An-Najah National University

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Electric and Magnetic Field Radiation Leakage from Microwave Ovens at Homes in Palestine

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Dedication

To my father who illuminated my path of success. I would like to thank My mother who taught me to survive no matter what the circumstances have changed. Thanks to my brothers who dreamed of this more than I do and to my sisters who helped and gave me hope. Special thanks to my friends and my teachers who lit our path science and knowledge. To all my family and everyone who helped me make this work possible.

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الاقرار

أنا الموقع ادناه مقدم الرسالة التي تحمل العنوان:

Electric and Magnetic Field Radiation Leakage from Microwave Ovens at Homes in Palestine

أقر بأن ما اشتملت عليه هذه الرسالة ، انما هي نتاج جهدي الخاص ، باستثناء ما تمت الاشارة اليه حيثما ورد ، وأن هذه الرسالة ككل ، أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى .

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name:	**اسم الطالب :**
Signature:	**التوقيع :**
Date:	**التاريخ :**

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List of Abbreviation

Symbol	Abbreviation
AC	Alternating Current
A/m	Ampere per meter
CENELEC	European Committee for Electrotechnical Standardization
dB	Decibel
DNA	Deoxyribonucleic Acid
E	Electric Field
ELF	Extremely Low Frequency
EMF	Electromagnetic Field
EMR	Electromagnetic Radiation
FDA	Food and Drug Administration
g/cm^3	Gram per centimeter cube
H	Magnetic Field
HF	High Frequency
I	Intensity
ICDs	Implantable Cardiovascular Defibrillators
ICNIRP	International Commission on Non–Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
Kg/m^3	Kilogram per meter cube
LF	Low Frequency
MF	Medium Frequency
NRPB	National Radiological Protection Board
OSHA	Occupational Safety and Health Administration
P	Power Density
RF	Radio Frequency
ROS	Reactive Oxygen Species
SAR	Specific Absorption Rate
SAR*	Specific Absorption Rate for Human Skin
SAR**	Specific Absorption Rate for Human Brain
SAR***	Specific Absorption Rate for Human Eye Sclera
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
S/m	Siemens per meter
T4	Thyroxine
UHF	Ultra High Frequency
UK	United Kingdom
U.S.	United State
UV	Ultraviolet

VHF	Very High Frequency
V/m	Volt per meter
W/m^2	Watt per meter square
W/kg	Watt per kilogram
η	Field Resistance
α	Linear Attenuation Coefficient
σ	Conductivity of the Tissue
ρ	Mass Density of the Tissue

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Abstract

The amount of radiation leakage, the electric field, magnetic field and the specific absorption rate (SAR) were investigated from 115 microwave ovens in domestic use in Palestine. The power density of radiation leakage from microwave ovens was measured using instruments. The age of ovens were between 1 month and 13 years old including 14 ovens with unknown age, with operating power ranging from 700 W to 1350 W of different types, manufacturers, and models. The power density of radiation from ovens was measured at different distances at the height of center of door screen. Electric field, Magnetic field and SAR were calculated at distances 5 cm and 20 cm from ovens. These values were much less than the specified Electromagnetic Field levels (EMF) of International Commission on Non–Ionizing Radiation Protection (ICNIRP) for 2.45 GHz radiofrequency. The power density of radiation leakages from microwave ovens does not depend on the oven age and operating power of ovens.

Chapter One

Introduction

Microwave ovens became indispensable device in most kitchens, because of their ease of use. Users of microwave ovens may concern about potential health hazards from the exposure to microwave radiation leakage.

Microwaves are a form of electromagnetic radiation (EMR) because of its ability to penetrate several things like rain, snow, clouds, and smoke. It is used in communication industry for transmitting information from one place to another. In addition, microwave ovens are used for cooking and heating food in homes (Dimple and Singh, 2012).

Microwave ovens are amazing household appliance devices used to heat up foods. Percy Spencer working for Raytheon, in 1947 invented the first microwave oven after Second World War from radar technology, called Radarange. Years later, the size and price of microwave ovens were decreased, enabling each house to have a microwave oven.

Microwave oven is a device that works on alternating current (AC) that uses microwave radiation at frequency 2.45 GHz, i.e. λ = 12.23 cm to heat and cook food in a short time by oscillating the water molecules contained in the food (Vollmer, 2004). Rays of microwave are absorbing by water, fats and sugars, this means that the molecules of these substances that contain water are electric dipoles and therefore rotate as they try to align themselves with the alternating electric field of the microwaves. Absorbing these rays through the atoms and molecules of the material dispersed energy, make them oscillate significantly, which collide with each other and produce heat necessary to be cooked (Aitkan and Ironmonger, 1996) Fig. (1.1).

Many people are concerned about the effect of EMR leakage from microwave ovens. They believe that these leakage radiations may interfere with other electronic apparatus and it may cause health risks when they use microwave ovens in their houses, restaurants and in cafeterias (Vollmer, 2004). This includes concern on whether harmful chemicals would be formed or nutritional quality of food would be lowered during microwave cooking, the food cannot be altered chemically while heated in a microwave oven (Vollmer, 2004).

The part that causes leaked of radiations is the door of microwave oven, which made of glasses and covered by metal grids. This metal grid consists of holes, which are small compared with the wavelength of the microwaves so it is like metal plate. The door has $\lambda/4$ radiation traps (Thuery and Grant, 1992). The use of a quarter-wavelength chokes away with the requirement for clean metal-to-metal contact and allows small gaps at the door interface (Bangay and Zombolas, 2004).

The oven door is the most dangerous place for microwave leakage but magnetic fields can occur all around the oven. This is not good news for children, who love to watch the foods bubbling inside oven. In addition to oven leakage, microwaving causes adverse effects in food (Vollmer, 2004).

