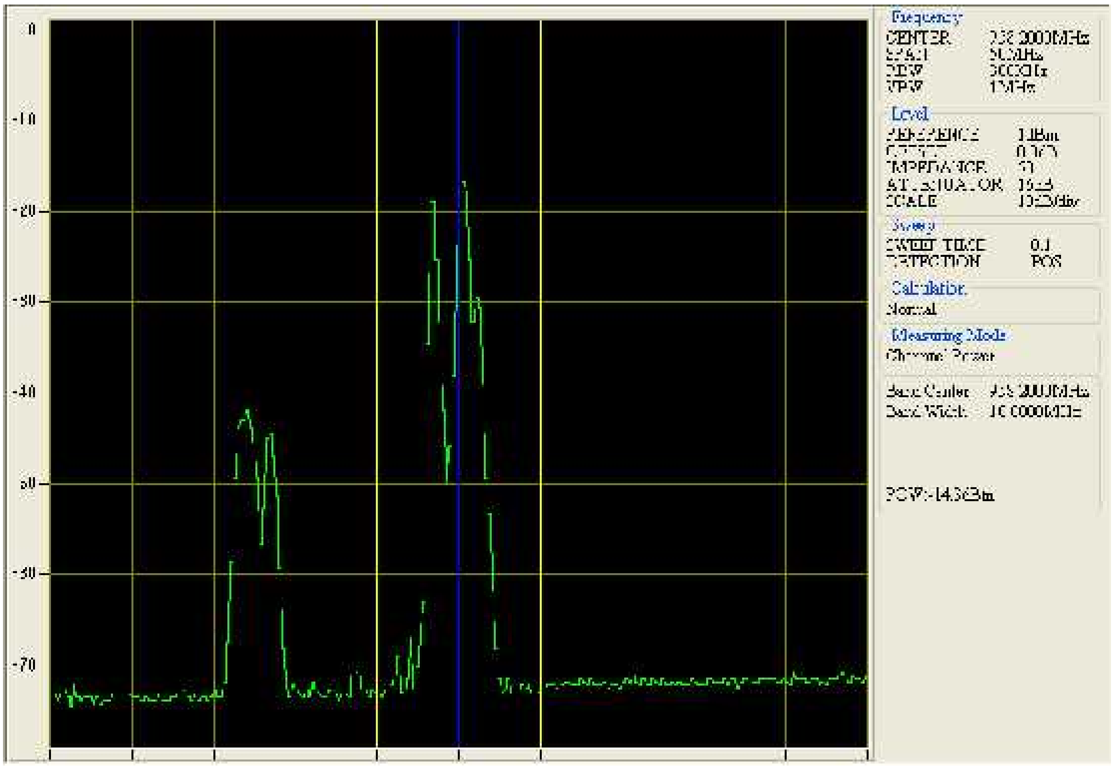


Electric field measurement at distance 40m away from Ein Sarah base station(Cell C).

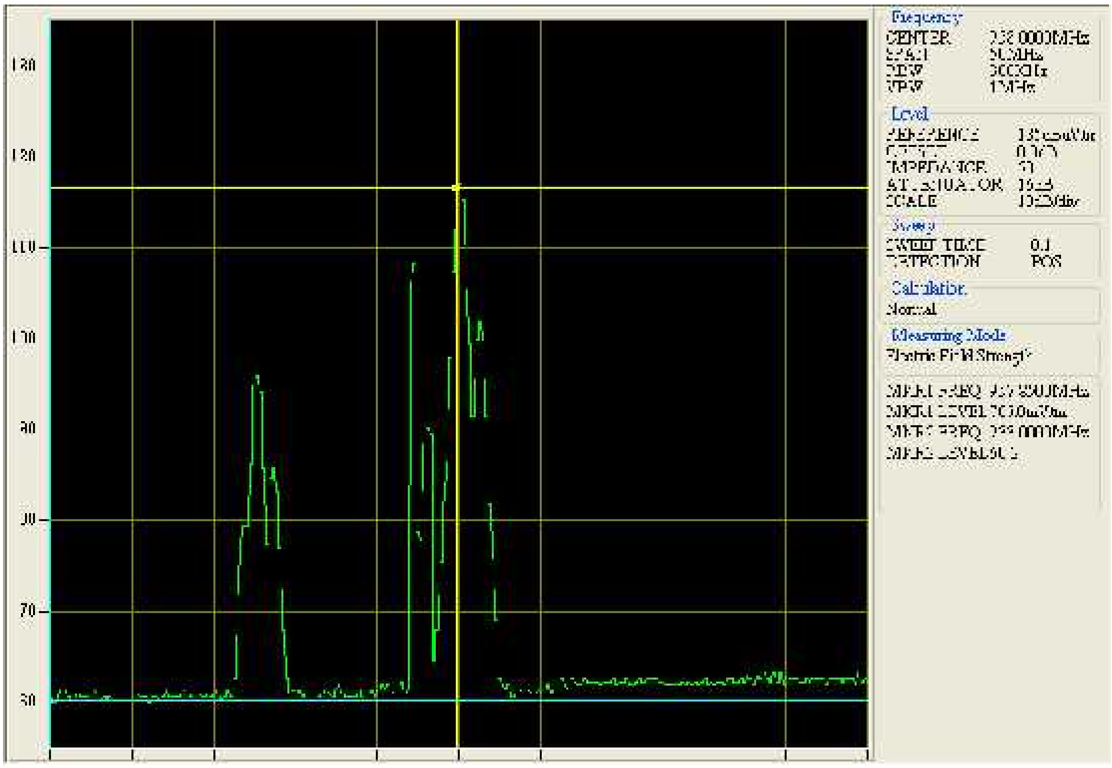


Power measurement at distance 40m away from Ein Sarah base station (cell C).

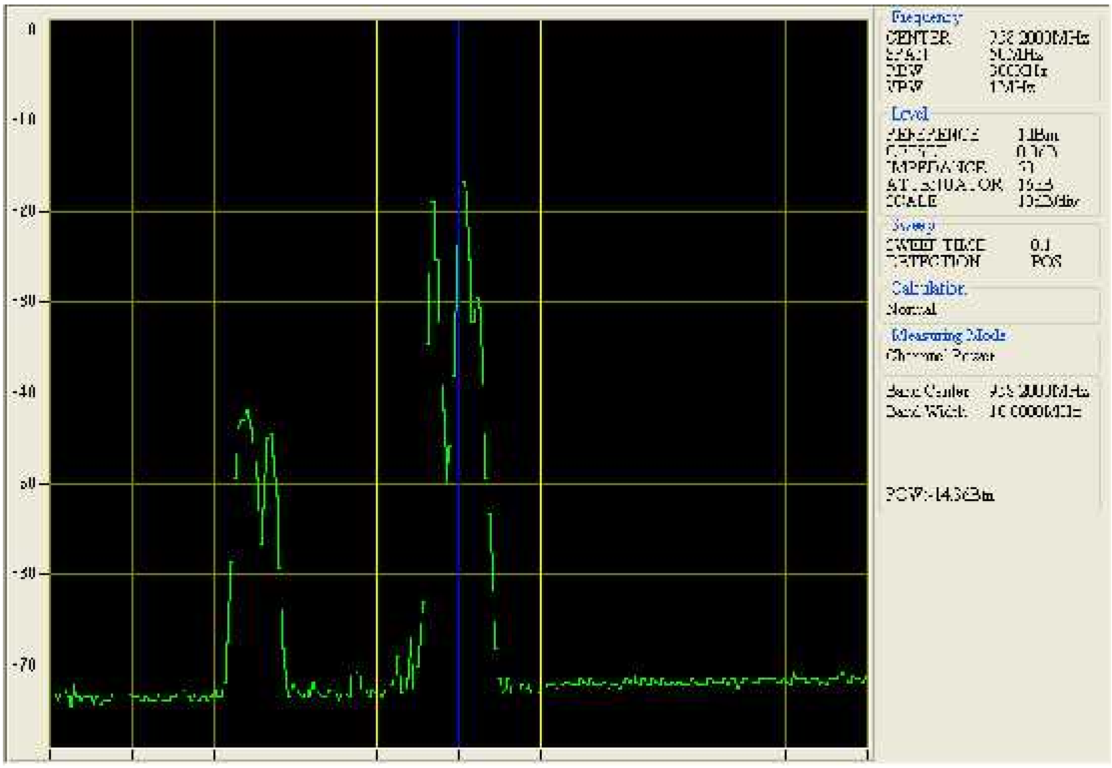
Electric field measurement at distance 60m away from Ein Sarah base station(Cell C).



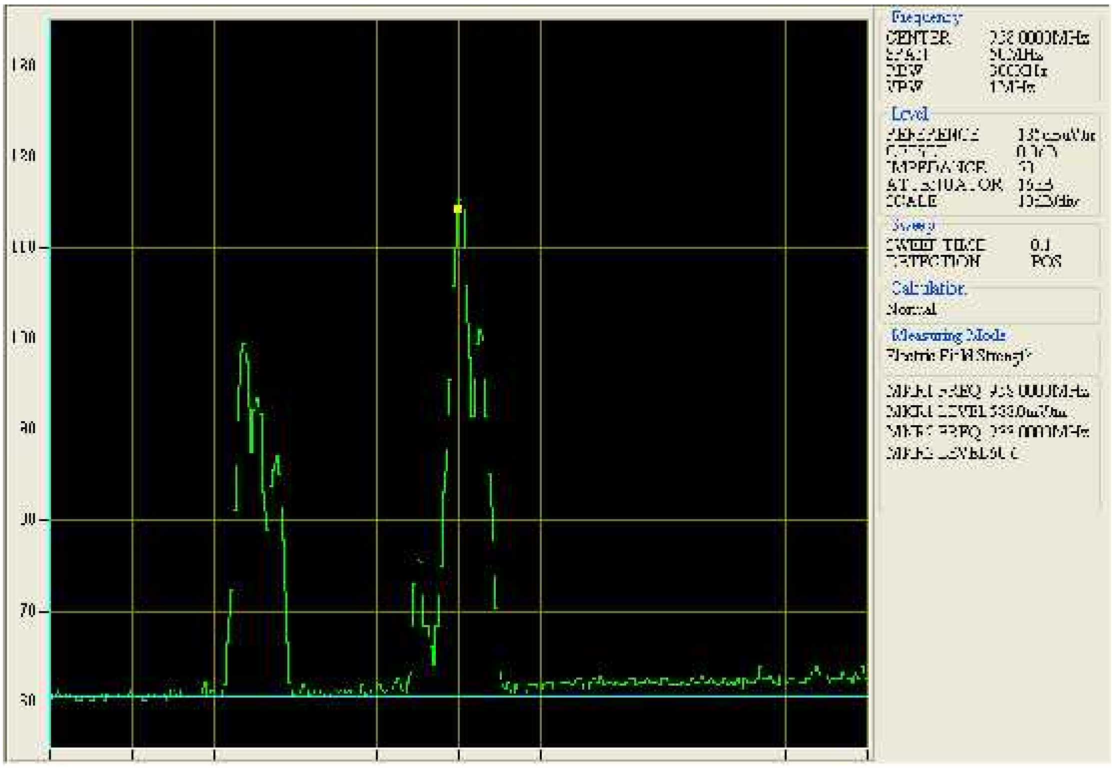
Power measurement at distance 60m away from Ein Sarah base station (cell C).



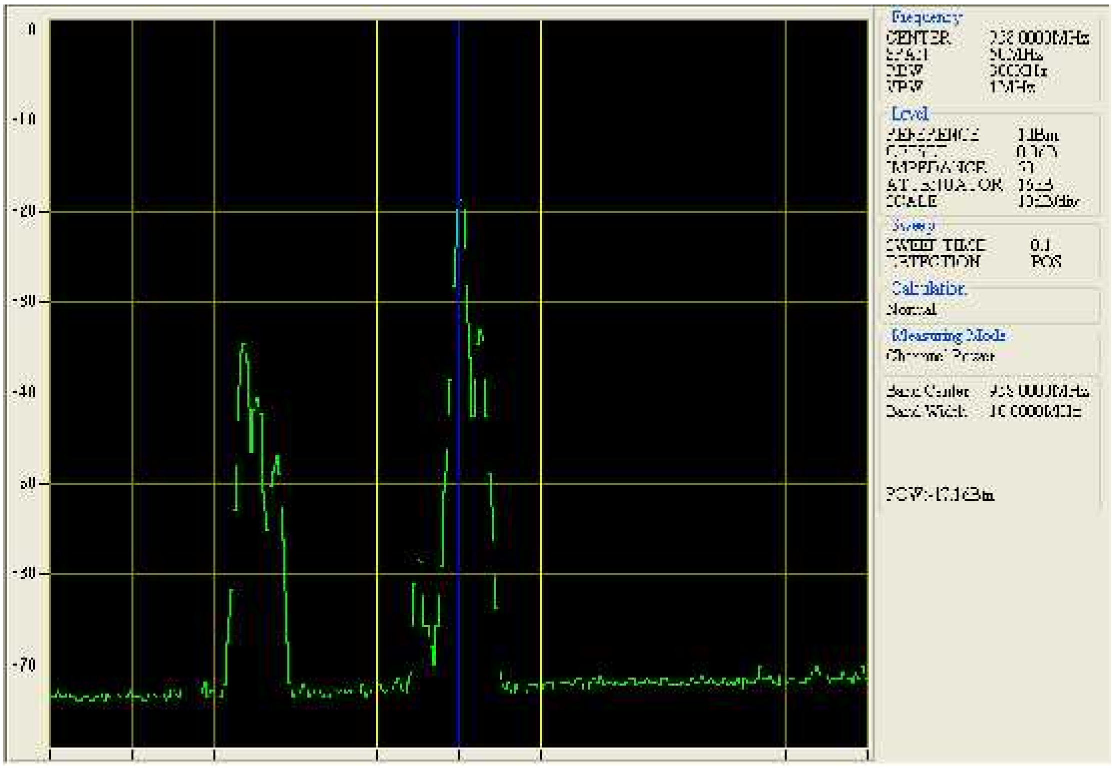
Electric field measurement at distance 80m away from Ein Sarah base station(Cell C).



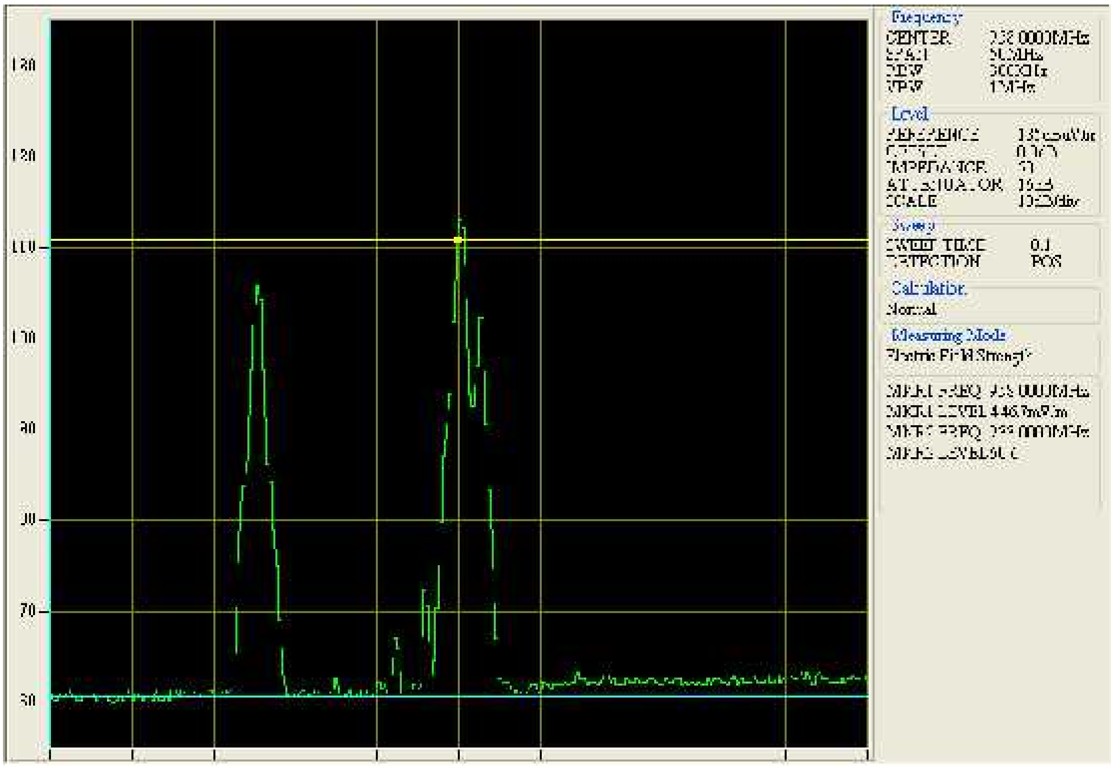
Power measurement at distance 80m away from Ein Sarah base station (cell C).



Electric field measurement at distance100m away from Ein Sarah base station(Cell C).



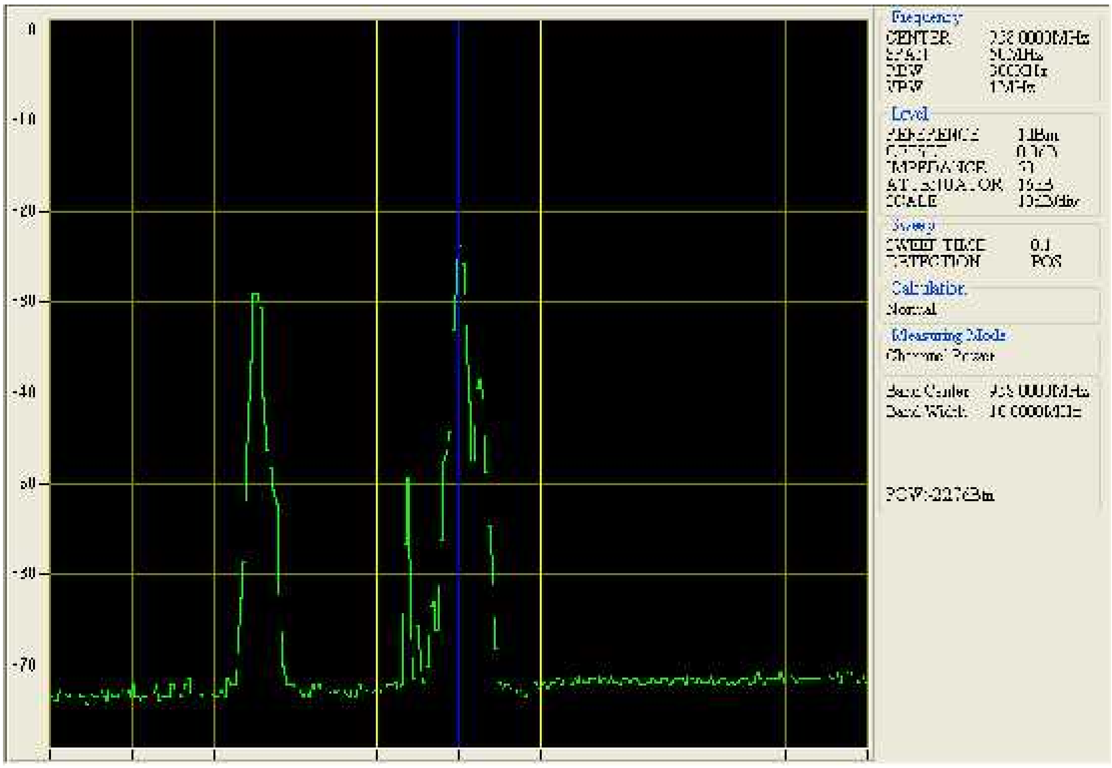
Power measurement at distance 100m away from Ein Sarah base station (cell C).



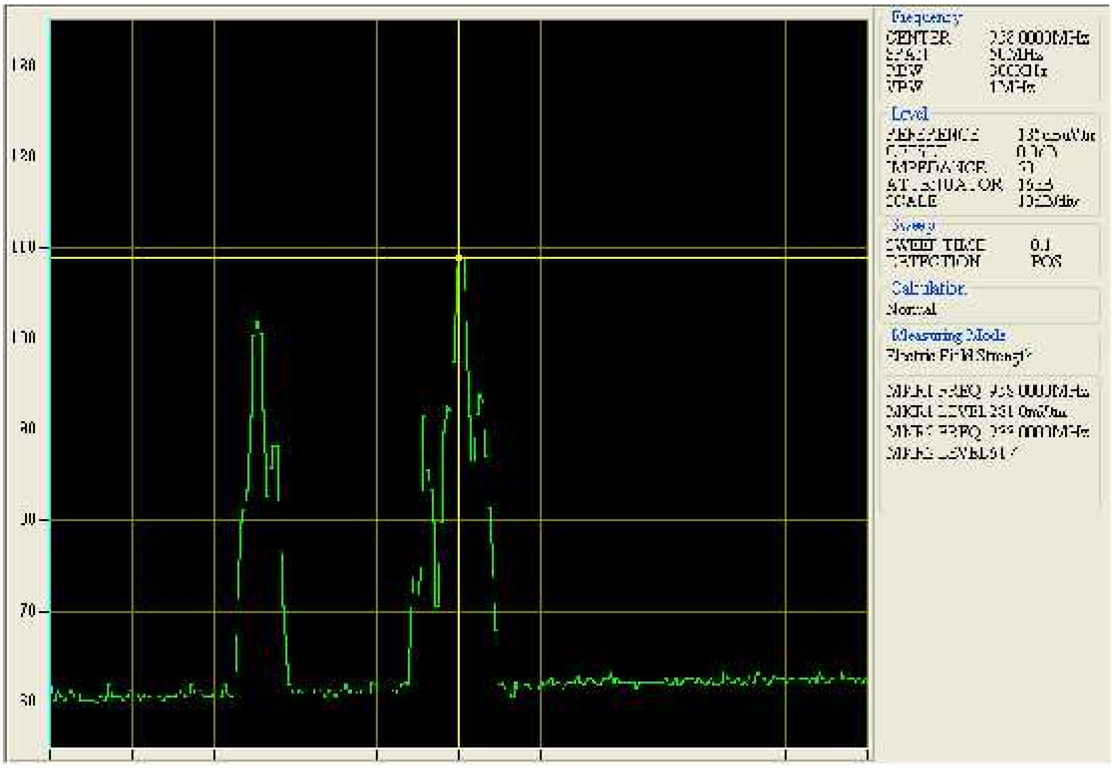
Electric field measurement at distance 120m away from Ein Sarah base station(Cell C).

Power measurement at distance 120m away from Ein Sarah base station (cell C).

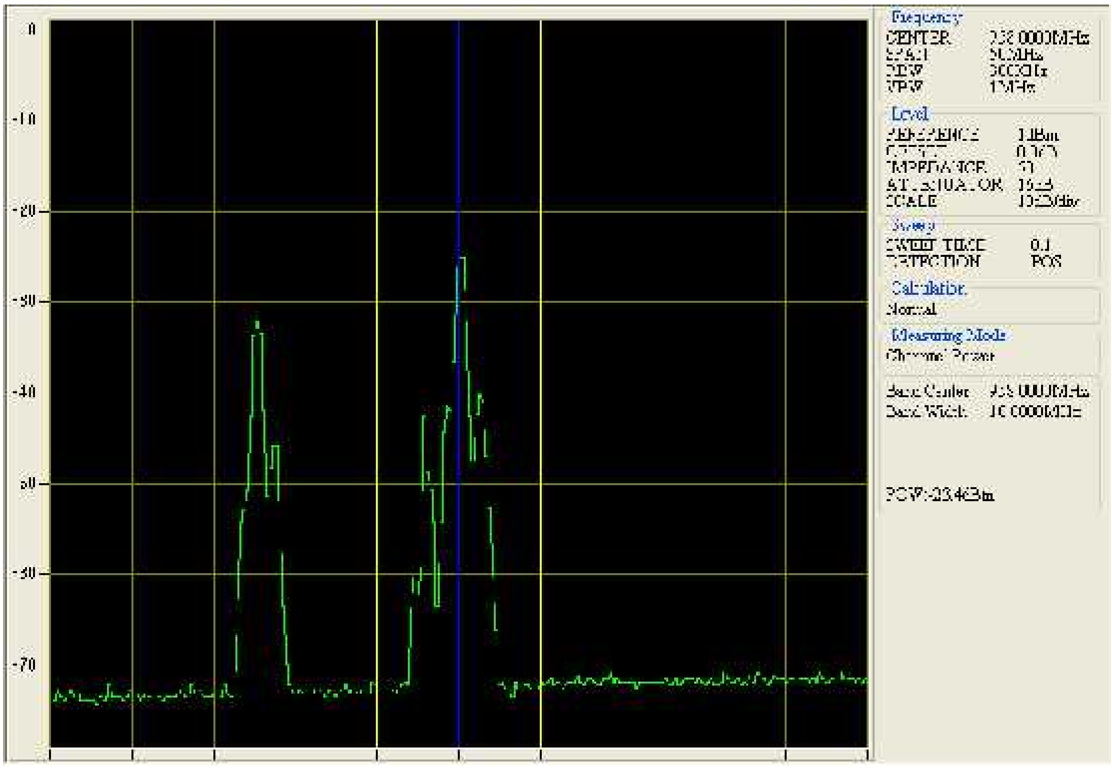
Electric field measurement at distance 200m away from Ein Sarah base station(Cell C).



Power measurement at distance 200m away from Ein Sarah base station (cell C).

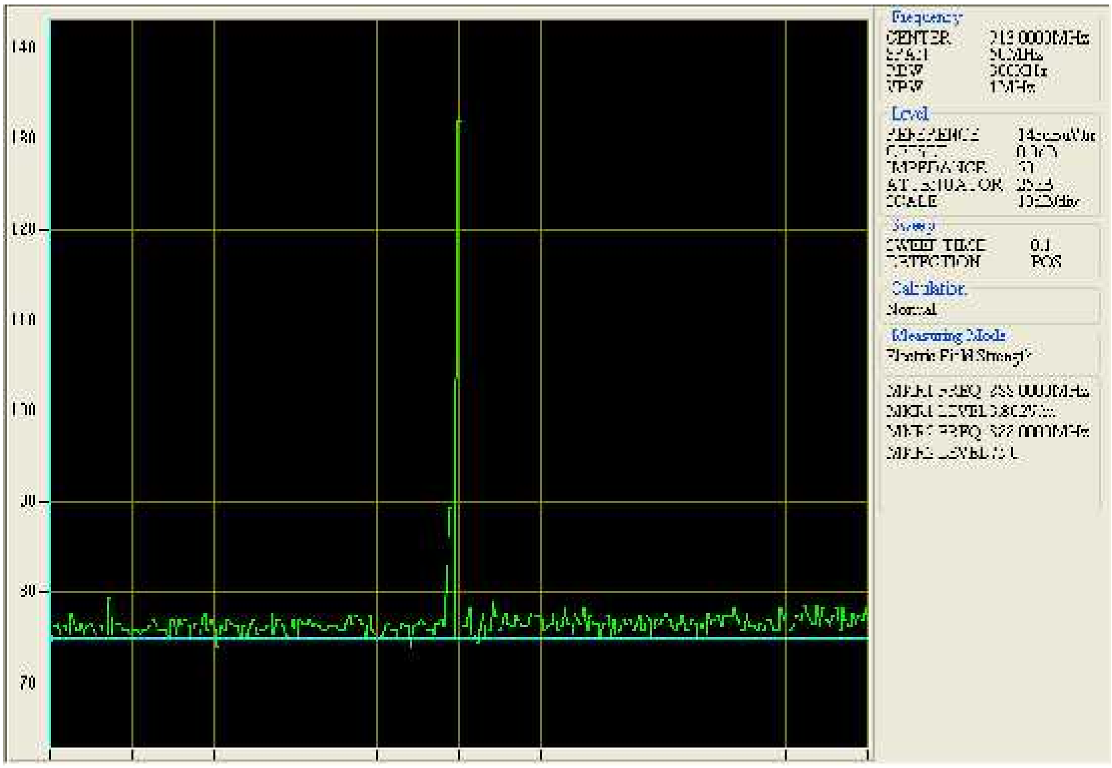


Electric field measurement at distance 300m away from Ein Sarah base station(Cell C).

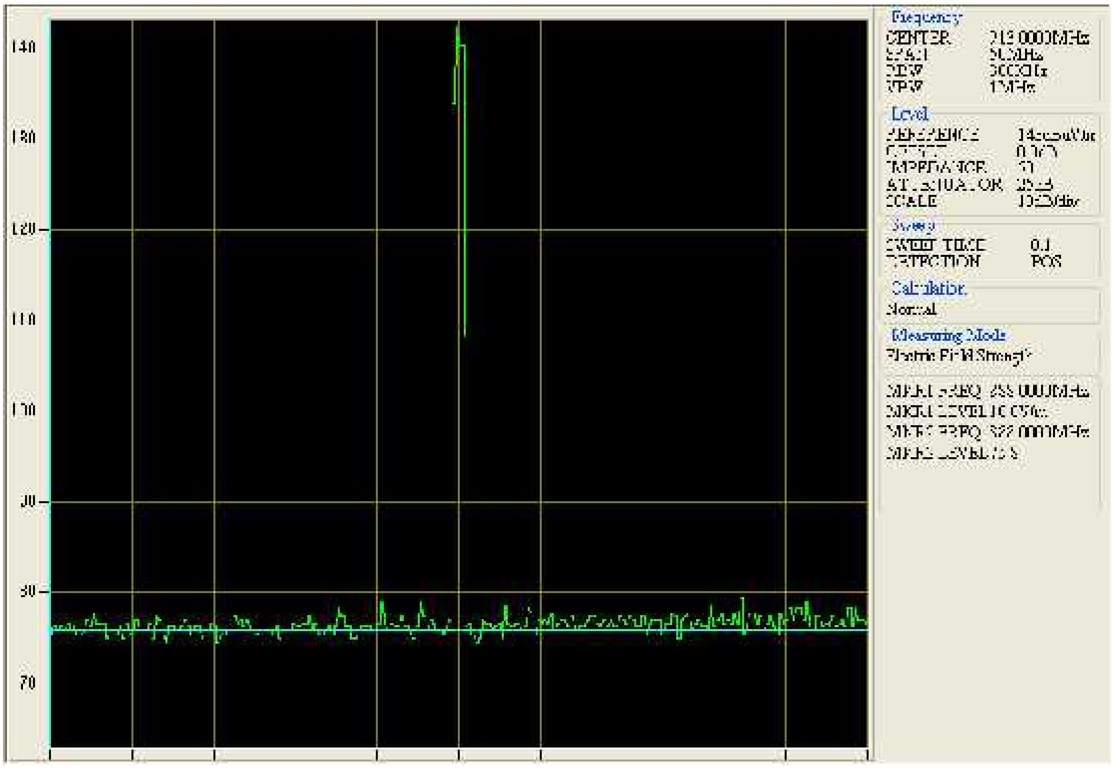


Power measurement at distance 300m away from Ein Sarah base station (cell C).

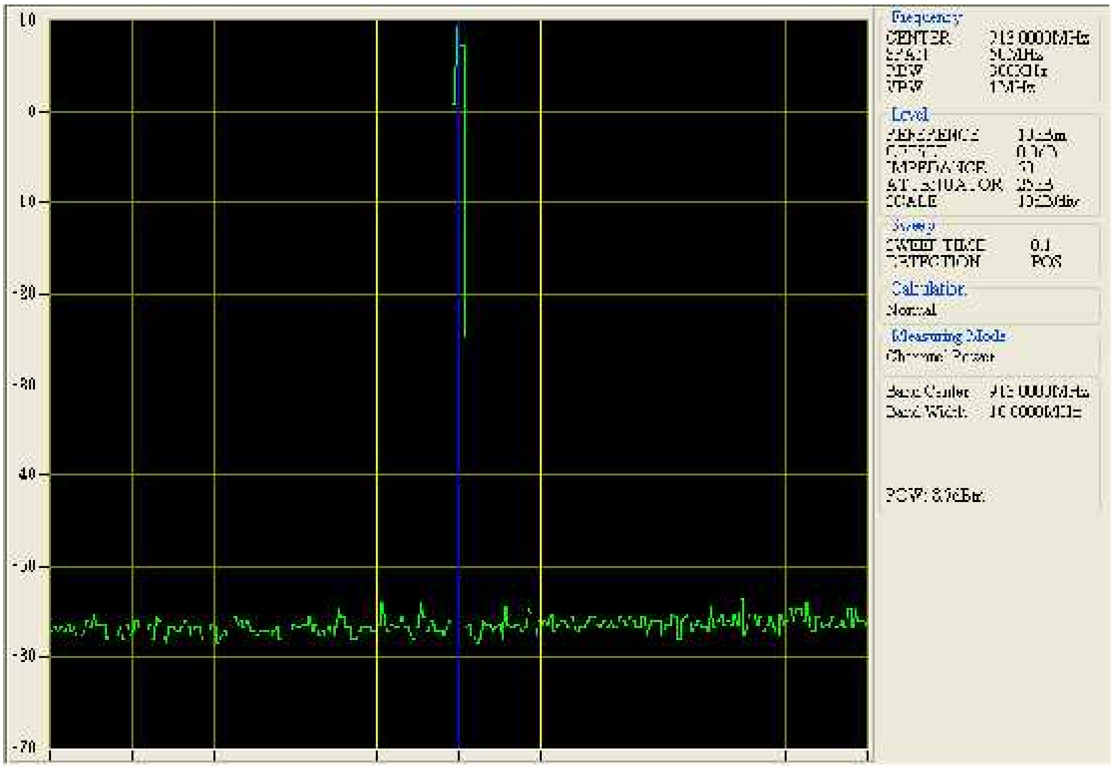
Mobile station (low power antenna):



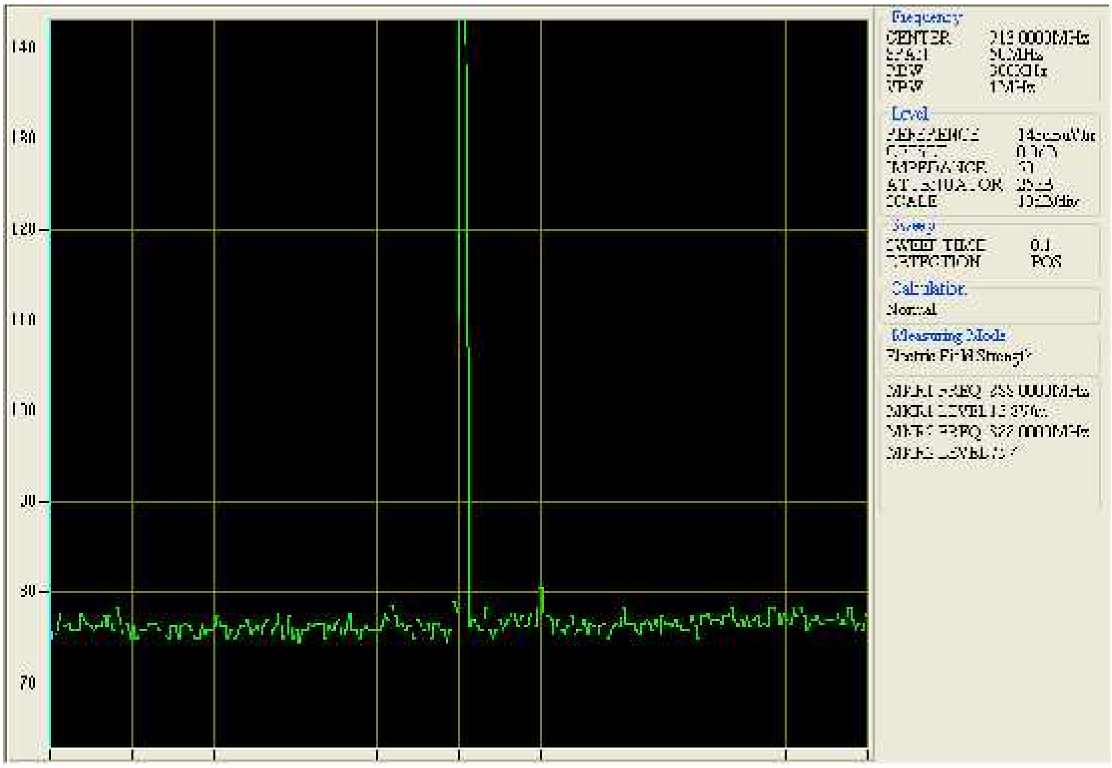
Electric field measurements at distance 3m away from a low power antenna at ground floor in Hebron center



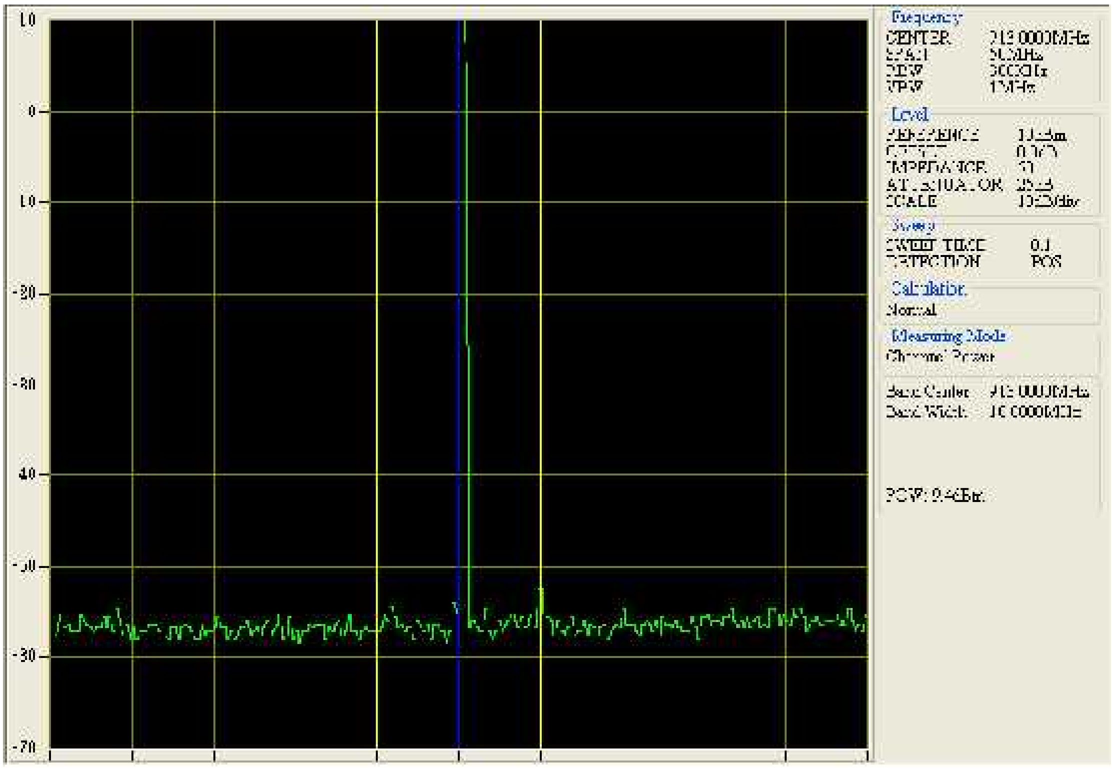
Electric field measurement at distance 10m away from a low power antenna at ground floor in Hebron center.



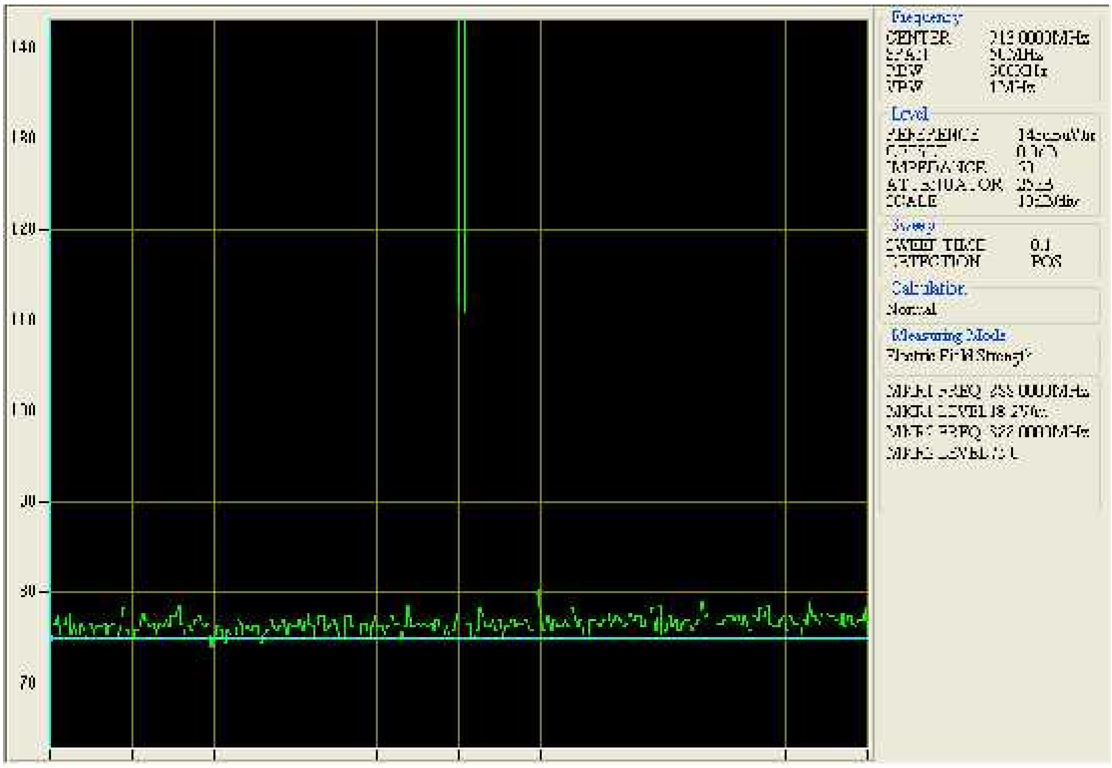
Power measurement at distance 10 m away from a low power antenna at ground floor in Hebron center.