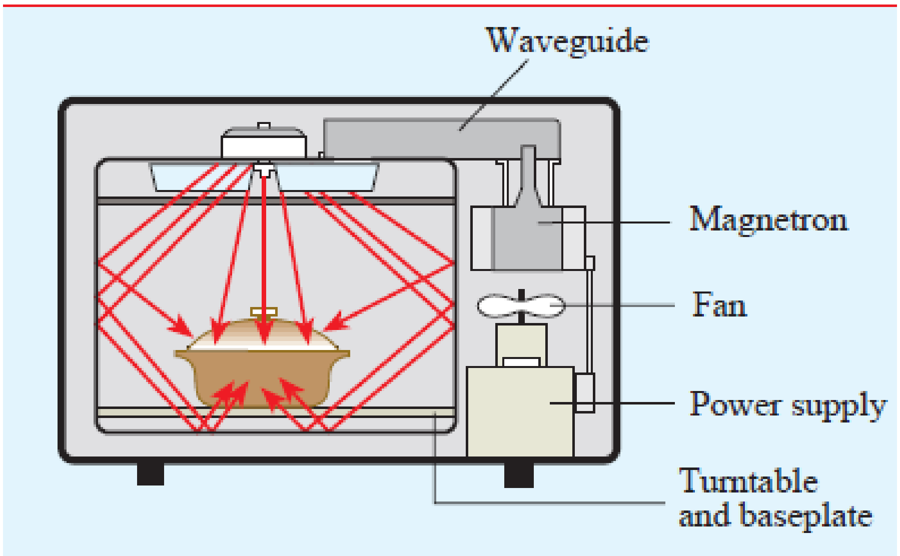

Fig. (1.1): Schematic diagram of typical microwave ovens (Vollmer, 2004)

1.1 Literature review

Mahajan and Singh found in their research that the long-term exposure of low frequency electromagnetic fields (EMFs) would cause health problems especially lack or fatigue, irritability, aggression, hyperactivity, sleep disorders and emotional instability. Large numbers of individuals are becoming hypersensitive to EMR. They showed that the RF energy heats up the tissues in a similar manner, a microwave oven heats the food and it can be dangerous in case of prolong exposure. Tissues can be damaged if exposed to RF energy because they are not capable of dissipating large amount of heat generated. This can lead to skin burns, deep burns and heat strokes. Eyes are most affected by the RF energy because the lack of blood flow to cool the cornea can lead to cataract (Mahajan and Singh, 2012).

Exposure to electromagnetic fields has shown to be in connection with Alzheimer disease, motor neuron disease and Parkinson disease (WHO, 2007). Various studies show that exposure to EMR reduce melatonin levels in people. Melatonin protects the brain against damage leading to Alzheimer disease; hence, degenerative diseases such as Alzheimer and Parkinson disease as well as cancer have linked to suppressed melatonin production in the body (Wood *et al*., 1998) (Wilson *et al*., 1990).

Another study found that the RF Exposure could adversely affect the heart: Pacemaker, implantable cardiovascular defibrillators (ICDs) and impulse generators, and become arrhythmic. This study showed that these radiations may stop pacemaker from delivering pulses in regular way or may generate some kind of external controlling pulse putting the patient to death (Altamura *et al*., 1997).

A study showed that heating garlic for 60 second in microwave oven could block garlic's ability to inhibit in vivo binding of mammary carcinogen. This study demonstrated that this blocking of the ability of garlic was consistent with inactivation of alliinase. Heating destroyed garlic's active allyl sulfur formation, which relate to its anticancer properties (Song and Milner, 2001).

Microwave absorption effect is much more significant by the body parts, which contain more fluid (water, blood, etc.) like the brain that consists of about 90% water. Effect is more pronounced where the movement of the fluid is less, for example, eyes, brain, joints, heart, abdomen, etc. The effect has shown to be much more severe for children and pregnant women by Neha and Girish Kumar in their study (Neha and Girish, 2009).

A study showed that the effects of radiations are not observed in the initial years of exposure as the body has certain defense mechanisms, and the pressure is on the stress proteins of the body namely the heat shock proteins (Leszczynski *et al*., 2002). Effects of radiation accumulate over time and risks are more pronounced after 8 to 10 years of exposure (Hardell *et al*., 2009). Researchers indicate that changes in exposure level might be more important than duration of exposure for producing effects in human beings (Cook *et al*., 1992).

The regular and long-term use of microwave devices (mobile phone, microwave oven) at domestic level can have negative impact upon biological system especially on brain. Increased reactive oxygen species (ROS) play an important role by enhancing the effect of microwave radiations, which may cause neurodegenerative diseases (Kesari *et al*., 2013).

A survey showed that electromagnetic waves of frequency 130 KHz and 150 KHz, which are used for radio navigation system spread in the atmosphere, and affect the people who are living near the radiator of signal. These frequencies have harmful effects on some selected tissues of the human beings. SAR of body fluid, cerebral spinal fluid and gall bladder tissues become greater to the safe limit announced by some international agencies (Kumar *et al*., 2012).

ELF and EMF induce effects in the comet assay are reproducible under specific conditions and occasional triggering of apoptosis rather than by the generation of DNA damage (Focke *et al*., 2010). A study indicated that the EMF exposure in preimplantation stage could have detrimental effects on female mouse fertility, and embryo development by decreasing the number of blastocysts and increasing the blastocysts DNA fragmentation (Borhani *et al*., 2011). Another study showed a relationship between exposure to radiofrequency fields during work with radiofrequency equipment and radar and reduced fertility (Møllerløkken and Moen, 2008).

In 2003, Charles and his group found positive associations between the highest level of exposure to EMFs and risk of mortality from prostate cancer (Charles *et al*., 2003). In the same year, a study showed that exposed mothers during pregnancy to the highest occupational level of ELF-MF, increase risk of childhood leukemia among children (Infante-Rivard and Deadman, 2003).

A study by Mousa on the radiated electromagnetic energy from some typical mobile base stations around the city of Nablus, his study found that the power density emitted by the base stations is lower than permitted levels (Mousa, 2011).

Microwaves radiation leakage from ovens decrease body weight, increase thyroxin (T4) and cortisol levels**,** and therefore has deleterious health effects. They showed in the study that radiation leakage from oven ranged from 6.5 to 57.5 mW/cm^2. Cortisol and T4 levels were significantly increased in the test group compared to the control group, respectively (Jelodar and Nazifi, 2010).

A study showed that the contribution of the magnetic field from microwave ovens for inducing some current density in the human body which is small (one µT induces a current density of ±5 $\mu A.m^{-2}$) (NRPB, 2001). When a man is just at a couple of centimeters of unshielded operating ovens, a much higher current density may induce (up to 500 µT induce a current density of 5 $\mu A.m^{-2}$ (Decat and Van Tichelen, 1995).

A study by Skotte surveyed microwave ovens used in restaurants and cafeterias, and found that for most of the large ovens leakage is in the range between 0.2 to 2 mW/cm^2 (Skotte, 1981). Another study by Muhammad and his group found that, only one microwave oven gives a value of 10.19 mW/cm^2 which exceeds the standard value (Muhammad *et al*., 2011).

Some ovens were found to radiate more than the specified limit, and that was attributed to oven age and the lack of cleaning and proper maintenance (Osepchuk, 1978). Correlation was observed between measured leakage and oven age. There is no apparent correlation was found between measured leakage and operating power (Alhekail, 2001).

Research demonstrated that the extended exposure to RF signals at an average SAR of at least 5.0 W/kg, are capable of inducing chromosomal damage in human lymphocytes (Tice *et al*., 2002).

Annual surveys investigated in the United Kingdom (UK) from 1980–1987, showed that only a small number of the inspected ovens leaked in excess of 5 mW/cm^2 at 5 cm from the surface of oven (Moseley and Davison, 1989).

Survey conducted at the United State Fermi National Accelerator Laboratory between 1974 and 1985, it was found that the mean maximum leakage within 5 cm of the oven surface was 0.2 ± 3.1 mW/cm^2 (Miller, 1987).zAlhekail studied the leakage from 106 microwave ovens and showed that only one oven exceeded the 5 mW/cm^2 emission limit. He found that the probability of finding an oven that leaks more than 5 mW/cm^2 is 0.6 % (Alhekail, 2001). This is a relatively high probability, when compared to the one found by Matthes where leakage measurements were performed on ovens brought in for cost-free check (Matthes, 1992). Alhekail found that several ovens leaking more than 1 mW/cm^2 (Alhekail, 2001).

Matthes studied 130 ovens. Ovens power was 350W- 1200W, and the age of the ovens was between 5 - 18 years, his study reported that all checked ovens were found to leak less than 1 mW/cm^2 (Matthes, 1992).

Survey was conducted in Ottawa, Canada, on 60 before-sale microwave ovens and 100 used ovens. None of the before-sale ovens were found to emit microwave radiation in excess of the maximum allowed leakage. They found only one used oven leaked in excess of the maximum allowed leakage. Six before-sale ovens from three different manufacturers were found to be noncompliant with the labeling requirements (Thansanodte *et al*., 2000).

Gilbert showed in his research that microwave ovens leaked radiation when door of ovens closed**.** His study was made of 187 commercials use ovens. He found that 20 % leak 10 mW/cm^2 or more, within two inches from the closed oven (Gilbert, 1970).

Astudy by Lahham and Sharabati about the amount of radiation leakage from 117 microwave ovens in domestic and restaurant use in the West Bank, Palestine. The amount of radiation leakages at a distance of 1 m was found to vary from 0.43 to 16.4 $\mu W/cm^2$ with an average value of 3.64

μW/cm^2. Leakages from all tested microwave ovens except for seven ovens (∼6 % of the total) were below 10 μW/cm^2. The highest radiation leakage from any tested oven was ∼16.4 μW/cm^2. This study confirmed a linear correlation between the amount of leakage and both oven age and operating power with a stronger dependence of leakage on age (Lahham and Sharabati, 2013).

1.2 Research objectives

The effect of electromagnetic radiation (leakage) from microwave ovens has been raised. Many people are concerned about the impact of radiation leaking from microwave ovens on their health. The aims of this study are:

1. Investigating radio frequency radiation leakage from 115 microwave ovens, at homes in Palestine.
2. Measuring the power density of radiation leakage as a function of distance from ovens, oven age and operating power of ovens.
3. Calculating the electric fields, magnetic fields of electromagnetic radiations leakage from ovens.
4. Calculating the SAR of some human body tissues and organs; human skin, human brain and human eye sclera.
5. Comparing the results of this work with the international standards of ICNIRP in tables (3.1) and (3.2).

Chapter Two

Theory

2.1 Non-ionizing radiation

There are typical sources of electromagnetic fields with frequency and intensity. The lower part of the frequency spectrum is considered non-ionizing EMR, with its energy levels are below than the required for effects at the atomic level. The non-ionizing EMR are classified into frequency bands, namely (SCENIHR, 2007):

- Radio frequency (RF) (100 kHz < F ≤ 300 GHz), which including low frequency (LF), medium frequency (MF), high frequency (HF), very high frequency (VHF), ultra high frequency (UHF) and microwave and millimeterwave (30 kHz to 300 GHz), as shown in table (2.1).
- Intermediate frequency (IF) (300 Hz < F ≤ 100 kHz)
- Extremely low frequency (ELF) (0< F ≤ 300 Hz)
- Static (0 Hz)
- Optical radiations: infrared (IR) (760 - 10^6) nm, visible (400 – 760) nm, (Ng, 2003).

Table (2.1): Typical sources of electromagnetic fields (SCENIHR, 2007)

Frequency range	Frequencies	Some examples of exposures sources
Static	0 Hz	VDU (video displays); MRI and other diagnostic / scientific instrumentation; Industrial electrolysis; Welding devices
ELF	0-300 Hz	Powerlines; Domestic distribution lines, Domestic appliances; Electric engines in cars, train and tramway; Welding devices
IF	300 Hz-100 KHz	VDU; anti theft devices in shops, hands free access control systems, card readers and metal detectors; MRI; Welding devices
RF	100 KHz-300 GHz	Mobile telephony; Broadcasting and TV; Microwave oven; Radar, portable and stationary radio, transceivers, personal mobile radio; MRI

Microwaves are form of electromagnetic radiation (non ionizing radiation), these waves are radio wave that wavelengths range from 1 mm to 1 meter, and the frequency is 300 MHz to 300 GHz (Dimple and Singh, 2012). The electromagnetic spectrum is shown in Figs. (2.1) and (2.2) (Zamanian and Hardiman, 2005).