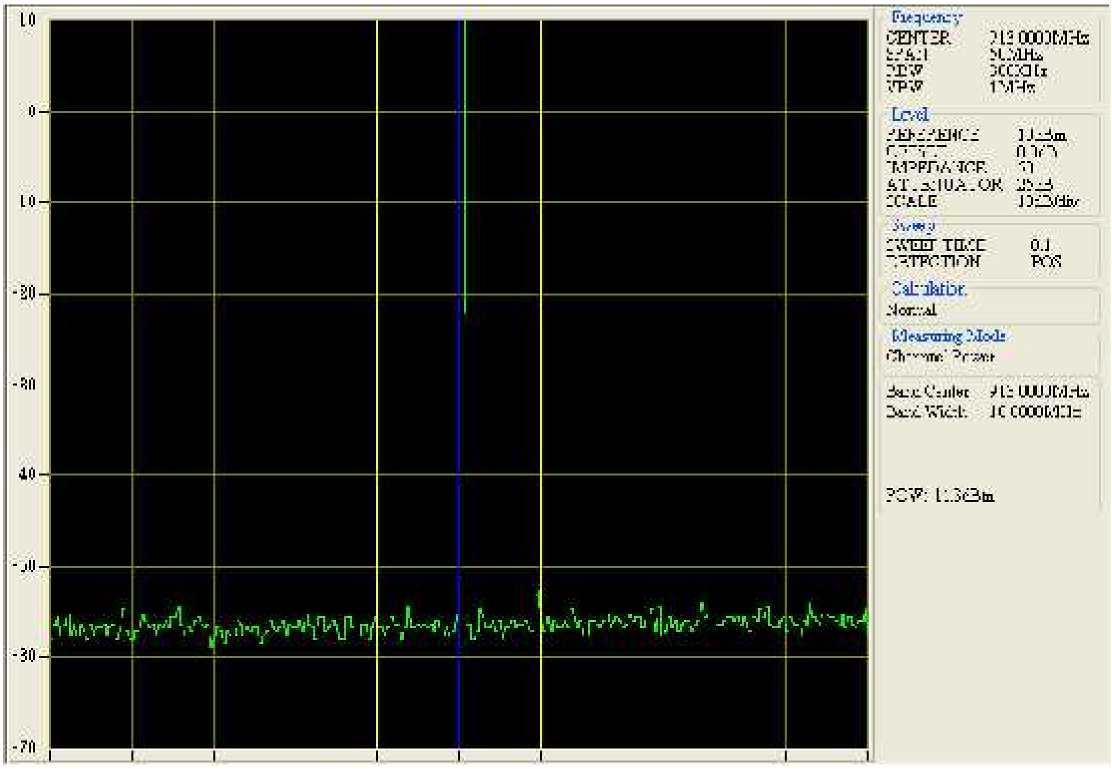
Electric field measurement at distance 15m away from a low power antenna at ground floor in Hebron center.



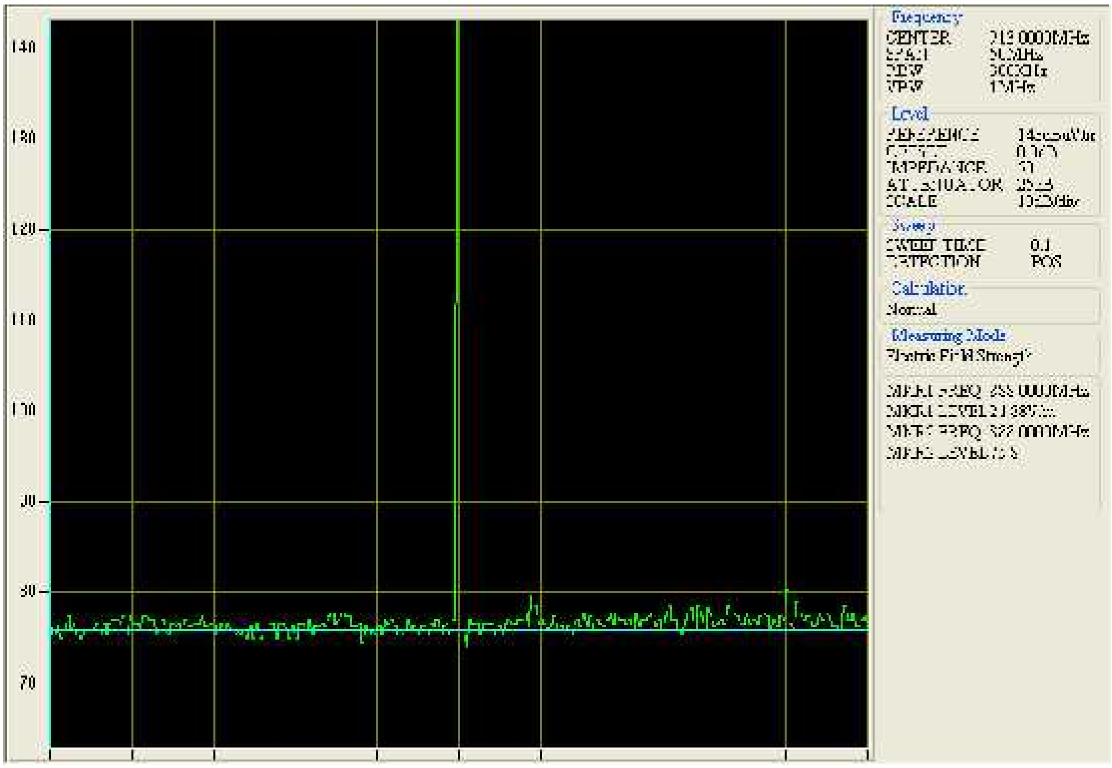
Power measurement at distance 15 m away from a low power antenna at ground floor in Hebron center.



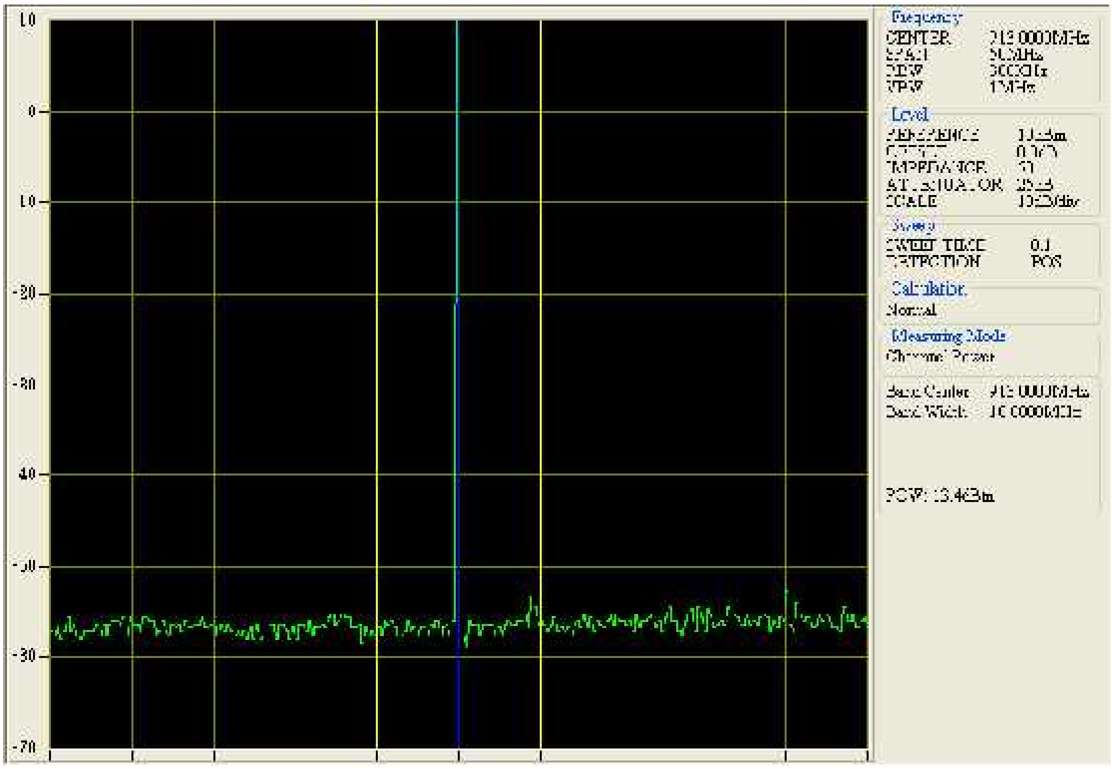
Electric field measurement at distance 25m away from a low power antenna at ground floor in Hebron center.



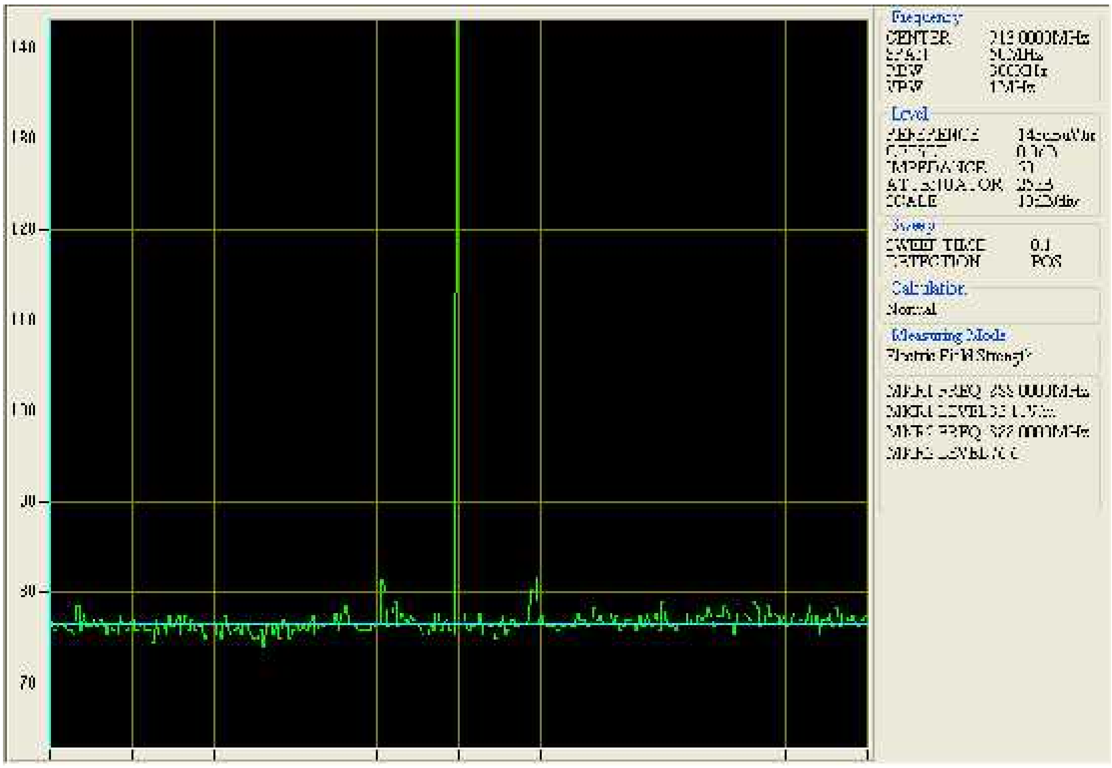
Power measurement at distance 25 m away from a low power antenna at ground floor in Hebron center.



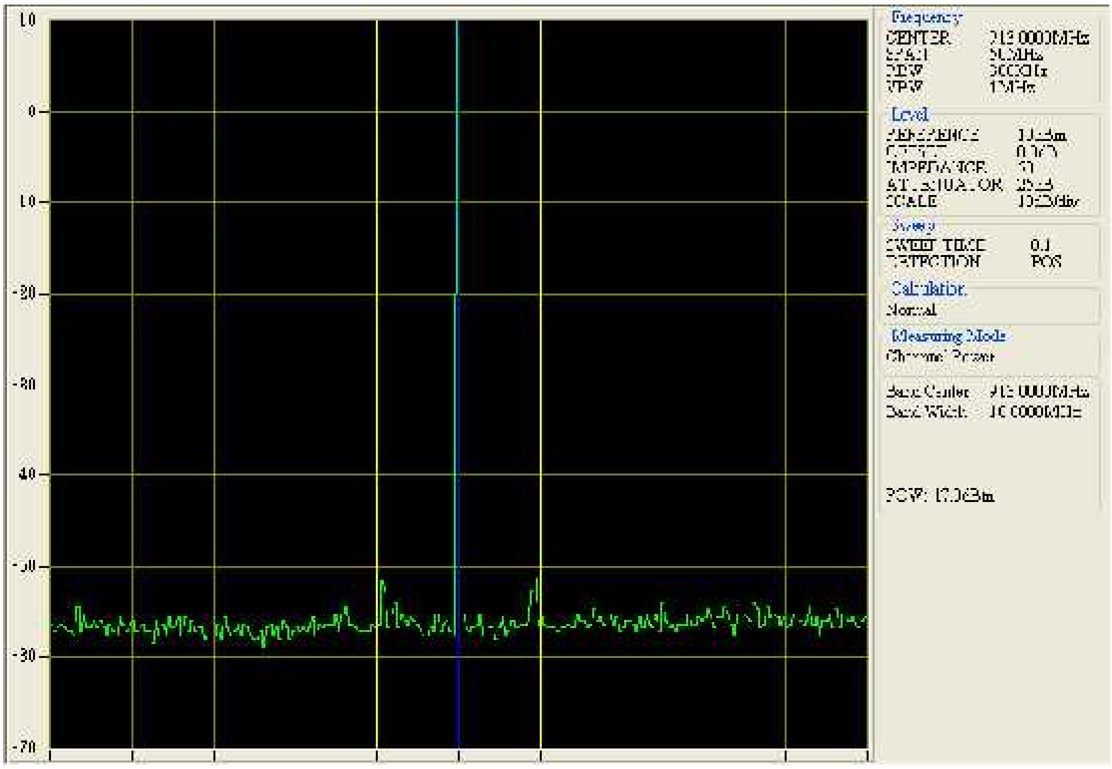
Electric field measurement at distance 50m away from a low power antenna at ground floor in Hebron center.



Power measurement at distance 50 m away from a low power antenna at ground floor in Hebron center.



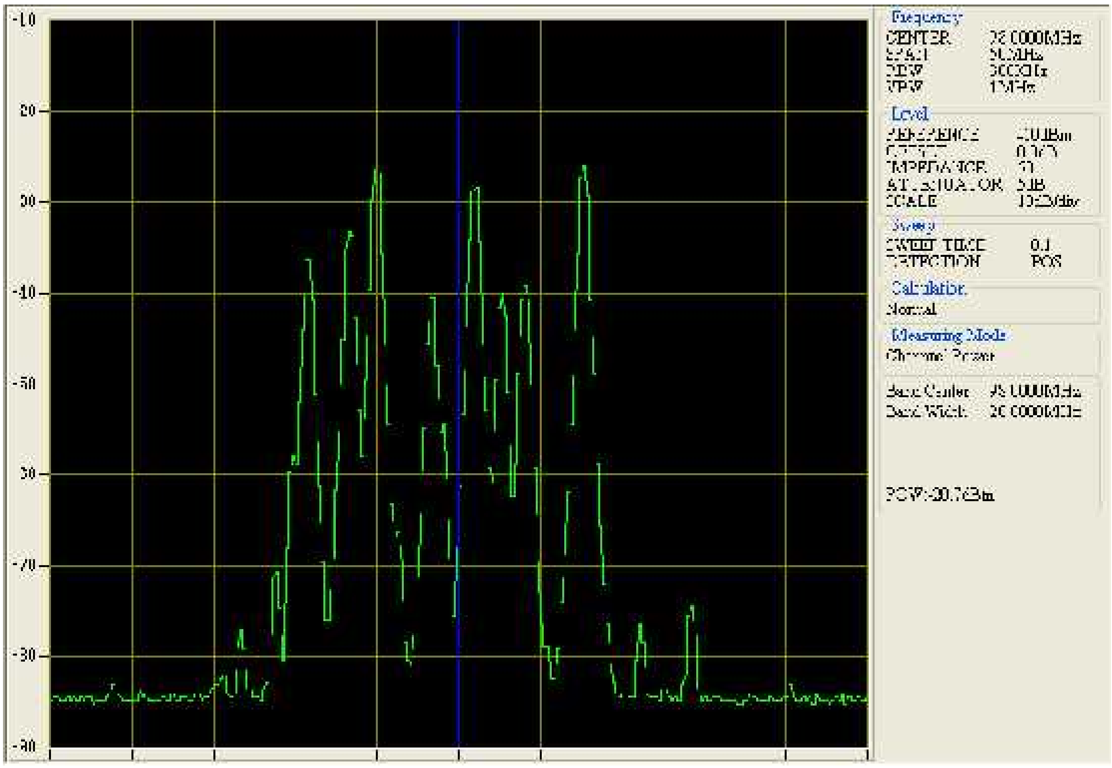
Electric field measurement at distance 100m away from a low power antenna at ground floor in Hebron center.



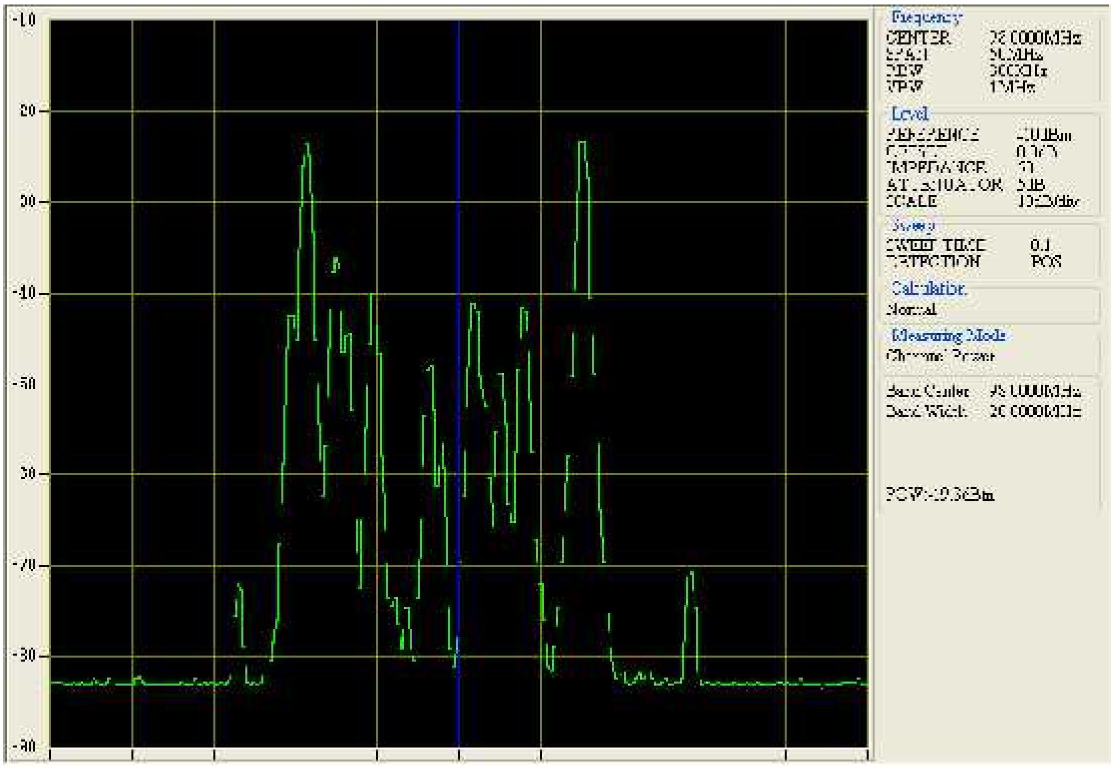
Power measurement at distance 100 m away from a low power antenna at ground floor in Hebron center.