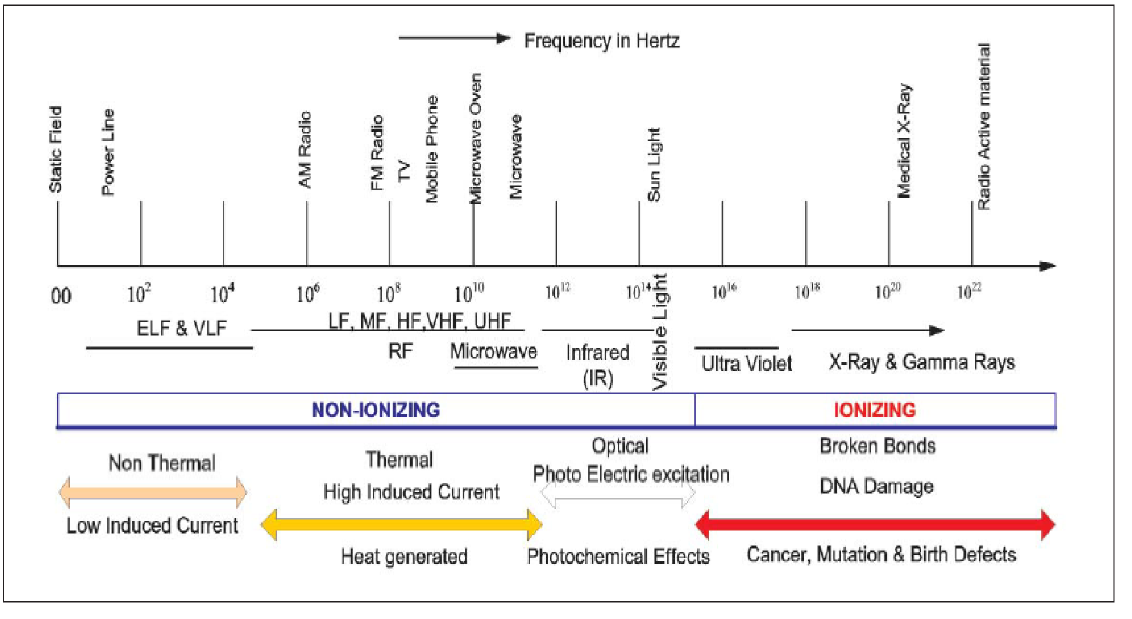

Fig. (2.1): Electromagnetic spectrum

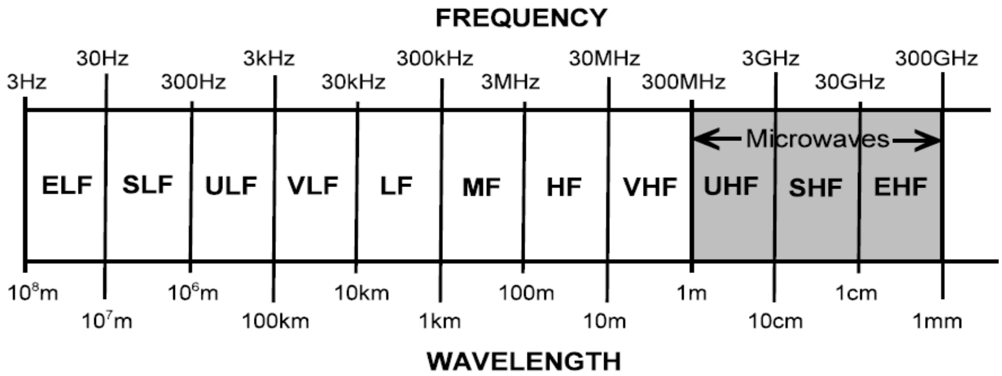

Fig. (2.2): The range of microwaves

2.2 How does microwave oven work?

The microwave oven is a versatile, time saving kitchen appliance that uses for thawing, cooking or reheating foods by exposing it to microwave radiation. The source of the radiation in a microwave oven is the magnetron tube, which is the heart of microwave oven. Magnetron is a tube that generates microwave radiations, in which electrons affected by magnetic and electric fields to produce radiation at about 2.45 GHz, and channeled by the waveguides. They are usually metal tubes of rectangular cross section, into the cooking chamber, which has metallic walls (Aitkan and Ironmonger, 1996). When these waves incident the metal walls they will be absorbed very effectively. Interaction will happened between the electric field of the waves and the free electron of the metal. These electrons re-radiated these waves in phase and at the same frequency so the microwaves reflected (Vollmer, 2004).

Most food contains water even dry food, water H_2O is a polar molecule with two hydrogen positive atoms and single oxygen negative atom. The water molecules are in constant motion and are normally randomly oriented. When these molecules exposure to EMF which are generated from magnetron, they will experience a torque from the electric field and will become aligned with direction of this field. Water molecules are oriented by the electric field Fig. (2.3), the direction of the electric field is changing rapidly about 2.45 billion times per second. Then polar water molecules follow the oscillation of the electric field, they collide more frequently with the molecules (water and other) around them. This microwaves have frequency equals the resonance frequency of water, Fig. (2.4) (Vollmer, 2004).

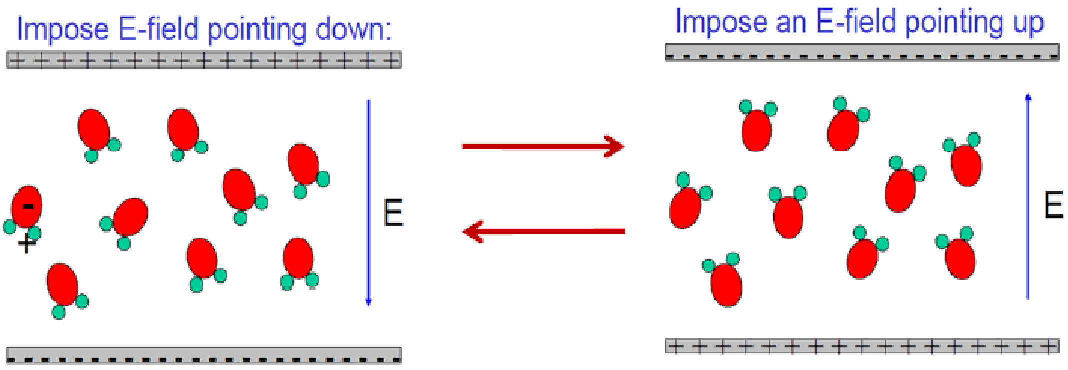

Fig. (2.3): Water molecules align with direction of electric field

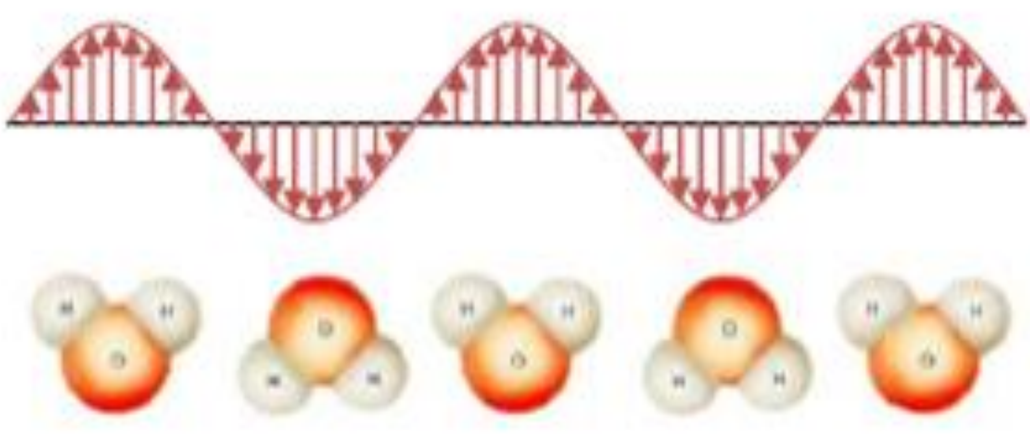

Fig. (2.4): Water molecules in an oscillating electric field

The molecules move faster and faster and the temperature increases, which causes heating. Inside a microwave oven, the electromagnetic waves resonate and form standing waves from reflections at the walls, these standing waves are simplified by the fact that the wavelength of the microwaves is roughly the same as the linear dimensions of the chamber. The microwave oven cooks all food evenly, but the nodes and antinodes of the standing waves can cause the food to burn in some places but to remain cool in others, without a turntable the food will not be cooked uniformly (Vollmer, 2004), Fig. (2.5).

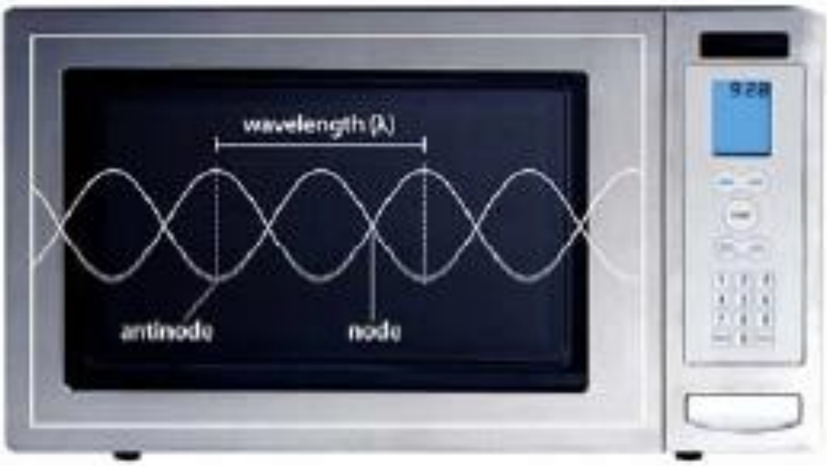

Fig. (2.5): Standing waves in microwave oven

2.3 The interaction of the electromagnetic fields with human body

RF energy is produced by many manufactured sources, which radiate EMR of different frequencies and intensities. including cellular phones and base stations, television and radio broadcasting facilities, radar, medical equipment, coffee makers, refrigerators, cloth washers and dryers, microwave ovens, RF induction heaters, … etc (Consumer and Clinical Radiation Protection Bureau, 2009).

When an electric or magnetic field penetrates into the body, it is attenuated and a part of it is absorbed inside the body tissue (Kumar *et al*; 2008). There are three basic coupling mechanisms, through which electric and magnetic fields interact directly with living matter: coupling to low-frequency electric fields, low-frequency magnetic fields and absorption of energy from electromagnetic fields (Sinik and Despotovic, 2002).

The interaction of electric fields with the human body causes: flow of electric charges, polarization of bound charge, and the reorientation of electric dipoles in tissue. The magnitudes of these different effects depend on electrical conductivity and permittivity of the body (Sinik and Despotovic, 2002). These electrical properties of the body vary with the type of body tissue and the frequency of the applied field, for example, human body consists of homogeneous tissue like muscle tissue and three layer tissue like skin and fat (Klemm and Troester, 2006). External electric fields induce a surface charge on the body; these results an induced current in the body, the distribution of which depends on exposure conditions, the size and shape of the body, and the body's position in the field (Sinik and Despotovic, 2002).

The interaction of magnetic fields with the human body results an induced electric fields and circulating electric currents. Their magnitudes are proportional to the radius of the loop, the electrical conductivity of the tissue, and the rate of change and magnitude of the magnetic flux density. The exact path and magnitude of the resulting current induced in any part of the body will depend on the electrical conductivity of the tissue (Sinik and Despotovic, 2002).

Exposure to electromagnetic fields at frequencies above about 100 kHz can lead to significant absorption of energy and temperature increases. In general, exposure to a uniform electromagnetic field results in a non-uniform deposition and distribution of energy within the body (Sinik and Despotovic, 2002).

The intensity of radiation that absorbed by a sample depends on the chemical density of the sample, its thickness, the cross section of absorption, and on the wavelength of the radiation of the sample (Harrison *et al*., 2011).

The beam will lose intensity due to two processes: the substance can absorb the light, or the light can be scattered by the substance when a narrow (collimated) beam of light passes through a substance. However, how much of the lost intensity was scattered, and how much was absorbed can be measured. Attenuation coefficient measures the total loss of narrow-beam intensity, including scattering as well (Bohren and Huffman, 1998).

The measured intensity I of transmitted through a layer of material with thickness x, related to the incident intensity I_o according to the inverse exponential power law that usually referred to as Beer-Lambert law:

$$I = I_o e^{-\alpha x} \qquad 2.1$$

Where, x is the path length of radiation and α the attenuation coefficient (or linear attenuation coefficient).

The linear attenuation coefficient and mass attenuation coefficient are related such that the mass attenuation coefficient is simply α/ρ, where ρ is the density in g/cm^3. When this coefficient is used in the Beer-Lambert law, then "mass thickness" (defined as the mass per unit area) replaces the product of length time's density (Bohren and Huffman, 1983). Beer observed that, the amount of radiation that absorbed by a sample is proportional to the concentration of dissolved substance (Harrison *et al.*, 2011).

As an electromagnetic wave travels through space, energy transferred from the source to other objects (receivers). The rate of this energy transfer depends on the strength of the electromagnetic field components. Microwave radiation is measured as power density, which is essentially the rate of energy flow per unit area. Power density is the product of the electric field strength (E) times the magnetic field strength (H) (OSHA, 1990).

$$P = E\,H \qquad 2.2$$

Where, P is the power density in W/m^2, E is the electric field strength in V/m, and H is the magnetic field strength in A/m (OSHA, 1990).

The power density can be written as:

$$P = \eta\, H^2 \qquad 2.3$$

η is the field resistance taken as $\left(\frac{\mu o}{\epsilon o}\right)^{1/2}$ = 377 Ω for free space (in air) (ICNIRP, 1998).

2.4 Specific absorption rate (SAR)

The frequently usage of microwave ovens generates concern about potential health effects on humans. It has become necessary to ensure that these devices do not expose their users to potentially harmful levels, and the known health effects center around tissue heating. A measure of this heating effect is known as specific absorption rate (SAR).

SAR is one of the important parameter that should be measured, when human and biological objects are exposed to electromagnetic radiation from microwave oven, they are absorbed electromagnetic energy. SAR is defined as the time derivative of the incremental energy (dW) absorbed by or dissipated in an incremental mass (dm) contained in a volume (dV) of a given mass density (ρ). It can be defined as (Seabury and ETS-Lindgren, 2005):

$$\text{SAR} = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho\, dV}\right) \qquad 2.4$$

SAR is related to electric fields at a point, which is the power of electromagnetic radiation absorbed per mass of tissue. SAR can be calculated as (Bangay and Zombolas, 2004):

$$\text{SAR} = \frac{\sigma\, E^2}{2\,\rho} \qquad 2.5$$

Where SAR is the Specific absorption rate in (W/Kg), σ is the conductivity of the tissue in (1/Ω.m), E is electric field strength in (V/m), and ρ is the mass density of the tissue in (Kg/m^3). The appropriate parameters for the conductivity σ, and the tissue density ρ of all different materials used for the calculation must be known. Equation (2.5) represents the rate at which the electromagnetic energy is converted into heat, through interaction mechanisms. It provides a quantitative measure of all interaction mechanisms that are dependent on the intensity of the internal electric field (Kumar *et al*., 2008).