FM radio stations:

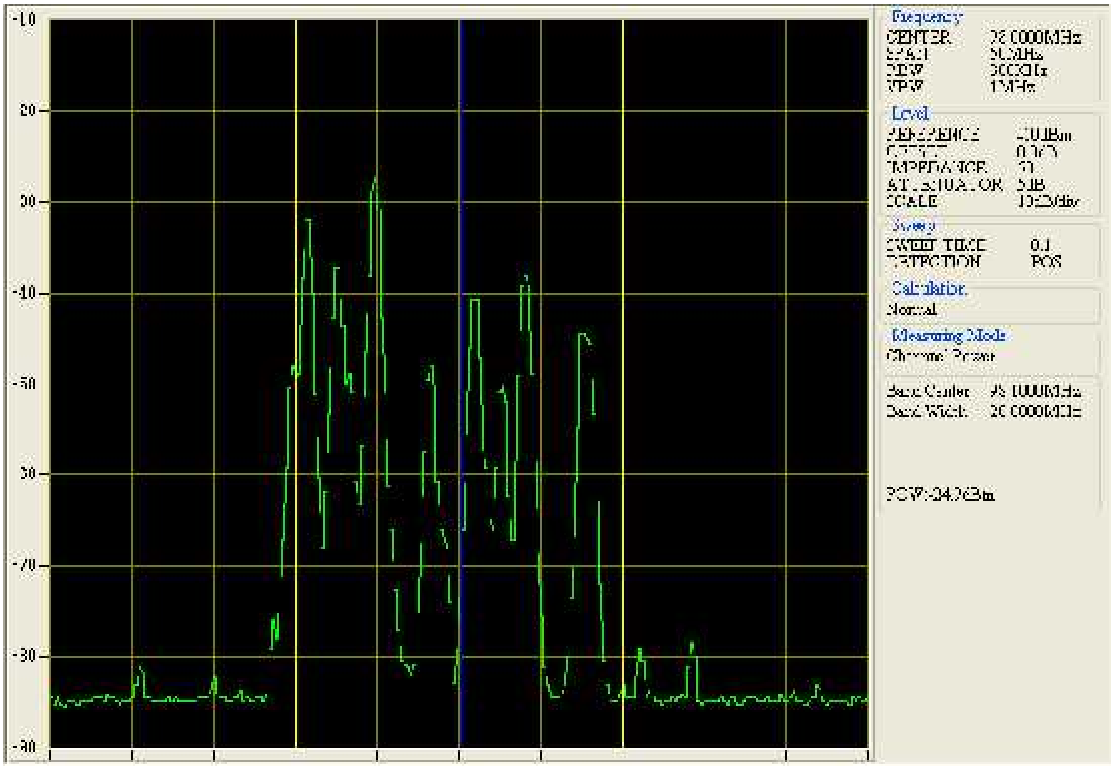
Power measurement of FM radio stations at 31°33'25.96"N 35° 5'45.65"E



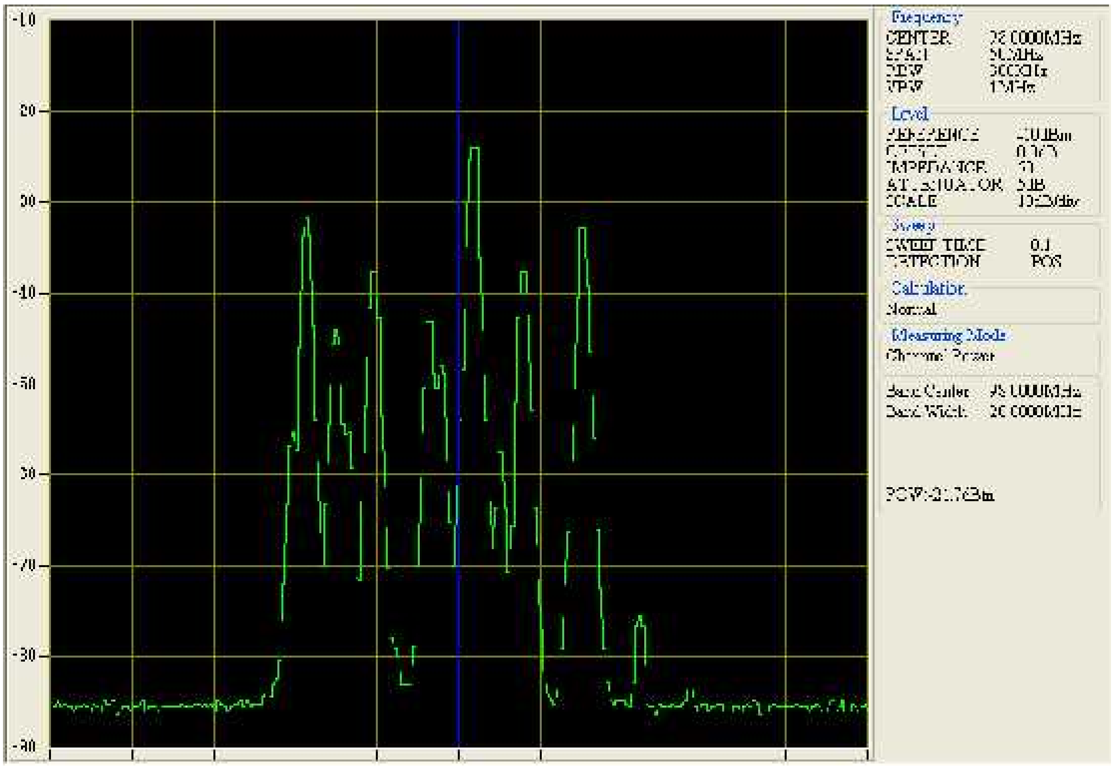
Power measurement of FM radio stations at 31°33'24.53"N 35° 5'45.40"E



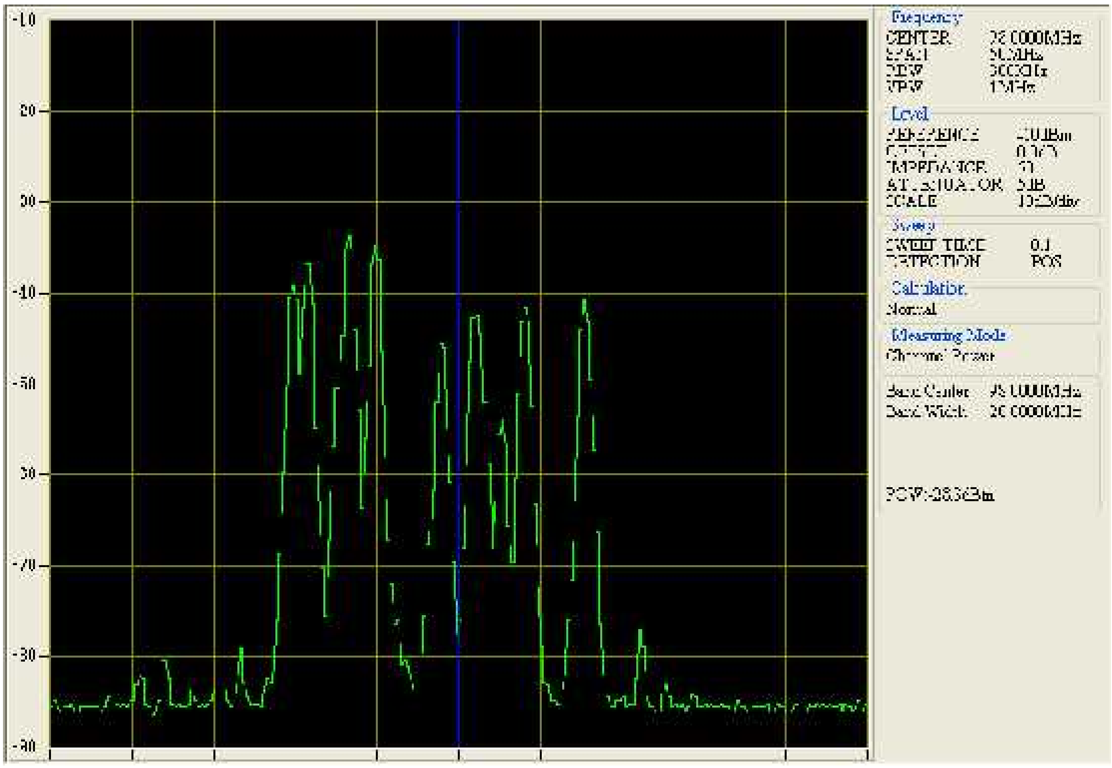
Power measurement of FM radio stations at 31°33'23.55"N 35° 5'45.08"E



Power measurement of FM radio stations at 31°33'22.18"N 35° 5'45.02"E

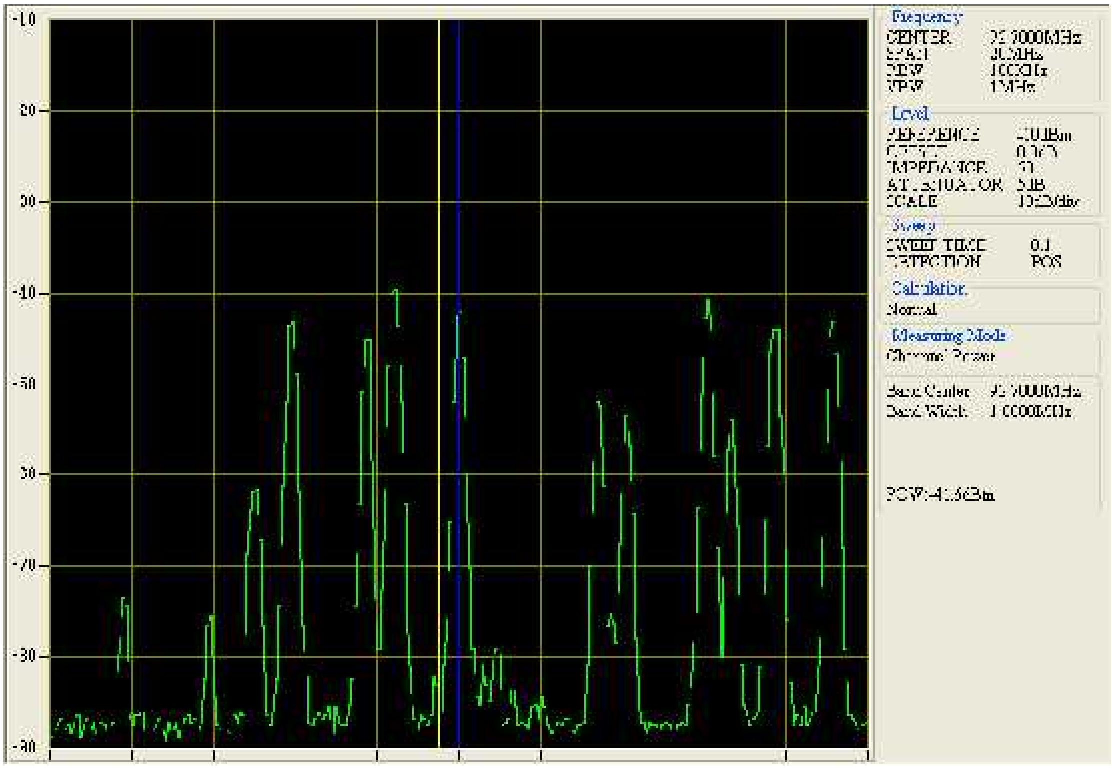


Power measurement of FM radio stations at 31°33'21.00"N 35° 5'45.37"E

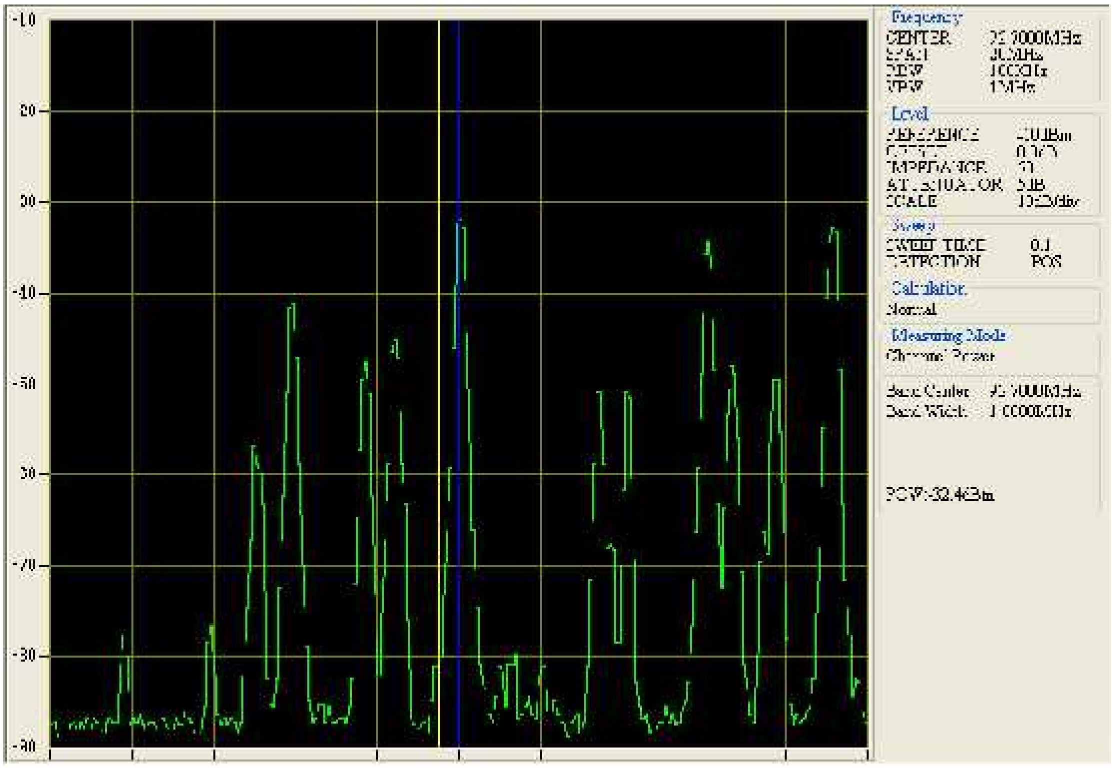


Power measurement of FM radio stations at 31°33'19.64"N 35° 5'45.98"E

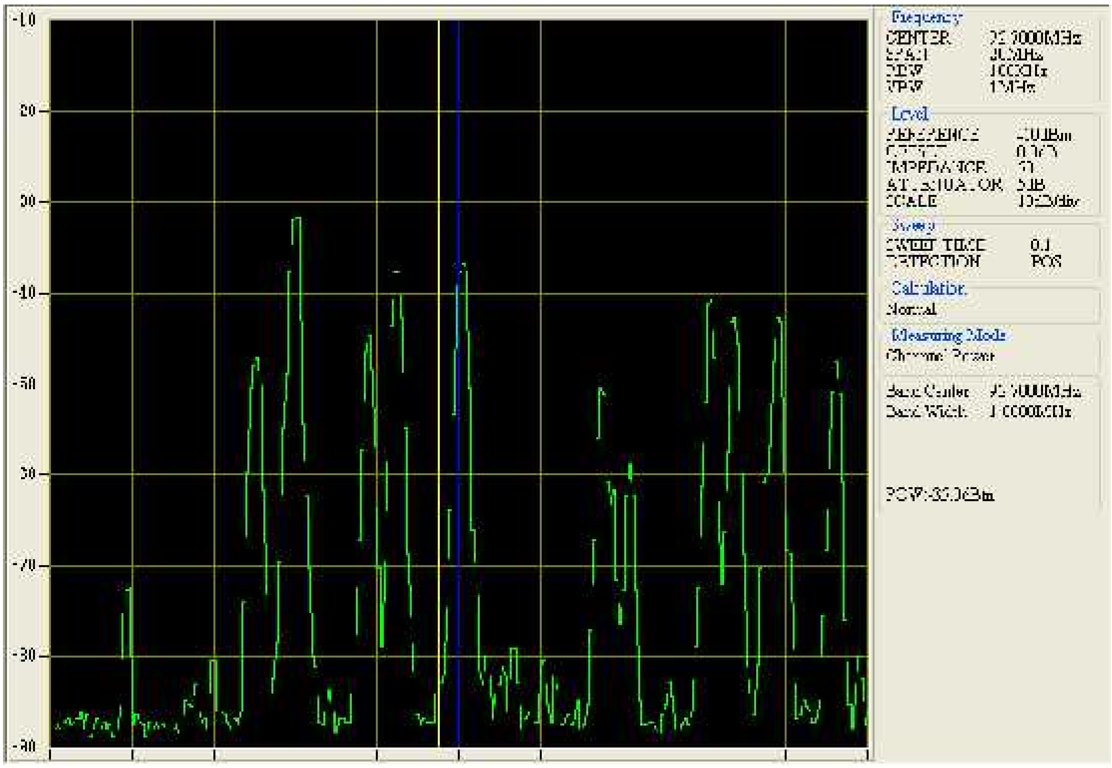
Alhoria FM radio station:



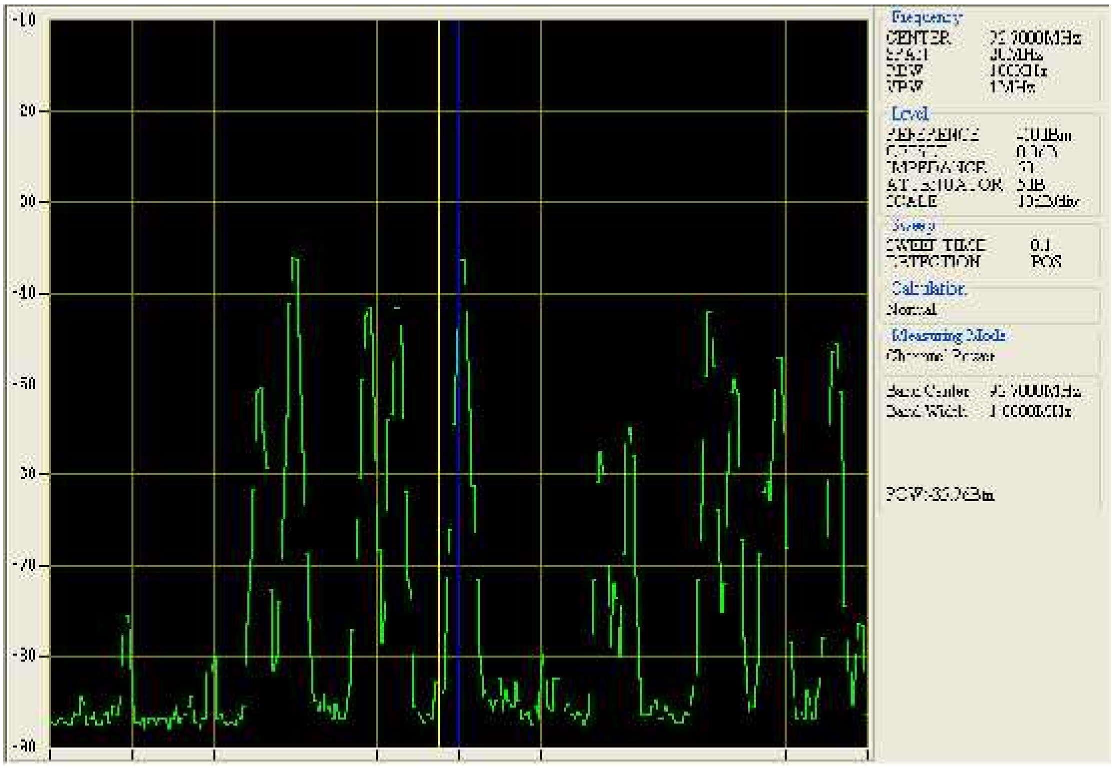
Power measuremen at distance 5m from Al-horia tower in Ras Al-jora



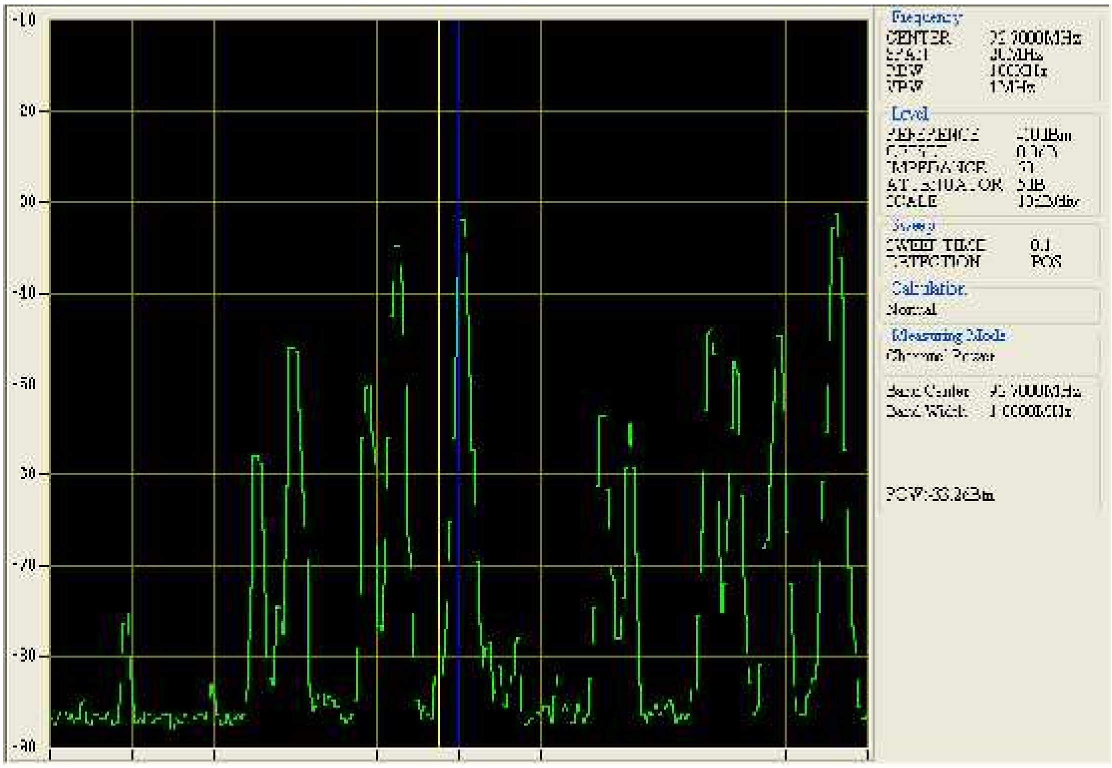
Power measurement at distance 10m from Al-horia tower in Ras Al-jora



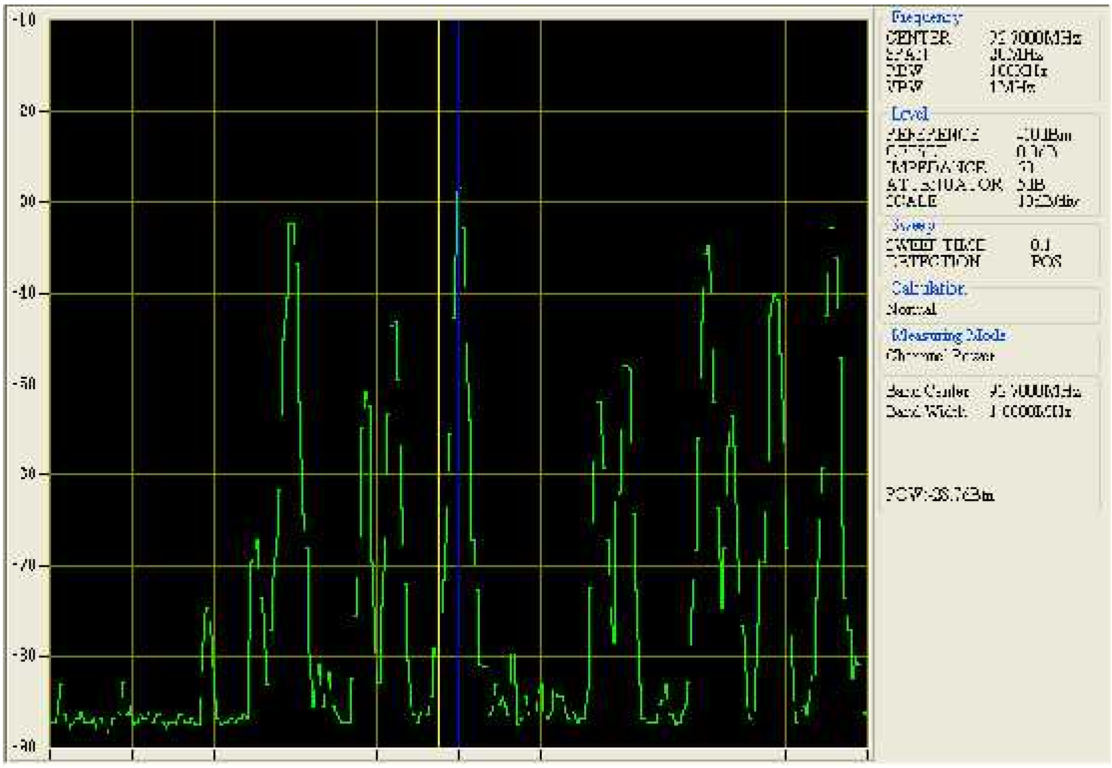
Power measurement at distance 20m from Al-horia tower in Ras Al-jora