There are some international radiation exposure safety standard available in major countries as; Europe, America, Korea and Japan. The international organizations are; European Committee for Electrotechnical Standardization (CENELEC), International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Institute of Electrical and Electronics Engineers (IEEE), that are mainly defined from the thermal point of view. For examples, the general public exposure limit of whole body average SAR is 0.08 W/kg, while the localized SAR for head and trunk is 2 W/kg (Chiang and Tam, 2008). In the case of the eye, the limit for the average SAR over 10 grams of tissue is 2 W/kg in the frequency range from 0.5 to 3.5 GHz (IEEE, 2005) (ICNIRP, 1988), these standard values of SAR in different organizations and countries are shown in Table (3.2).

Chapter Three

Methodology

3.1 The studied microwave ovens

In this study, 115 microwave ovens of different types and models were tested in domestic use in Nablus, Palestine. The age of ovens ranged from 1 month to 13 years, with 14 ovens of unknown age. Operating power of ovens ranged from 700 W to 1350 W.

The power density leakage from microwave ovens was measured at different distances at the height of center of door screen; a detector is set up to measure EMR leakage in different directions from microwave ovens.

The principle of heating food in microwave ovens depends on the presence of water molecules in it, therefore the leakage power density from microwave ovens was measured by putting water in a plate in the cavity of ovens; any source of electromagnetic fields was turned off in homes such as; TV and wireless internet. All the inspected ovens were adjusted to operate at maximum output power, by touch power level pad and select a high cooking power level. The measurements were made using acoustimeter and microwave leakage detector EMF-810.

The light intensity was measured in different sites of the houses especially in the kitchens using hioki 3423 lux hitester digital illumination meter, values of light intensity are found to be within the range (500 – 750) lux. The noise pressure level was measured in all tested houses using sound pressure level meter and, it was within the range (50 - 60) dB, which is considered quiet place. The intensity level of light and sound noise level were measured to make sure that; they don't influence the measured values. It has been found by some researchers that there are an effect from exposure to sound, light intensity and other sources of EMR (Sadeq *et al*., 2013) (Sadeq, 2011) (Ibrahim *et al*., 2013) (Sheikh *et al*., 2013) (Sheikh, 2013) (Abdelraziq *et al*., 2003) (Abdelraziq *et al*., 2000) (Qamhieh *et al*., 2000) (Sa'abnah, 2011) (Suliman, 2014) (Thaher, 2014) (Subha, 2014) (Abu hadba, 2014) (Al-Faqeeh, 2013) (Abo-Ras, 2012).

The power of EMR was measured near these microwave ovens. Data was collected and logged in the special data collection sheet which was designed. The sheet included information about the oven of various models such as manufacturer, dates of manufacturing, country of origin, operating power, frequency, age, number of users, daily use, age of users, location of the oven at home, user awareness and physical condition, this sheet is shown in Appendix (C). Microwave oven has label of information and labels of awareness, some ovens did not have labels of awareness, and there is no warning labels in the local language were fixed on any of the surveyed ovens.

3.2 Instrumentations

Five Instruments were used in our test and measurements. These instruments are briefly described in the following:

1. Acoustimeter AM-10 RF meter is dedicated RF radiation meter. This meter is used to measure radiation from different sources. It measures RF radiation from 200 MHz right up to 8 GHz ±3 dB, and measures average exposure levels from 1 to 100,000 microwatts per

square meter [µW/m2], peak exposure levels from 0.02 to 6.00 volts per meter [V/m]. Acoustimeter is shown in Fig. (3.1) (Acoustimeter User Manual, 2011).

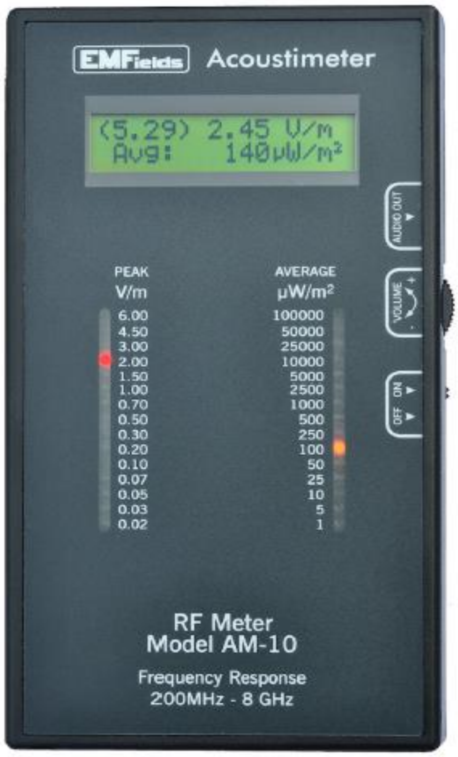

Fig. (3.1): Acoustimeter AM-10 RF meter (Acoustimeter User Manual, 2011)

2. Hioki 3423 lux hitester digital illumination meter is used to measure the light intensity in selected homes. This instrument is suited for a wide range of application. It measures a broad range of luminosities, from the low light provided by induction lighting up to a maximum intensity of 199,900 lux, with accuracy ±4%. This instrument is shown in Fig. (3.2) (Hioki 3423 Lux Hitester Instruction Manual, 2006).

Fig. (3.2): Hioki 3423 Lux Hitester Digital Illumination Meter (Hioki 3423 Lux Hitester Instruction Manual, 2006)

3. Microwave leakage detector EMF-810. This instrument is used to measure electromagnetic field value for the microwave frequency, precisely on the frequency value 2.45 GHz, and to detect the leakage of microwave oven with accuracy < 2 dB. Accuracy tested less than 2.45 ± 50 MHz and measurement range from 0 to 1.999 mW/cm^2. Microwave leakage detector, which is used in this study, is shown in Fig. (3.3) (Microwave Leakage Detector Operation Manual).

Fig. (3.3): Microwave leakage detector EMF-81 (Microwave Leakage Detector Operation Manual)

4. Sound pressure level meter that is used to measure the sound level in dB of selected homes, (Quest Technologies U.S.A, Model 2900 type 2) with accuracy of ± 0.5 dB at 25 °C. This device gives the readings with a precision of 0.1 dB. This instrument is shown in Fig. (3.4) (Instructions manual for sound level meter, 1998b).

Fig. (3.4): Sound pressure level meter (Instructions manual for sound level meter, 1998b)

5. Scan probe EM-E, model CTM020. It is used to detect the presence of an electromagnetic field, and provides audio and visual indication of relative field strength. The scan probe offers a green / yellow / red 5-LED light bar and audible tone, which changes pitch with field strength. Scan probe is shown in Fig. (3.5) (Instruction Manual for Scan Probe, China, 2006)

Fig. (3.5): Scan probe EM-E (Instruction Manual for Scan Probe, China, 2006)

3.3 Statistical analysis

The data was analyzed by using excel program. Excel was used to find the relation between the power density of radiation leakages and the distance from microwave ovens, the age of ovens and the operating power of ovens. Electric field, magnetic field and SAR were calculated at distance 5 cm and 20 cm by using excel program.

3.4 Standard values

The maximum amount of leakage (emission) from microwave ovens has been specified by the United State code of federal regulation (CFR) 21 part 1030, at distances of 5 cm from the oven to be 1 mW/cm^2 before the oven is sold, and 5 mW/cm^2 throughout its operating life (FDA, 1992). In addition, by ICNIRP, limit general public exposure to RF power to 1 mW/cm^2 at 2.45 GHz radiofrequency (ICNIRP, 1998).

Table 3.1 shows the reference levels for general public exposure to time varying electric and magnetic fields (ICNRP, 1998). The reference levels for limiting exposure are obtained from the basic restrictions for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection (Vecchia, 2007).

Table (3.1): Reference levels for occupational and general public exposure to time-varying electric and magnetic fields (ICNIRP, 1998)

Exposure category	**Frequency range**	**E-field strength (V/m rms)**	**H-field strength (A/m rms)**	**Equivalent plane wave power flux density S_{eq} (W/m^2)**
Occupational	100 KHz -1 MHz	614	1.63/*f*	-
	1 MHz -10 MHz	614/*f*	1.63/*f*	$1000/f^2$
	10 MHz -400 MHz	61.4	0.163	10
	400 MHz -2 GHz	$3.07 \times f^{0.5}$	$0.00814 \times f^{0.5}$	*f* /40
	2 GHz -300 GHz	137	0.364	50
General public	100 KHz -150 KHz	86.8	4.86	-
	150 KHz -1 MHz	86.8	0.729/*f*	-
	1 MHz – 10 MHz	$86.8 / f^{0.5}$	0.729/*f*	-
	10 MHz - 400 MHz	27.4	0.0729	2
	400 MHz -2 GHz	$1.37 \times f^{0.5}$	$0.00364 \times f^{0.5}$	*f* /200
	2 GHz -300 GHz	61.4	0.163	10

Table (3.2) shows the safety standard values of SAR in major countries and international organizations.

Table (3.2): The safety standard values of SAR in major countries and international organizations (ICNIRP, 1998)

Classification		Korea	Japan	U.S.	CENELEC	ICNIRP	IEEE
Frequency range (Hz)		10^5~ 10^{10}	10^5 ~ 3 x 10^8	10^5 ~ 6 x 10^8	10^6 ~ 3 x 10^{11}	10^5~ 10^{10}	10^5~ 3 x 10^6
Normal use (W/kg)	Whole body	0.08	0.08	0.08	0.08	0.08	0.08
	Head/ trunk	1.6	2	1.6	2	2	2
	Limbs	4	4	4	4	4	4
Occupational user (W/Kg)	Whole body	0.4	0.4	0.4	0.4	0.4	0.4
	Head/ trunk	8	10	8	10	10	10
	Extremities	20	20	20	20	20	20

Note: Head/trunk refers to body parts excluding the limbs; the SAR standard for limbs is the average maximum value for 1 gram of human tissue in Korea and the U.S. while in Japan, CENELEC, ICNIRP and IEEE limbs is based on the average maximum value for 10 grams of human tissue.

Chapter Four

Results and Discussion

This chapter represents the results and discussion of this study. Results of power density measurements, the electric, magnetic fields and SAR are calculated and explained in section (4.1). Results of power density measurements with age of ovens and operating power are shown in sections (4.2) and (4.3). Results of power density measurements, calculated electric field, magnetic field and SAR for different manufacturers are shown in section (4.4). The calculated SAR is shown in section (4.5).

4.1 Results of power density measurements

Our study was carried out for 115 microwave ovens in domestic use at homes in Palestine, by Acoustimeter AM-10 RF meter at different distances. In this study, the power density of radiation leakage from 115 microwave ovens at distances 5 cm and 20 cm are shown in table (4.1).

Table (4.1): The power density of radiation leakages from 115 microwave ovens at distances 5 cm and 20 cm

<table>
<tr><th colspan="2">Distance from oven (cm)</th><th>The lowest value of P (mW/m^2)</th><th>The highest value of P (mW/m^2)</th><th>An average value of P (mW/m^2)</th></tr>
<tr><td colspan="2">5</td><td>1.54</td><td>76.01</td><td>50.92</td></tr>
<tr><td colspan="2">20</td><td>1.57</td><td>67.82</td><td>34.86</td></tr>
<tr><td rowspan="2">14 ovens with unknown age</td><td>5</td><td>1.54</td><td>69.95</td><td>47.32</td></tr>
<tr><td>20</td><td>1.57</td><td>53.16</td><td>28.59</td></tr>
</table>

These values are much less than standard values in table (3.1). A study in Germany reported that all checked ovens were found to leak less than 1 mW/cm^2 (Matthes, 1992).

The age of ovens were between 1 month and 13 years old including 14 ovens with unknown age, with operating power ranging from 700 W to 1350 W, and of different types, models and manufacturers.

The electric field and magnetic fields were calculated using equations (2.2) and (2.3). The highest calculated values of electric field were 5.35 V/m at 5 cm distance from oven, and 5.06 V/m at 20 cm distance from oven. The lowest calculated values of electric field were 0.77 V/m at 5 cm, and 0.76 V/m at 20 cm. The highest calculated values of magnetic field were 141.20 x 10^{-4} A/m at 5 cm distance from oven, and 134.10 x 10^{-4} A/m at 20 cm far from oven. The lowest calculated values of magnetic field were 20.00 x 10^{-4} A/m at 5 cm distance from oven, and 11.50 x 10^{-4} A/m at 20 cm distance from oven. All of these values were less than the standard values according to table (3.1).

The measured power density of radiation leakage as a function of distance from one of the ovens is shown in Fig. (4.1); the data of this figure is given in table (a_1) in Appendix (A). The average of the measured power density of radiation leakage as a function of distance, for the group of ovens operating at the same power 700 W, is shown in Fig. (4.2), the data of this figure is tabulated in table (a_2) in Appendix (A).