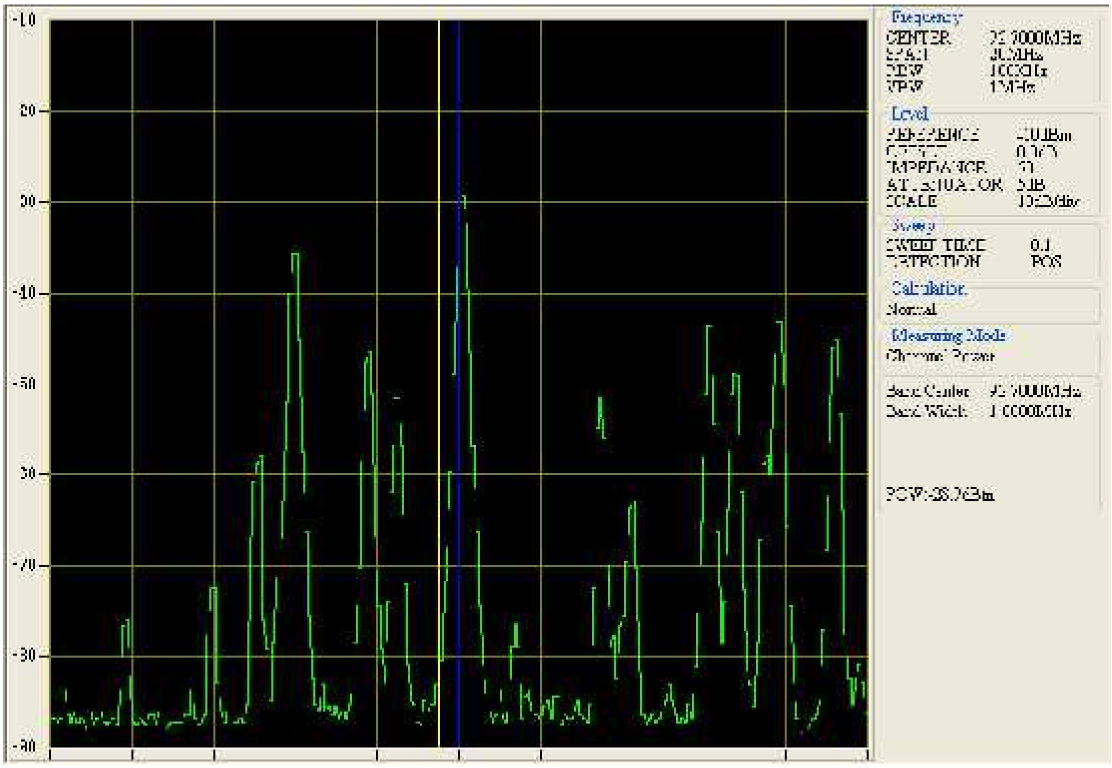
Power measurement at distance 30m from Al-horia tower in Ras Al-jora



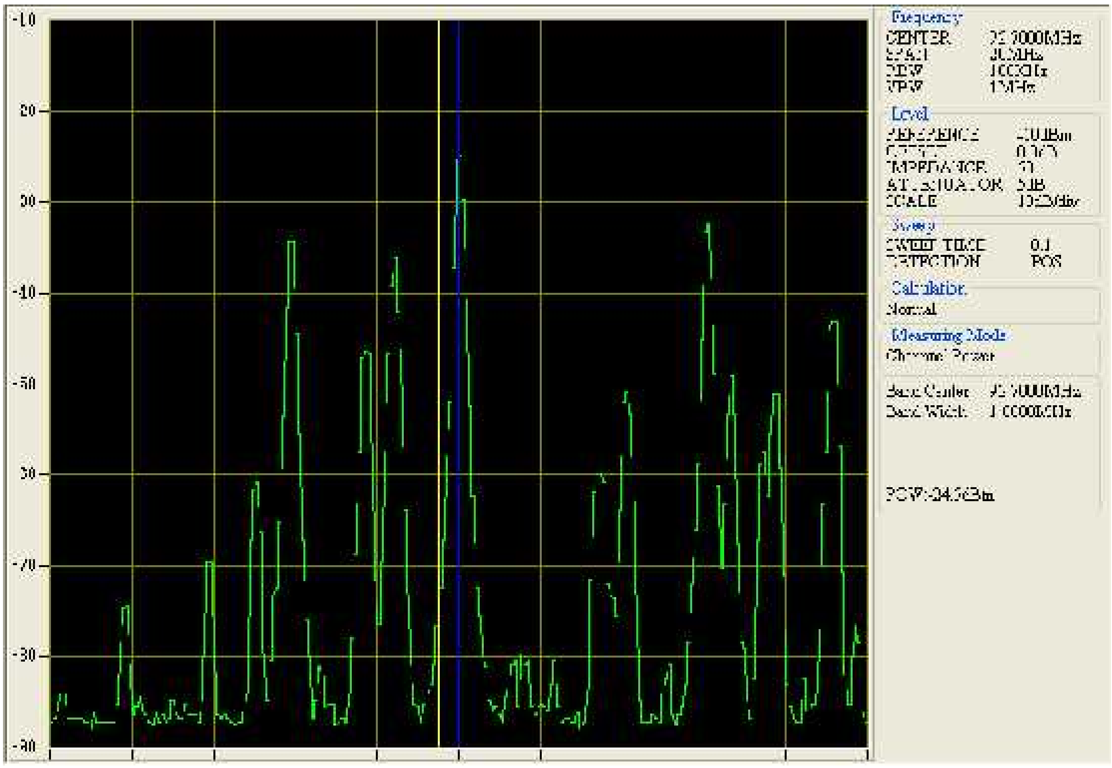
Power measurement at distance 50m from Al-horia tower in Ras Al-jora



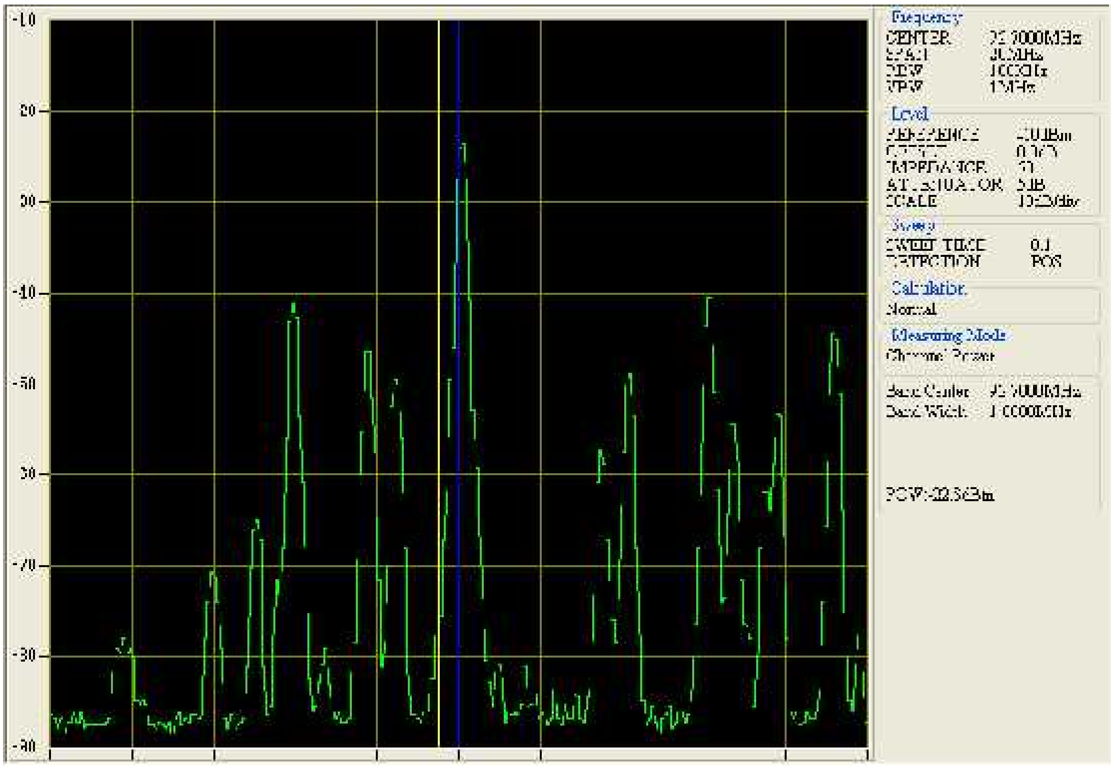
Power measurement at distance 60m from Al-horia tower in Ras Al-jora



Power measurement at distance 70m from Al-horia tower in Ras Al-jora

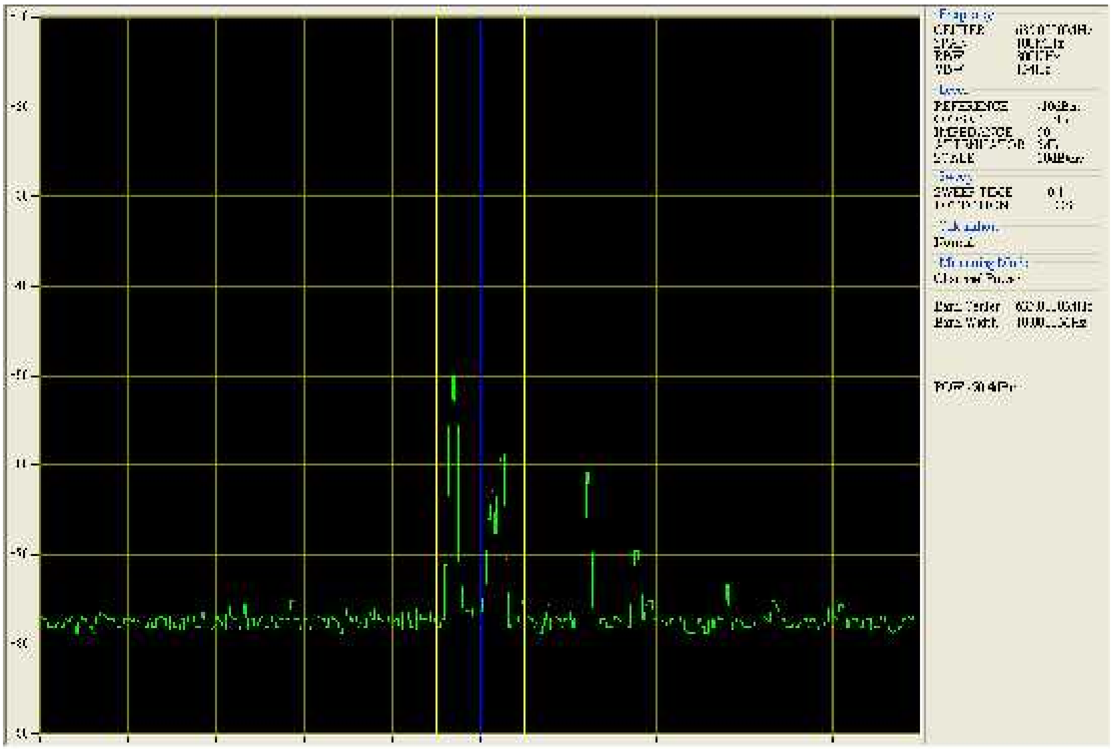


Power measurement at distance 80m from Al-horia tower in Ras Al-jora

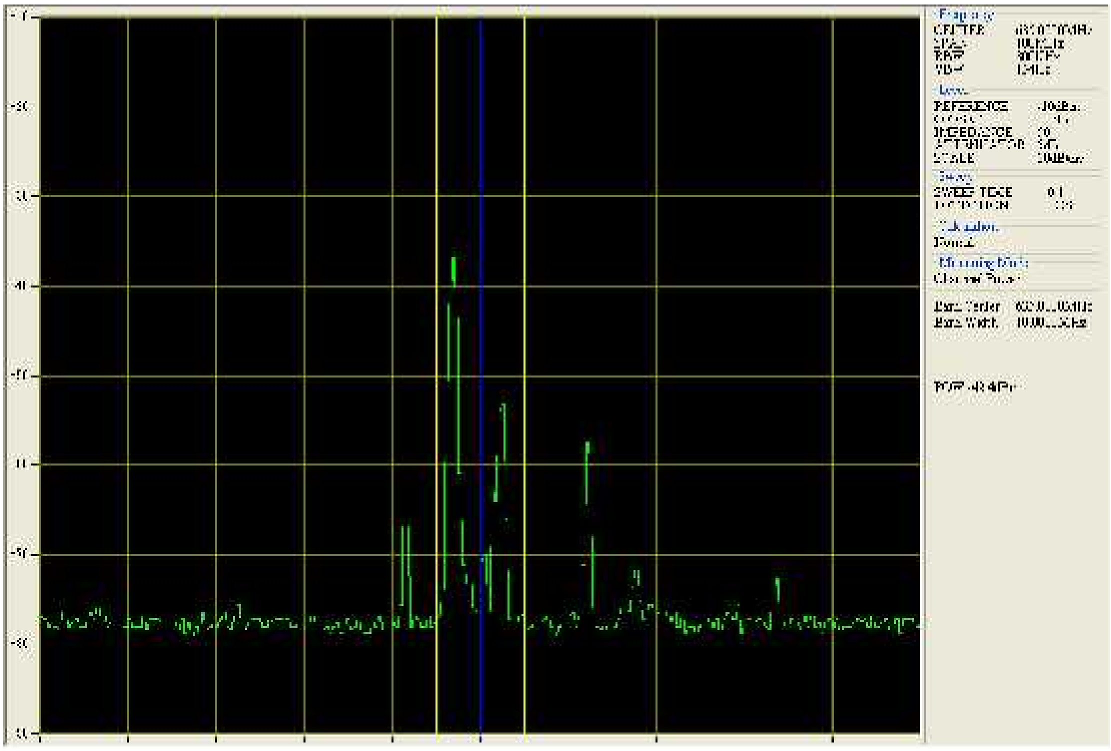


Power measurement at distance 100m from Al-horia tower in Ras Al-jora

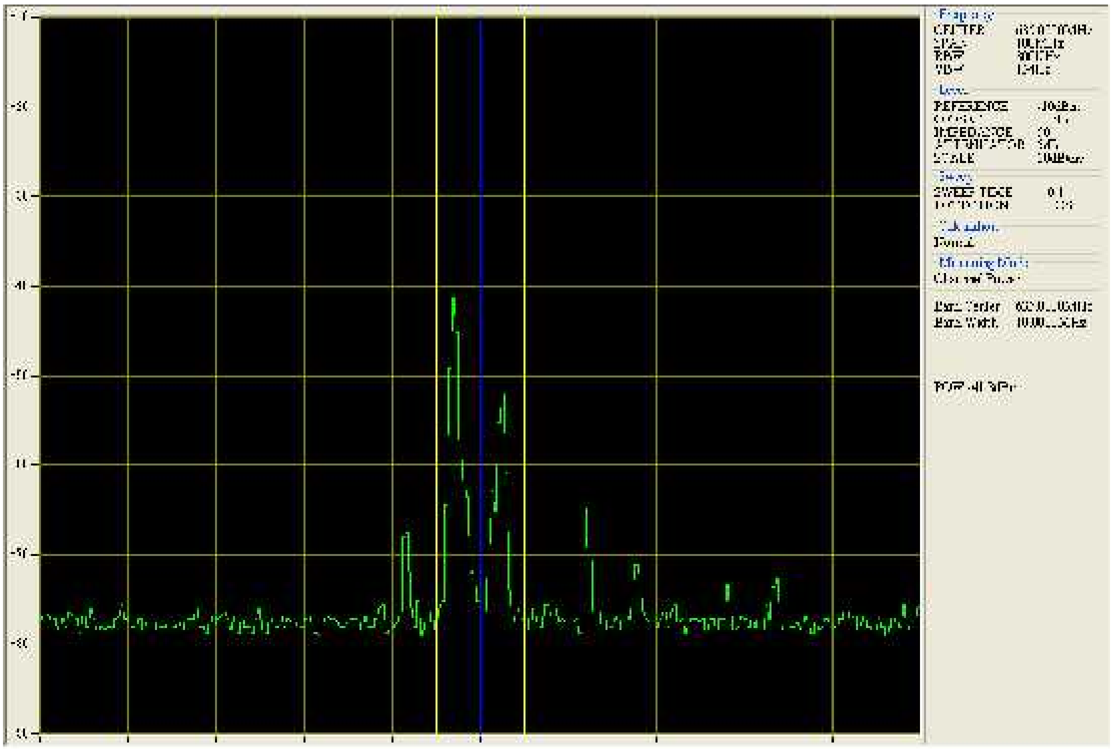
Al-Nawrs TV station:



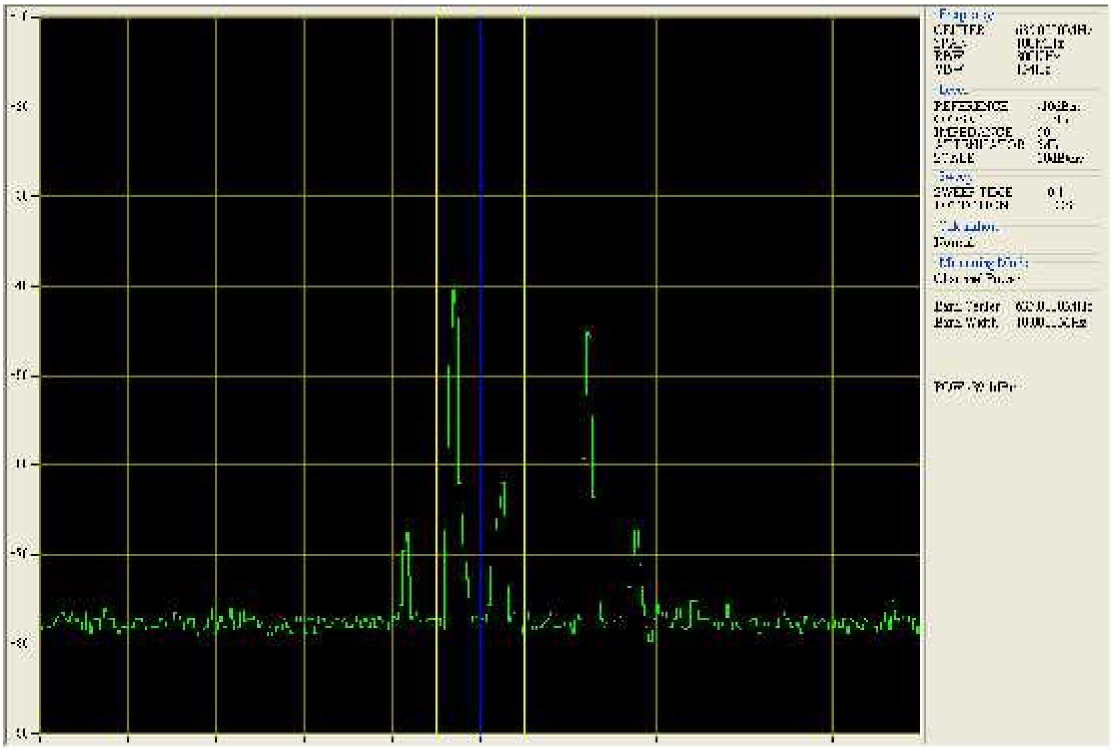
Power measurement for Al-Nawrs TV station at distance 10 m.



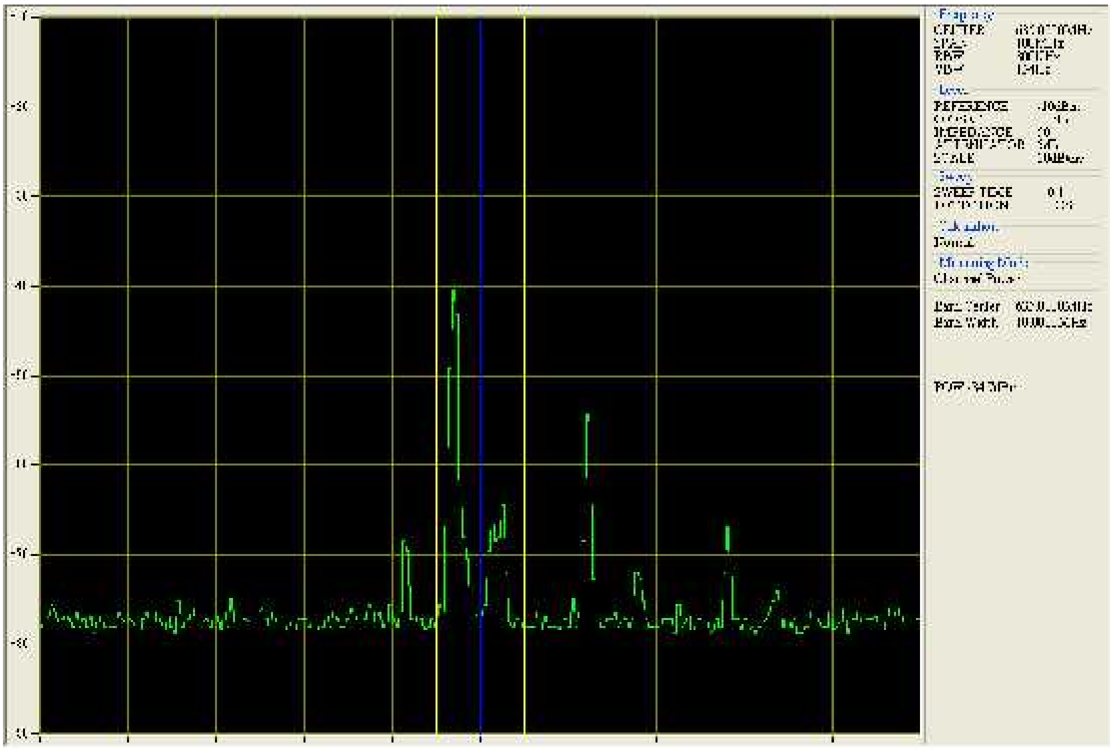
Power measurement for Al-Nawrs TV station at distance 50 m.



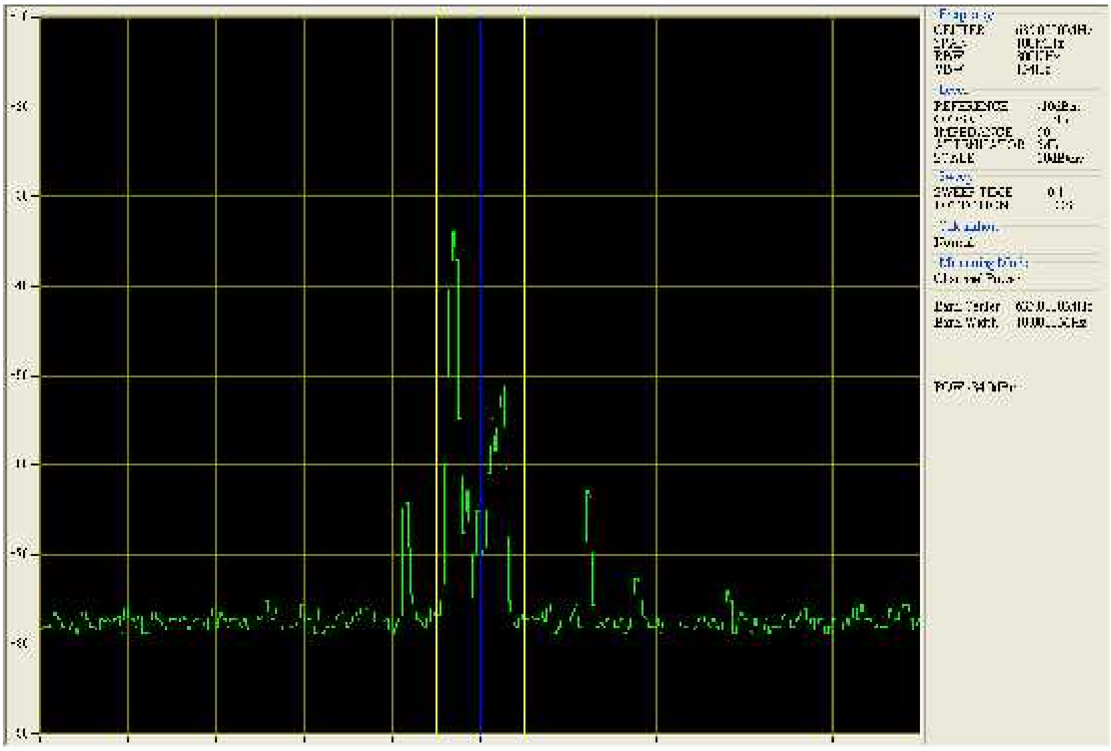
Power measurement for Al-Nawrs TV station at distance 100 m.



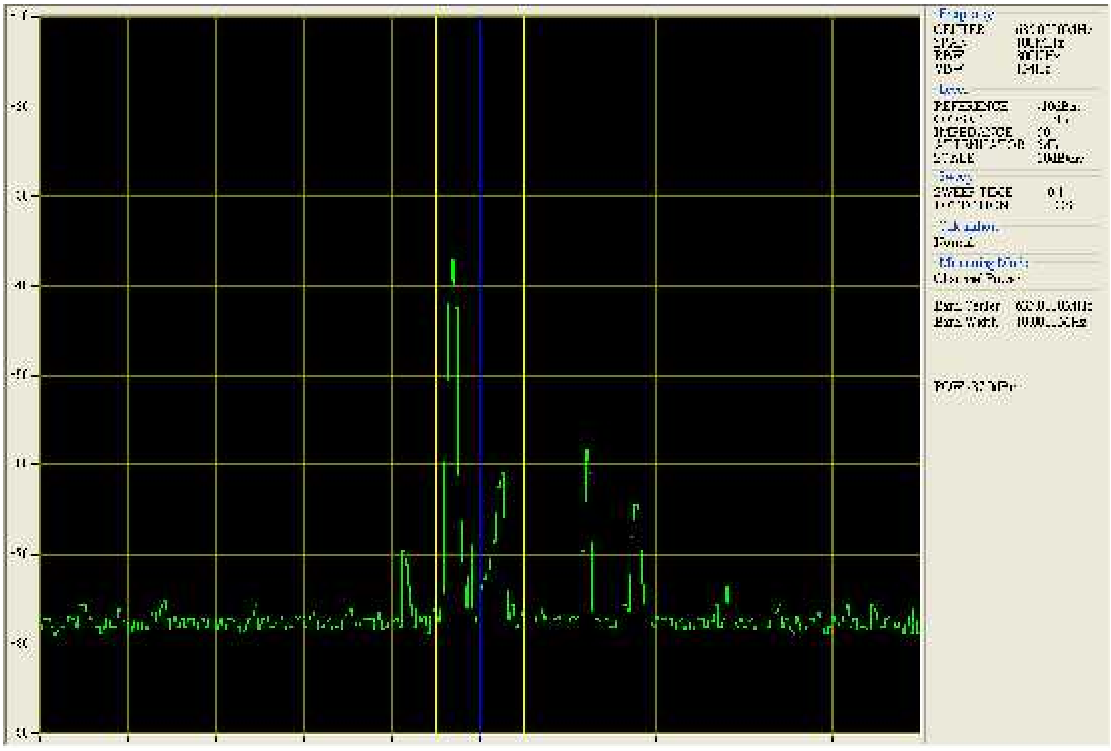
Power measurement for Al-Nawrs TV station at distance 150m.



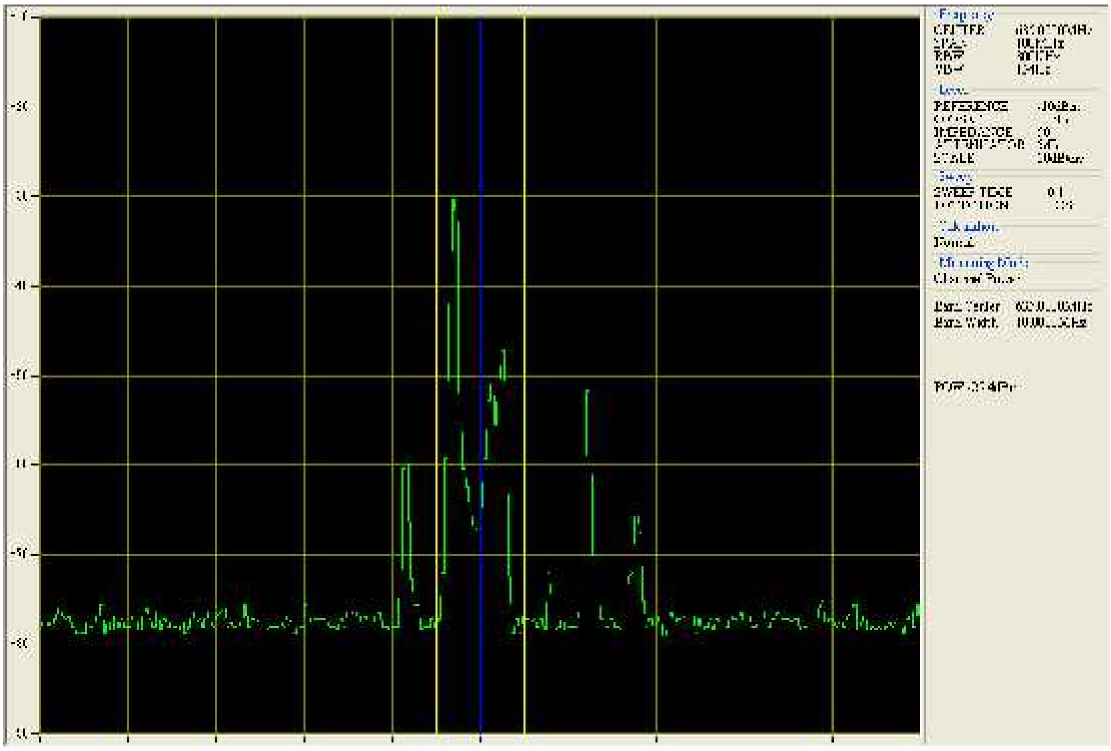
Power measurement for Al-Nawrs TV station at distance 250 m.



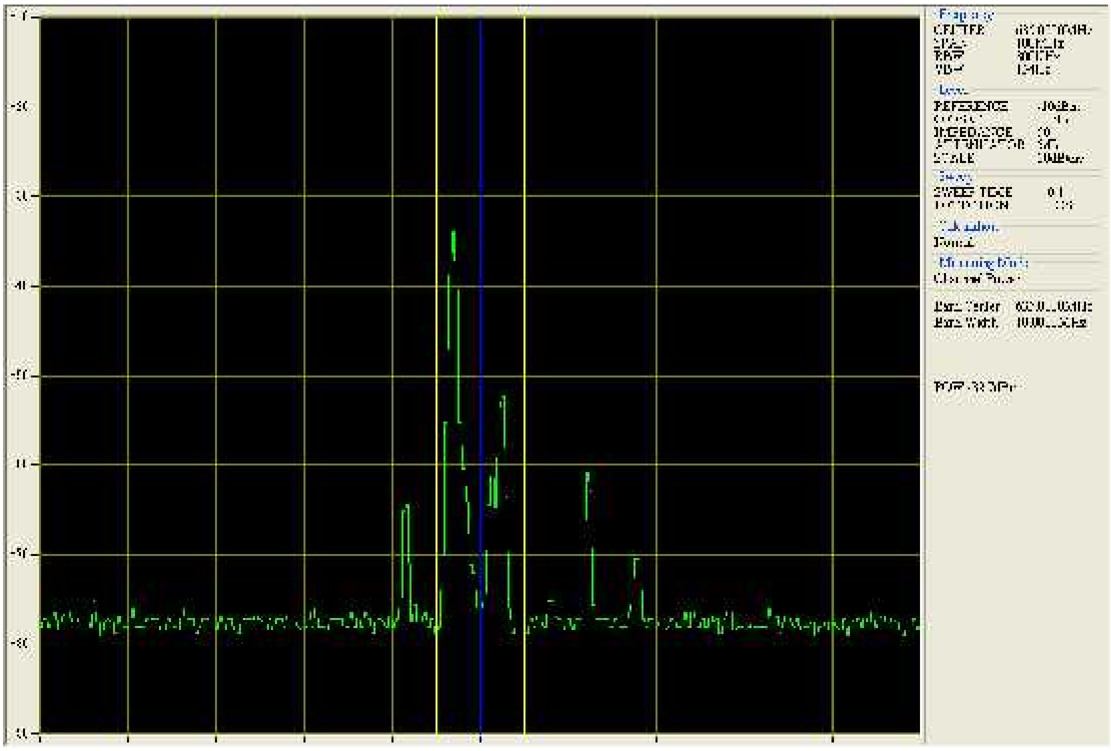
Power measurement for Al-Nawrs TV station at distance 300 m.



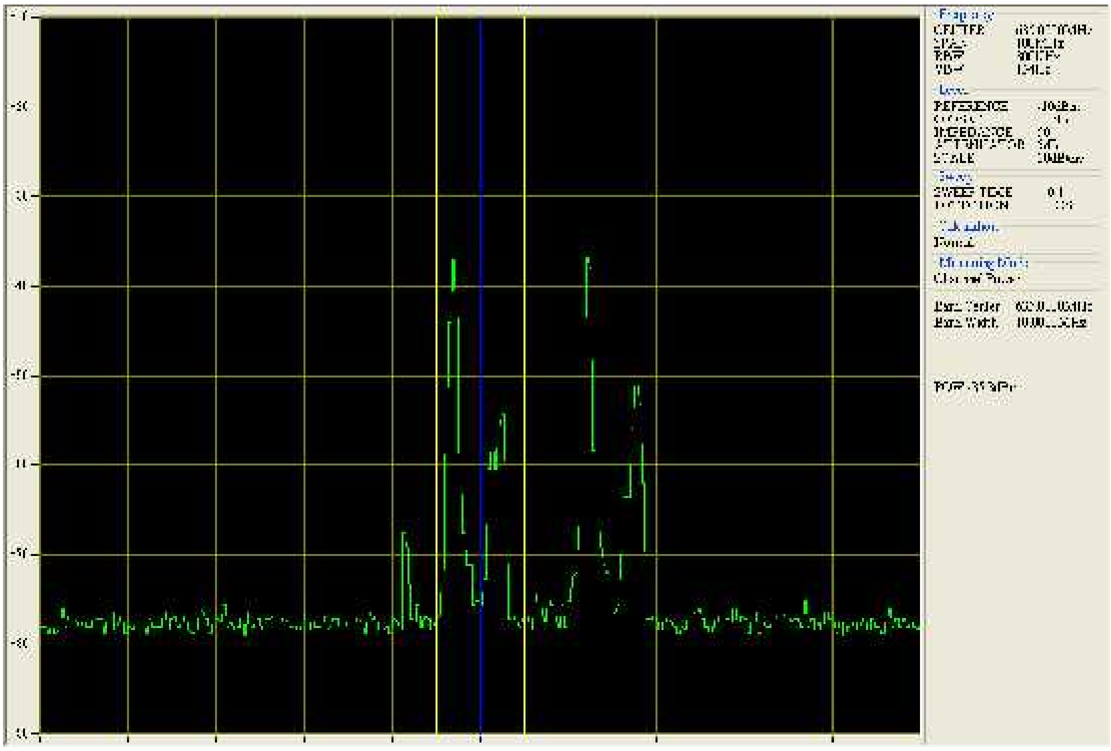
Power measurement for Al-Nawrs TV station at distance 350 m.



Power measurement for Al-Nawrs TV station at distance 400 m.

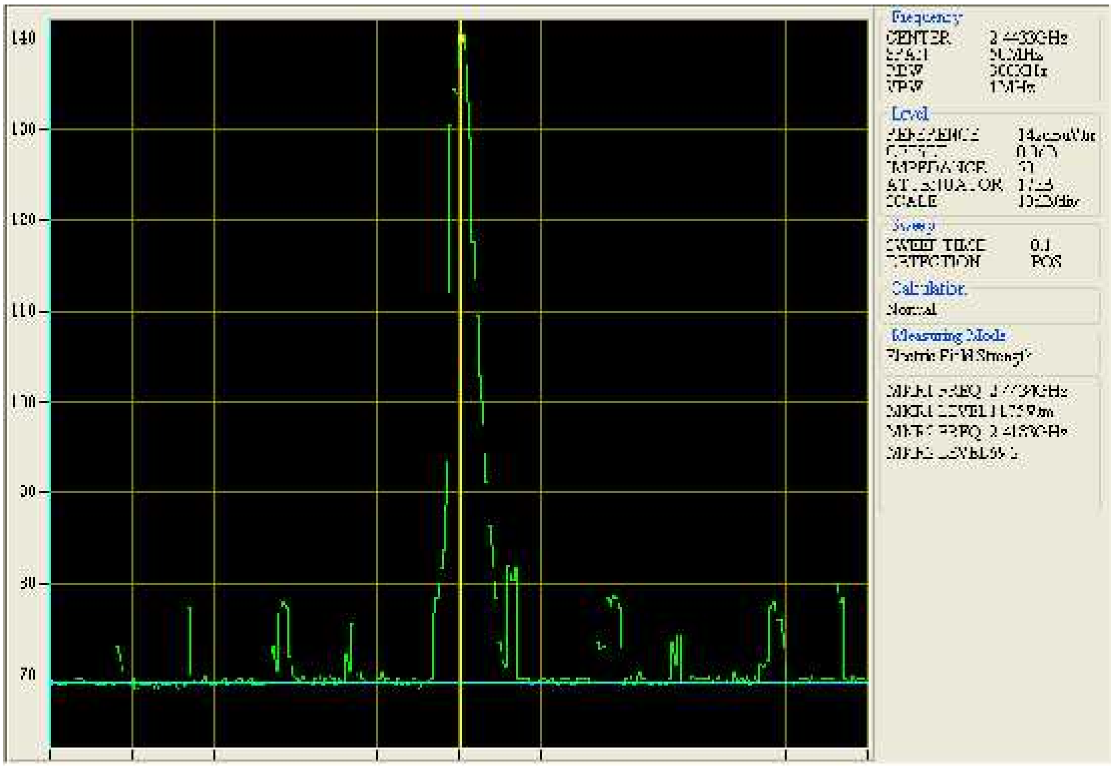


Power measurement for Al-Nawrs TV station at distance 450 m.

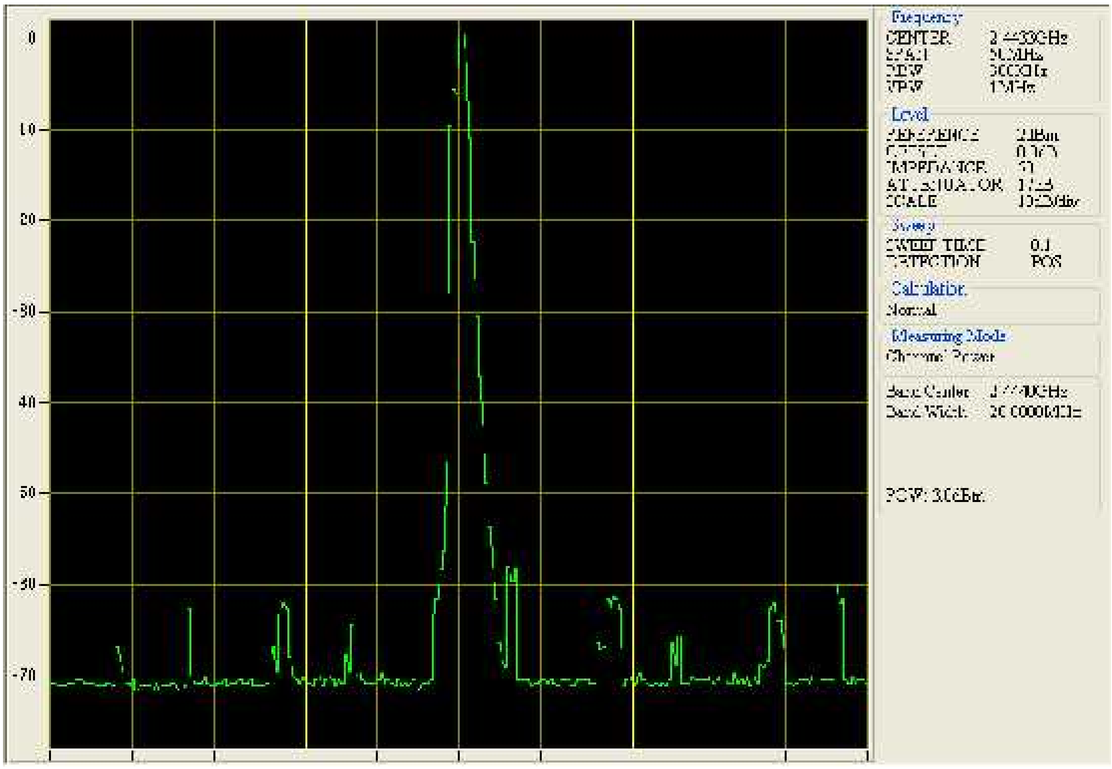


Power measurement for Al-Nawrs TV station at distance 500 m.

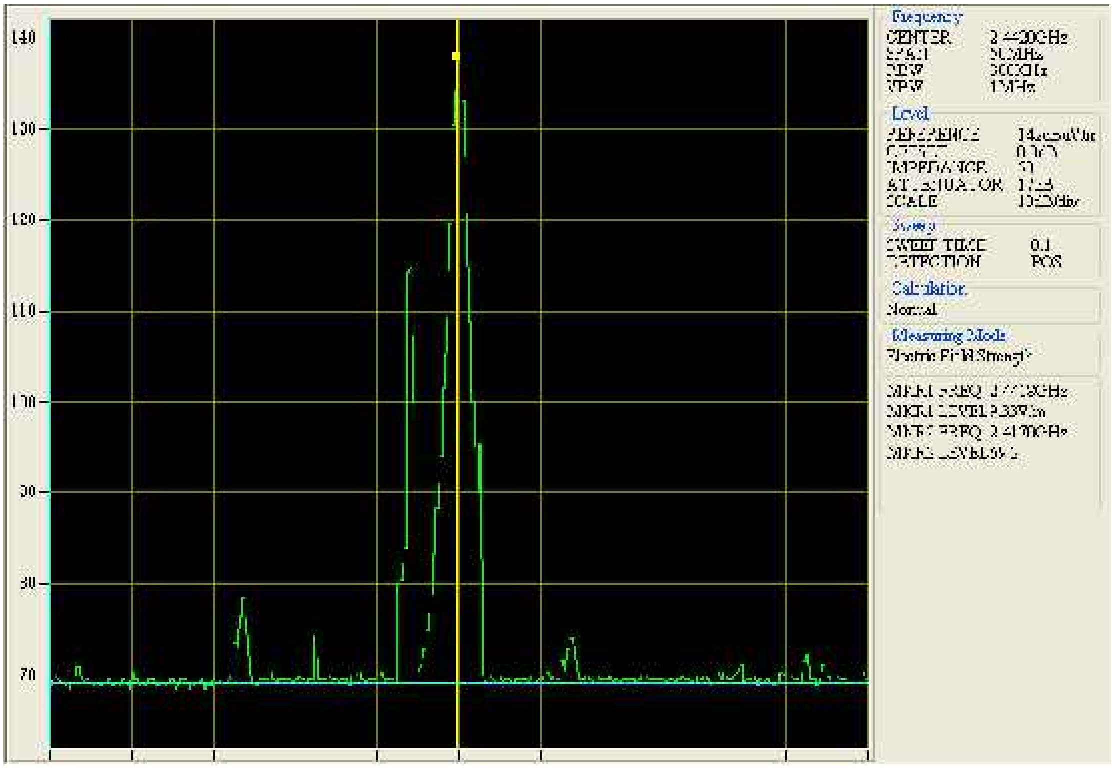
Universal microwave oven:



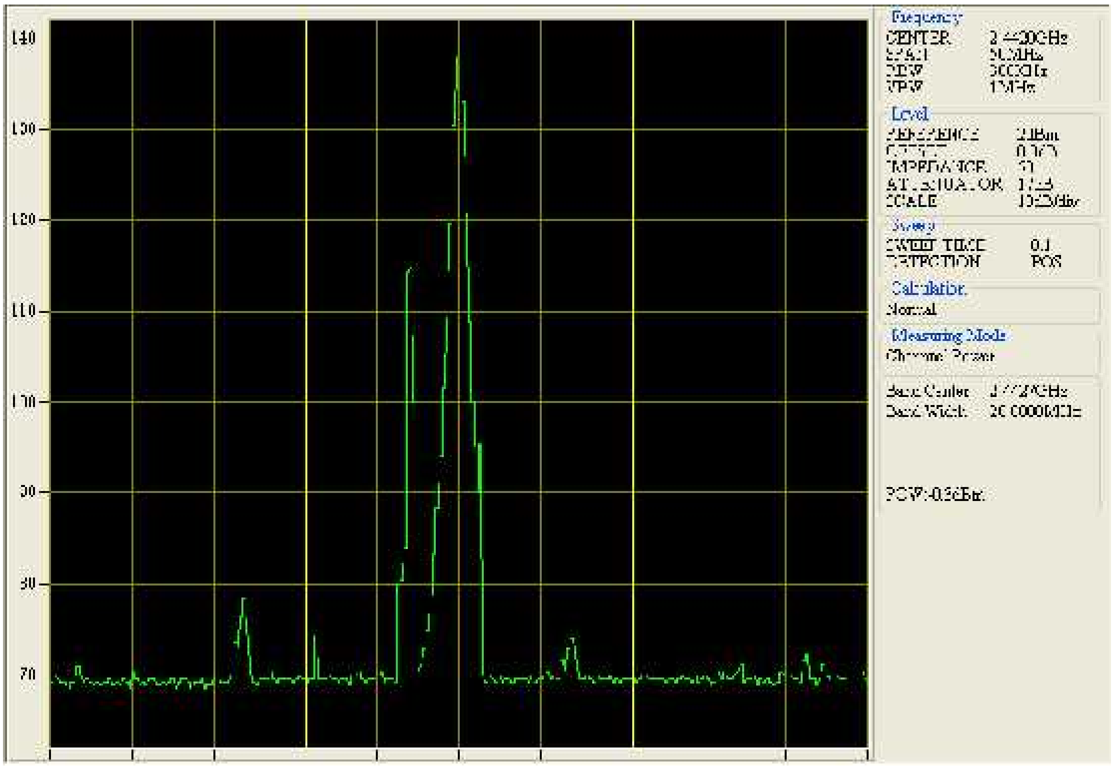
Electric field measurement at distance 1cm away from Universal microwave oven.



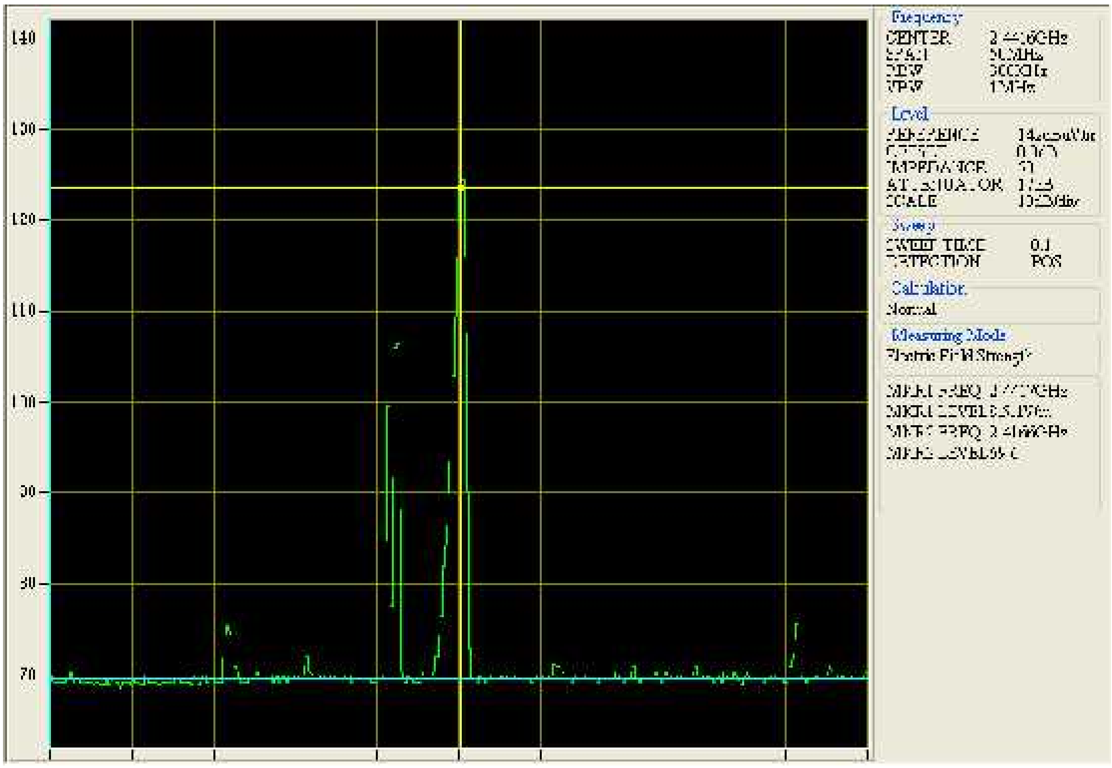
Power measurement at distance 1cm away from Universal microwave oven.



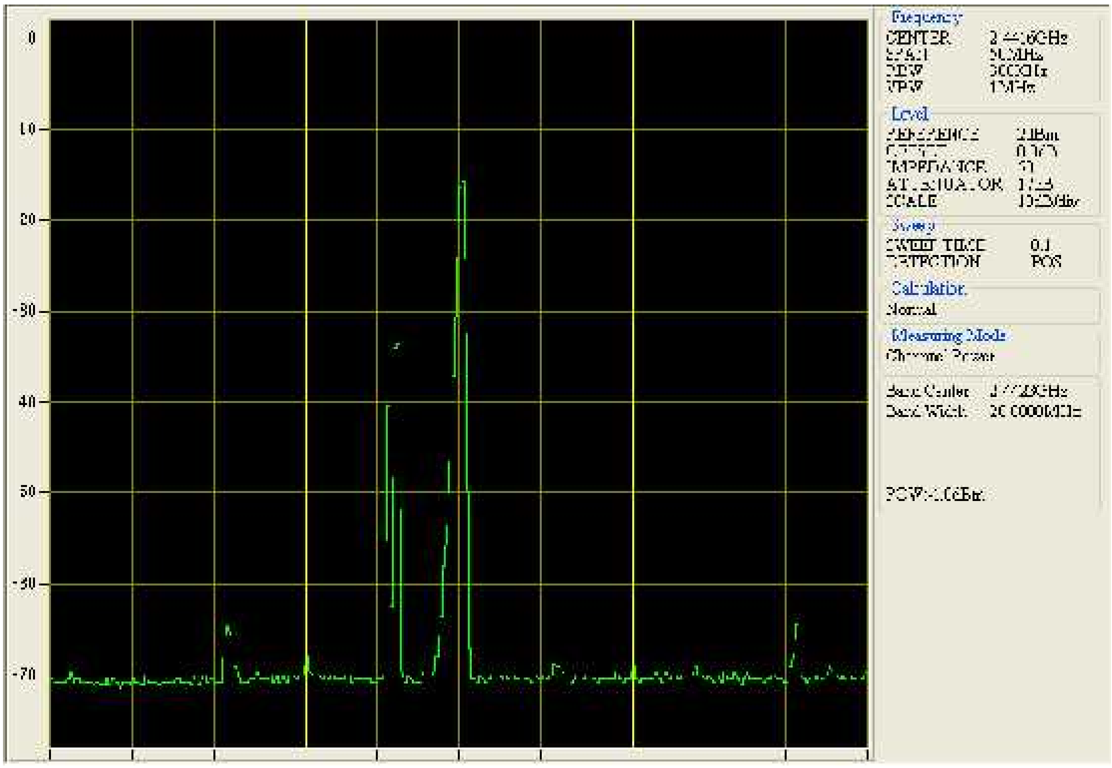
Electric field measurement at distance 10cm away from Universal microwave oven.



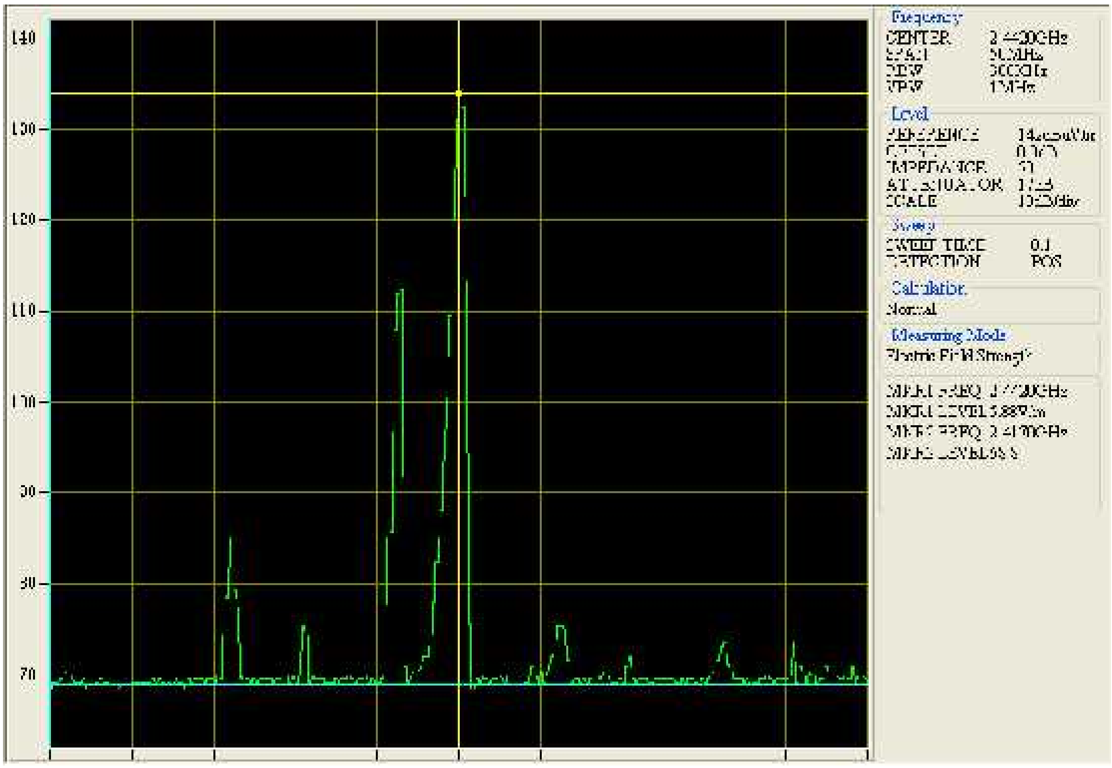
Power measurement at distance 10cm away from Universal microwave oven.



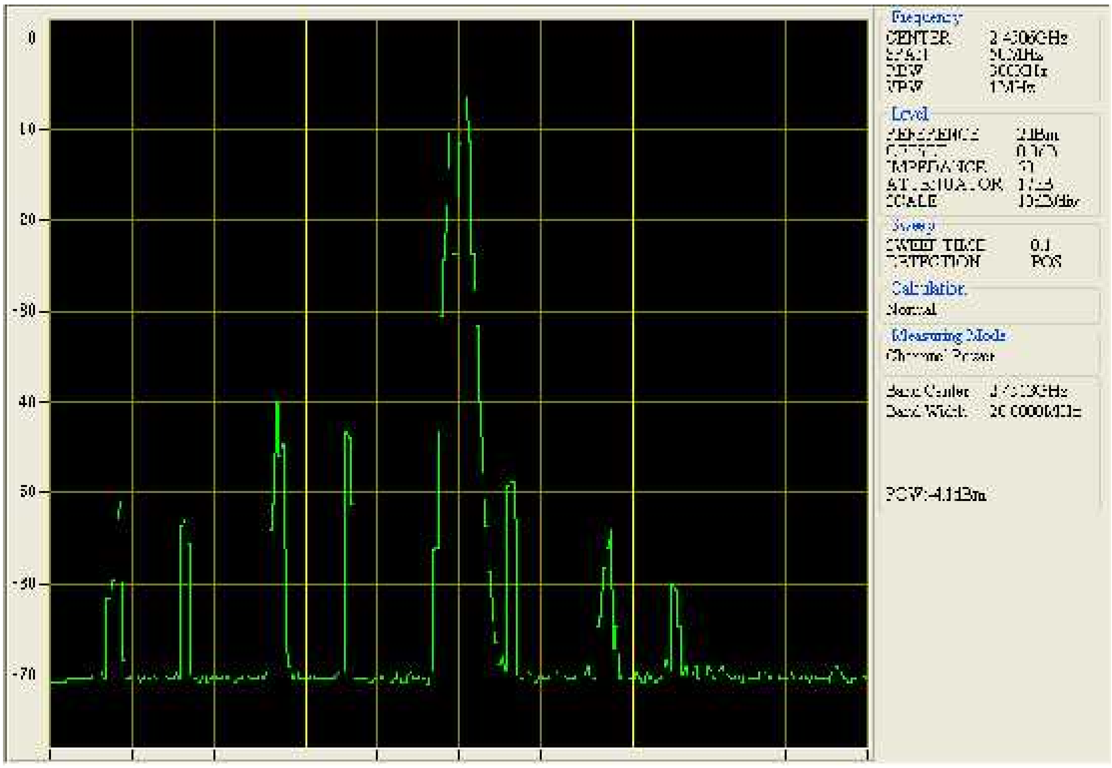
Electric field measurement at distance 20cm away from Universal microwave oven.



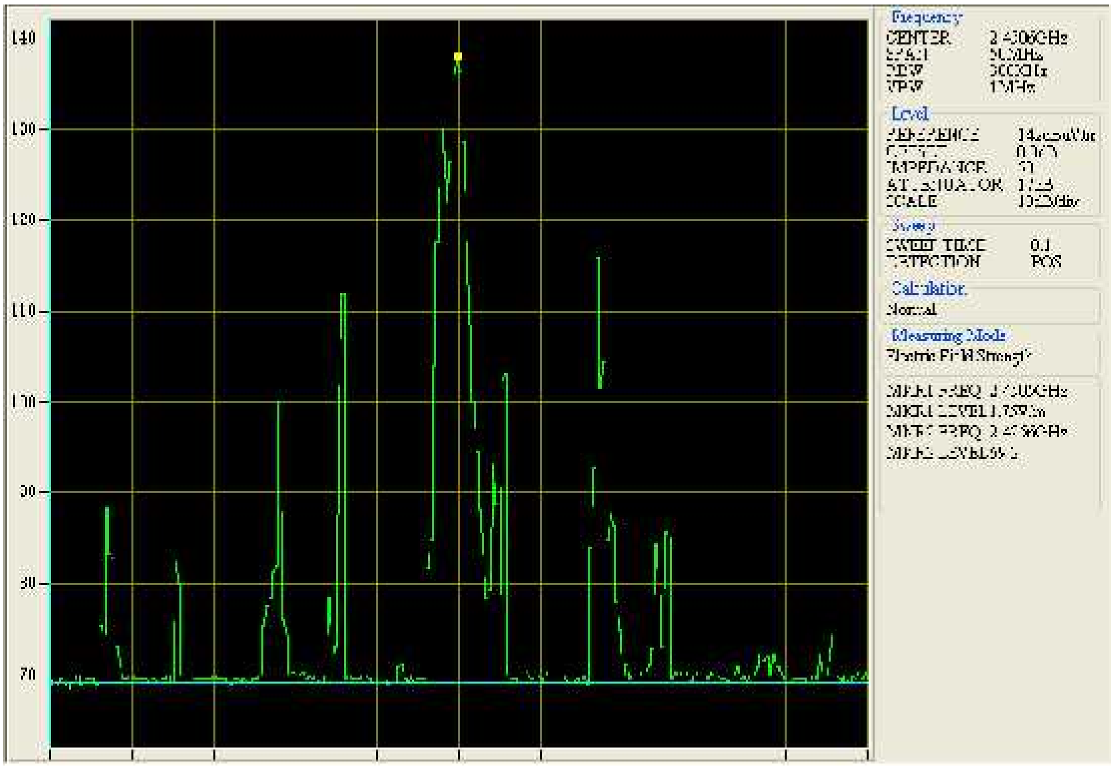
Power measurement at distance 20cm away from Universal microwave oven.



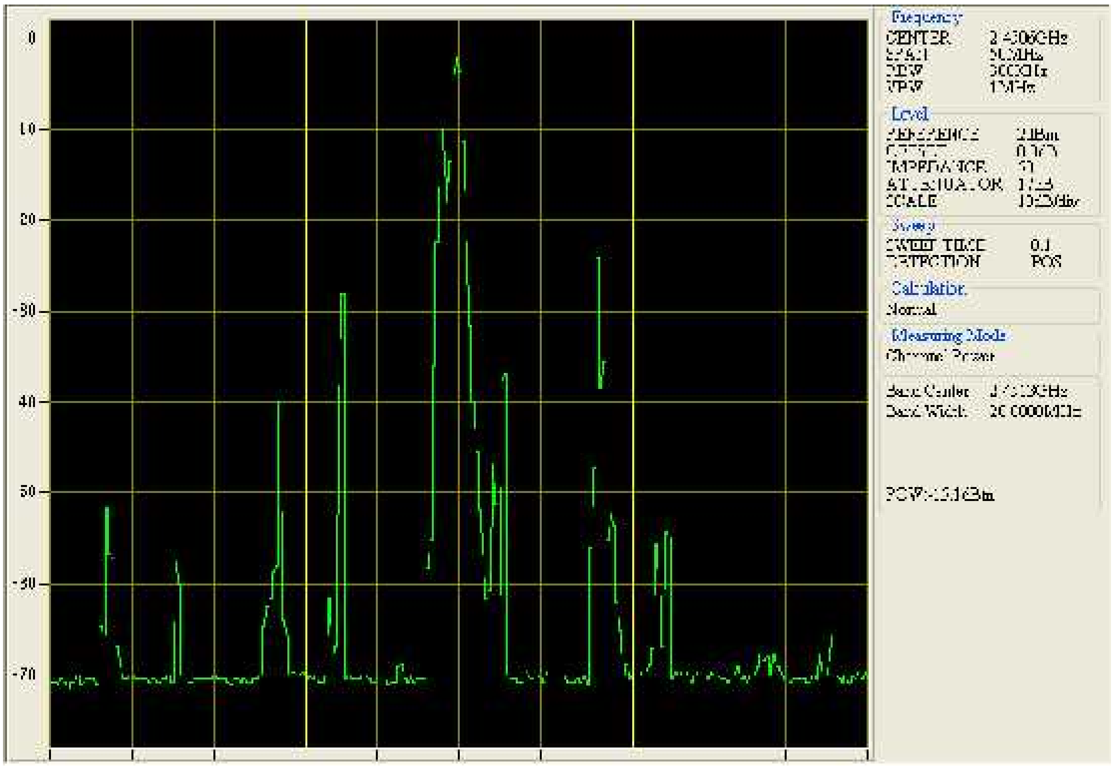
Electric field measurement at distance 30cm away from Universal microwave oven.



Power measurement at distance 30cm away from Universal microwave oven.



Electric field measurement at distance 50cm away from Universal microwave oven.



Power measurement at distance 50cm away from Universal microwave oven.

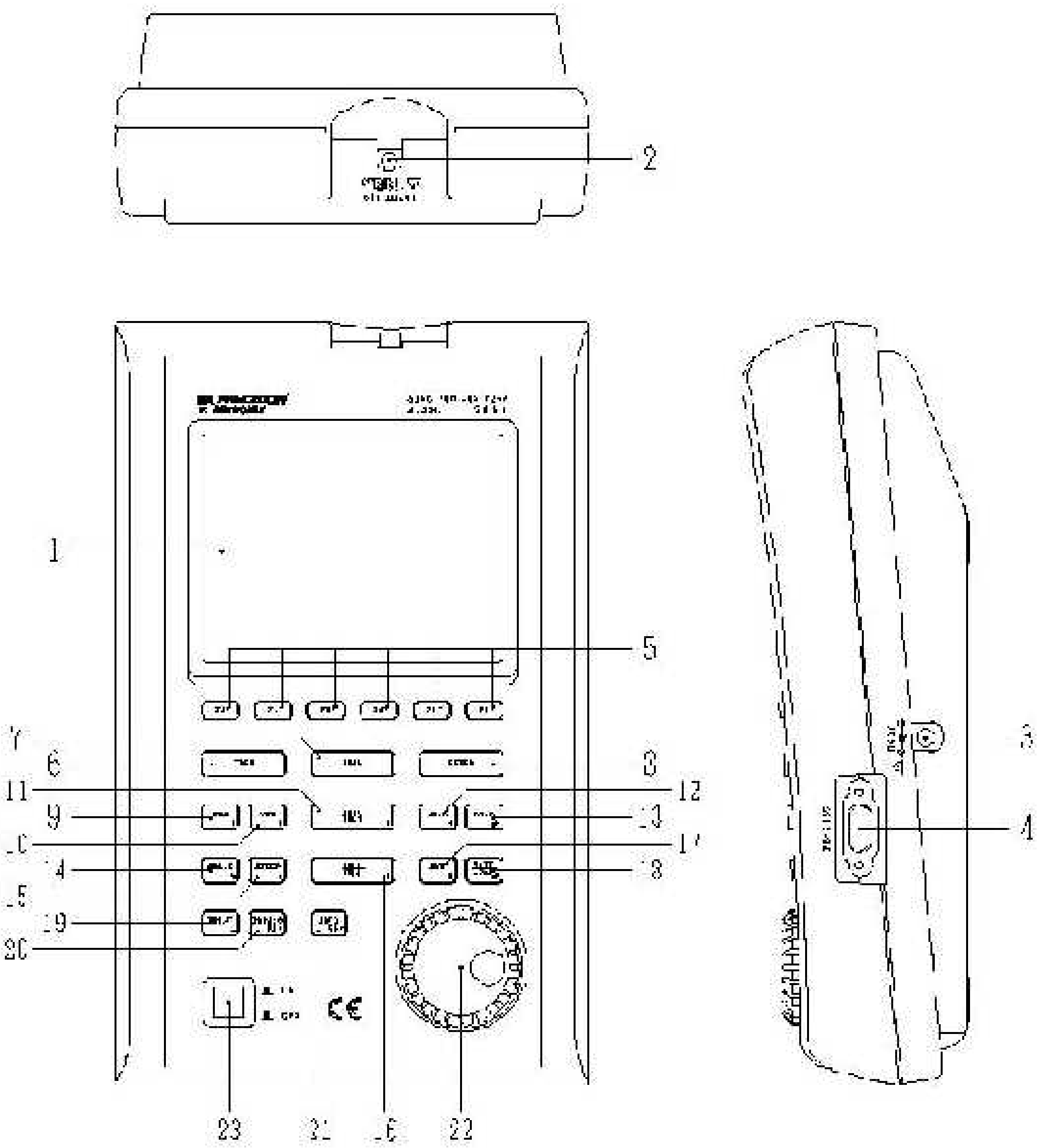
Appendix-B

Spectrum Analyzer 2650

2650 is a handheld spectrum analyzer ideal for the evaluation of W-CDMA, CDMA, GSM, PDC, PHS, Wireless LAN, 802.11 and Bluetooth systems. It was designed to be the most cost effective spectrum analyzer for quick and easy high-precision signal measurements.

Features:

- Channel power measurement.
- Measuring frequency range from 50KHz to 3.3GHz..
- Adjacent channel power measurement
- Occupied bandwidth measurement
- Electric field strength measurement (with optional dipole antennas)
- Magnetic field strength measurement (with optional PR 26M)
- Min/Max hold
- Average and over write mode
- Marker measurement
- Switchable 50 or 75 ohm input impedance
- Peak search
- Auto tuning
- Auto range
- Save/Load
- Hard copy of display (with optional PT 2650)



1) LCD screen
This is a large liquid crystal display with 240 (V) × 320 (H) dots. It simultaneously displays traces (8 div× 10 div), various setting values, measured values, etc.

2) Input connector
SMA (J) connector.

3) Input connector for DC power source
Connects AC adaptor BC2650.

4) RS-232C connector
Connects PC and printer, by using RS-232C cable.

5) Function keys (F1 to F6)
Functions change according to operation. Have functions corresponding to the on-screen displays.

6) Center frequency key

2650: Use this key to set the center frequency. It can set between 0 to 3.3GHz (100kHz step).

7) Frequency span key
2650: Use this key to set the frequency span. It can set between 200kHz to 2GHz, ZERO SPAN and FULL SPAN (3.3GHz).

8) Reference level key
Set the reference level, etc. Reference level can set between +10dBm and -60dBm (1dB step).

9) Resolution bandwidth key
Use this key to set the resolution bandwidth. It can set between 3kHz and 3MHz.

10) Video bandwidth key
Use this key to set the video bandwidth. It can set between 100Hz and 1MHz.

11) AUTO tuning key
Tune up to the maximum level in 3.3GHz zones, and display by the optimal setup. This does not operate normally when the signal level is lower than -40dBm , or when the input frequency is below 50MHz, or when the frequency span is ZERO SPAN or FULL SPAN.

12) Measuring function key
Available for Channel power, Adjacent channel leakage power, Occupied frequency bandwidth, Electric field strength and Magnetic field strength measurement (optional).

13) Calculation function key
Available for Max hold, Min hold, Average and Over write.

14) Display scale key
Use this key to select the display scale of amplitude axis from 2dB/div or 10dB/div.

15) Sweep key
Use this key to set the sweep time between 10ms to 30s or set the detection mode.

16) Hold/Run key
Stops or restarts the measurement.

17) Marker & Peak search key
Use this key to set and move a marker.

18) Save/Load key
Saves 100 traces and 100 setups, and loads 1trace and 1setup.

19) Print key
When pressing this key, the image is printed with a printer PT 2650 (optional) as it is.

20) RS-232C key

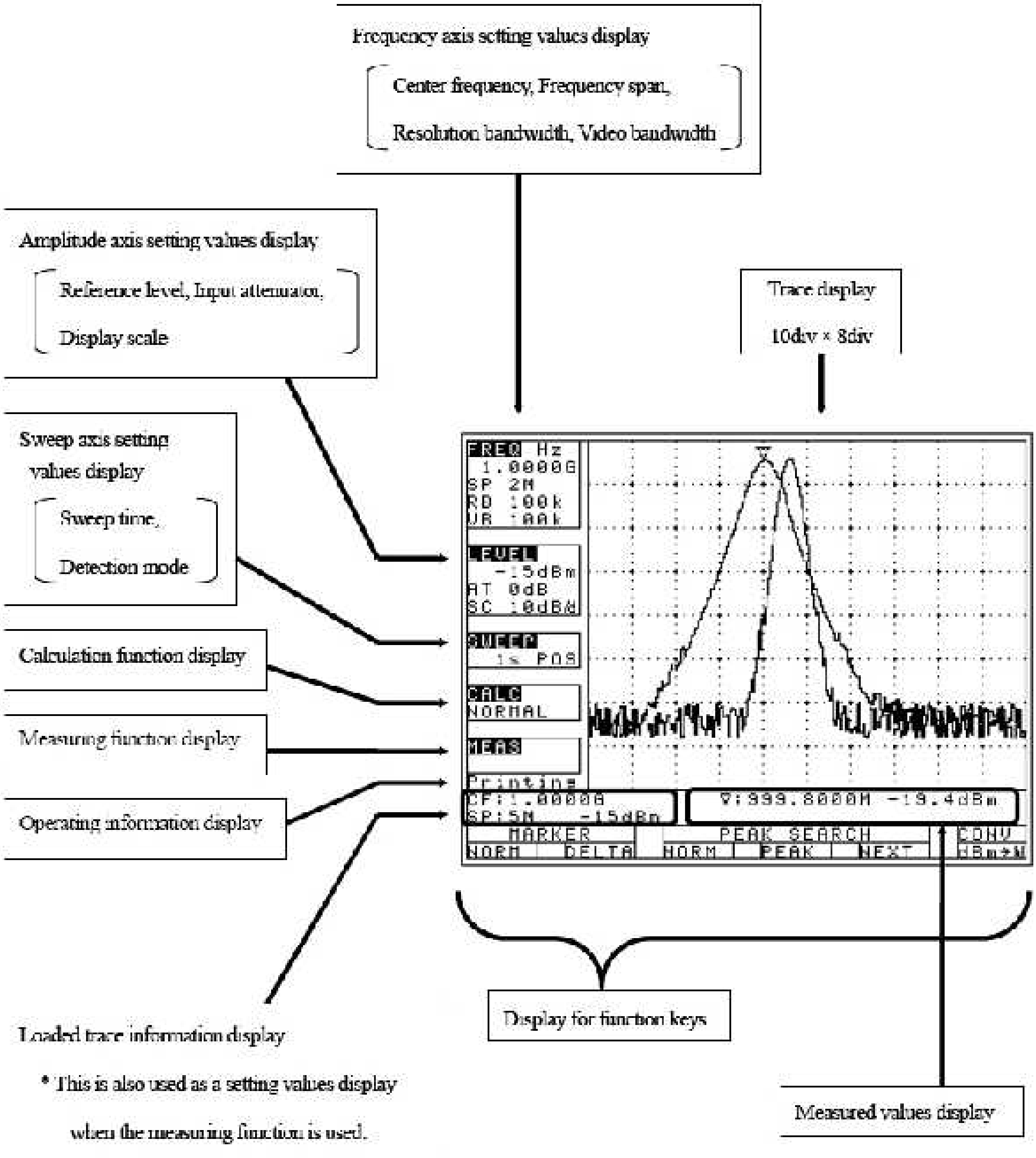
Sets baud rate and transfers a current or saved trace.

21) Display control key
Sets contrast, backlight ON/OFF, brightness of backlight, invert display and buzzer ON/OFF.

22) Rotary encoder
Use this to make various settings.

23) Power switch
Use this to turn the power ON or OFF.

- **Description of the screen:**



Frequency Section	
Frequency Range	50KHz to 3.3GHz
Center Frequency	
Setting Resolution	100KHz, Allows rotary encoder, numeric keys and function keys
	(up and down) for setting CF.
Accuracy	< +(30+100T)KHz @ 200KHz to 10MHz span
	< +(100+700T)KHz @ 20MHz to 3.3GHz span
	at 23ºC (+5ºC), T = sweep time(s)
Frequency Span	
Setting Range	0Hz (zero span), 200KHz to 2GHz (1-2-5 steps) and 3.3GHz (full span)
Accuracy	less than +3% @ 23ºC (+5ºC)
Resolution Bandwidth	3dB bandwidth
Setting Range	3KHz to 3MHz (1-3 step) and AUTO
Accuracy	less than +20%
Selectivity	1:12 (nominal) @ 3dB:60dB
Video Bandwidth	100Hz to 300KHz (1-3 step), OFF and AUTO
SSB Phase Noise	-90dBc/Hz (typical) @ 100KHz offset
Spurious Response	less than –60dBc
Amplitude Selection	
Reference Level	
Setting Range	+10 to –40dBm in 1dB step
Accuracy	less than +0.8dB @ RBW:3MHz, VBW:OFF, ATT:0dB, 23ºC (+5ºC)
Unit	dBm, dBV, dBmV, dB mV
Average Noise Level	-110dBm (typical) @ RBW:3KHz, VBW:100Hz
Input Impedance	50W
Input VSWR	less than 2.0
Input Attenuator	
Operating Range	0 to 25dB @ 1dB step coupled with reference level
Switching Error	less than +0.6dB
RBW Switching Error	less than +0.6dB
Display Scale	
Scale	10dB/div, 2dB/div
Accuracy	less than +0.8dB/10dB
	less than +0.2dB/2dB
	less than +1.6dB/70dB
Input Damage Level	+23dBm (CW average power), 25VDC
Input Connector	SMA(J)
Sweep Section	
Sweep Time	
Setting Range	10ms to 30s (1-3 step) and AUTO
Accuracy	less than +0.1% (less than +1.5% @ full span)
Trigger Mode	AUTO @ zero span
Detection Mode	Positive peak, Negative peak, sample

B&K Precision Corporation
22820 Savi Ranch Parkway, Yorba Linda, CA 92887
Tel: 714-921-9095, Fax: 714-921-6422
www.bkprecision.com

BK PRECISION
ELECTRONIC TEST INSTRUMENTS

Appendix-C

<u>EMR-21C E-Field Measurement Systems</u>

EMR-20C and EMR-21C

E-Field Measurement Systems

- **100 kHz to 3 GHz**
- **0.6 to 800 V/m (-20C)**
- **0.2 to 320 V/m (-21C)**
- **Completely Automatic Zeroing**
- **Easy-to-Use Design**
- **Lightweight and Rugged**
- **Cost Effective**
- **Isotropic Detection**
- **24 Month Calibration Interval**

Description

The EMR-20C and –21C are complete systems that consist of a meter and probe, along with a charging system for the NiCad batteries.

The EMR-20C and EMR-21C are supplied with a calibrated Type 8 probe that provides coverage for many industrial systems operating at 915 and 2450 MHz, as well as measuring extremely low field levels. Users appreciate the wide measurement range and extreme ruggedness of this multi-purpose survey system. The EMR-20C and -21C have even been designed to withstand drops from two meters directly on the sensor head!

Operation of this series of survey systems could not be any easier. All you need to do is connect the probe and turn on the meter. The system automatically detects the probe and auto-zero's the system – even while immersed in an RF field environment. Electric field readings are displayed in units of V/m, W/m^2 and mW/cm^2, with over 62 dB of measurement range, without touching a button!

Both the EMR-20C and -21C feature a bi-directional fiber-optic link. With the optional software and cables, real-time readings can be displayed on a personal computer.

Specifications

	EMR-20C	EMR-21C
Frequency Range	100 kHz to 3 GHz	
Field Measured	E-Field Only, Isotropic Detection, Diode Sensor	
Measurement Range	0.6 to 800 V/m (CW signals > 300 kHz) 0.6 to 20 V/m (True RMS)	0.2 to 320 V/m (CW signals > 300 kHz) 0.2 to 10 V/m (True RMS)
Measurement Resolution	0.01 V/m	
Overload Levels	700 mW/cm²(CW) 70 W/cm²(Peak)	175 mW/cm²(CW) 17.5 W/cm²(Peak)
Absolute Error	±1 dB (27.5 V/m and 27.12 MHz)	
Linearity Error[a]	0.6 to 1.25 V/m = ±3dB 1.25 to 2.5 V/m = ±1 dB 2.5 to 400 V/m = ±0.5 dB 400 to 800 V/m = ±0.7 dB	0.6 to 1.2 V/m = ±1dB 1.2 to 200 V/m = ±0.5 dB 200 to 320 V/m = ±0.7 dB
Frequency Response Error[b]	100 kHz to 100 MHz = ±0.45 dB 100 MHz to 3 GHz = ±1.4 dB	
Isotropic Deviation (Typical)	Field probe only = ±0.5 dB for Freq. > 1 MHz Complete system = ±1.0 dB for Freq. > 1 MHz	
Temperature Error	+ 0.2 / - 1.0 dB (0 to +50°C)	
H-field Immunity	100 kHz to 5 MHz = >35 dB – 20 dB x log f (f in MHz) Above 5 MHz = > 20 dB (Typical)	>20 dB Typical
Settling Time	1 second (0 to 90% of measured value) Typical	
Display Refresh Rate	400 msec. Typical	
Units Displayed	V/m, A/m, mW/cm², W/m²and "% of limit value"	
Levels Displayed	Current reading, maximum reading or average reading	
Audible Alarm	Variable setting, piezoelectric	
Interfaces	Fiber Optic, serial interface for results transfer, remote operation and calibration	
Power Supply	Rechargeable AA batteries (supplied)	
Operating Temperature	0 to +50°C	
Size (H x W x D, approx.)	18.3" x 3.78" x 2.52" (465 x 96 x 64 mm)	
Weight (approx.)	450 grams	

Notes:

a Referenced to 27.5 V/m and 27.12 MHz

b Error after using supplied correction factors, includes calibration accuracy

Ordering Information

Model	Ordering Part Number	Accessories Supplied	Optional Accessories
EMR-20C	2244/70	Meter, Probe, 2 AA NiCad batteries, charger and calibration report	Soft carrying case – 2244/60 Rigid carrying case – 2244/62 Tripod (non-metallic) – 2244/90.31 EMR-TS Software, FO adapter and cable – 2244/90.36
EMR-21C	2244/46		

Appendix-D

Reduction of electromagnetic radiation exposures of mobile phones

Since, in most cases, the cell phone is normally held very close to a users body (especially the head), it is imperative to address the issue of near-field exposure. Several fabrics, kits, and devices that can fitted to a regular cell phone are commercially available. These shielding devices would be most effective when the phone is used outdoors, far from reflecting surface. Their effectiveness when the phone is operated inside a car for example is expected to be less due to reflection.

Hands free set

In the first half of the year 2000, various publications appeared concerning a possible increase in the SAR through the use of headset. With the aid of a headset connected to the mobile telephone (a cable with a microphone and a small loudspeaker to be worn in the ear) it is possible to make calls without holding the telephone against the ear. One of the advantages of the use of a headset is that the user has his or her hands free when telephoning.

Assume that the headset cable is an ideal antenna for 900 MHz electromagnetic fields. This headset antenna picks up the fields emitted by the mobile telephone. The maximum power P_0 that an ideal antenna can extract from the electromagnetic fields is equal to:

$$p_0 = \frac{p_{telephone}}{4\pi d^2} \cdot \frac{\lambda^2}{2\pi} \cdot G_T \cdot G_R \qquad \dots\dots\dots\dots \quad D_1$$

Where $P_{telephone}$ is the maximum transmission power of the mobile telephone, λ is the wavelength of the electromagnetic field, G_T and G_R are the gain factors of transmitting antenna and d is the distance between the telephones transmitting antenna and the headset antenna. In practices, G_T and G_R have values between 1and 2.

As an example, take a distance of one wave length between the transmitting antenna and cable. This is around 30 cm for 900 MHz; the formula then indicates that the maximum power available on the headset antenna is only a fraction of what the transmission power may be. With a maximum initial power of 2W for GSM telephone, this works out at an available power of around 10-40 mW on the headset.

Bluetooth kit

Bluetooth is a new system for wireless communication between electronic devices, such as between the computer mouse, keyboard, printer and PC. The range is several meters. The maximum transmission power may be 100mW, but for most applications it is 1mW. The frequency used is2.4 GHz. An important application is awireless link between a headset/microphone combination and a GSM telephone.

This creats a hand free set in which the SAR in the head is considerably lower (by factor of 100to 1000) than with normal use of the GSM telephone, since the telephone can be held at some distance from the head, for example in a coat pocket or a bag.

In addition to, Bluetooth can be defined as the best known of what are called personal area networks (PANs). Wireless PANs can replace the USB and other cables used to pass data among closely located electronic equipment. The typical data transmission speed of Bluetooth is around 700 kilobits per second over distance up to 10 meters. Devices incorporating Bluetooth include mobile phone headset and computer accessories such as printer, keyboards, and the computer mouse.

Techno AO for mobile phones

This tiny piece of technology; shown in Figure D_1; protect human from athermal effects of electromagnetic radiation from mobile phones. Mobile phones produce athermal (non-heating) and thermal (heating) radiation, which can be a major source of chronic electromagnetic stress for their users.

Figure D_1: 87979 Techno AO for mobile phones

Chronic stress related to electromagnetic pollution manifests itself through a variety of elements such as headaches, memory loss, insomnia, irritability, back pain, decrease in concentration and alertness, and can compromise the immune system as well as the users hormone balance.

ADR protect for mobile phones

This little device has been very popular for reducing the harmful effects created by mobile phone, computers and microwaves on human body. Research has shown that it works on the acupuncture channels. It has also shown an improvement in the circulation of the blood and strengthening of immune system.

The ADR protect creates a very small electromagnetic field which acts as a trigger to equalize the levels of energy in all the acupuncture channels and restore balance to the body. This helps the body's protective mechanisms to compensate for the harmful effects of electromagnetic pollutants, as Figure D_2.

Figure D_2: ADR protect for mobile phones

ADR protect is a tiny disc 22mm in diameter which is made of flexible magnetic foil. It has the specific spatial distribution of magnetic field. It will not disturb the transmission or reception of mobile phones or other electronic devices.

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