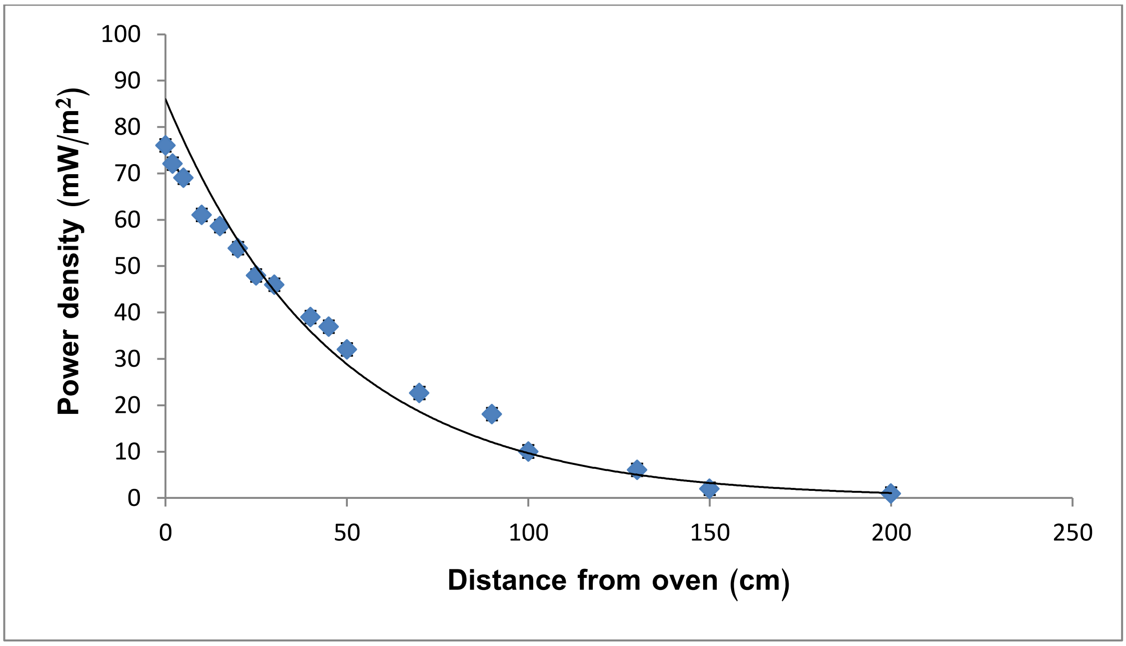

Fig. (4.1): The measured power density of radiation leakage as a function of distance from one oven

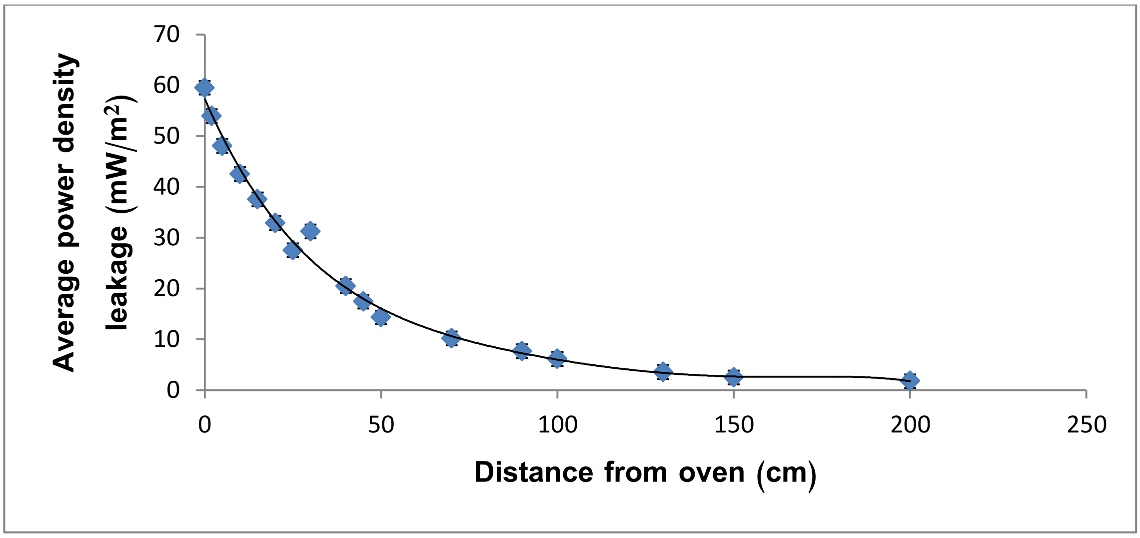

Fig. (4.2): The average of the measured power density of radiation leakage as a function of distance from group of ovens operating at the same power 700 W

Figs. (4.1) and (4.2) indicate that the measured power density of radiation leakage decrease with distance from the ovens. The power density as a function of distance from one oven was the same for a group of ovens operating at the same power. A study showed that the measured power density decreases with distance from microwave oven (Lahham and Sharabati, 2013).

4.2 Results of power density measurements with age of ovens

The age of all ovens was between 1 month and 13 years old including 14 ovens with unknown age. The electric field and magnetic field were calculated using equations (2.2) and (2.3). The average power density of radiation leakages from all ovens of different ages of the same operating power, the magnitudes of electric field and magnetic field are shown in tables (4.2) and (4.3), at distances 5 cm and 20 cm far from ovens.

Table (4.2): The measured and calculated parameters* for microwave ovens of the same operating power at 5 cm distance from oven

Operating Power (W)	No. of Ovens	Avg. Age (months)	Avg. P (mW/m^2)	Avg. E (V/m)	Avg. H (A/m) X 10^{-4}
700	50	34	49.09	4.25	112.64
750	1	156	61.33	4.81	127.50
800	15	38	49.70	4.27	113.41
850	8	20	51.42	4.39	116.41
900	20	35	56.15	4.56	120.83
950	1	156	43.22	4.04	107.00
1000	5	65	58.49	4.68	124.01
1350	1	60	53.77	4.50	119.43
700	6	Un-known age	34.75	3.58	89.15
800	5		53.53	4.47	118.57
850	1		62.02	4.84	128.00
900	1		55.17	4.56	121.00
1000	1		69.11	5.10	135.40

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

Table (4.3): The measured and calculated parameters* for microwave ovens of the same operating power at 20 cm distance from oven

Operating Power (W)	No. of Ovens	Avg. Age (months)	Avg. P (mW/m^2)	Avg. E (V/m)	Avg. H (A/m) X 10^{-4}
700	50	34	33.46	3.40	91.09
750	1	156	30.00	3.36	89.21
800	15	38	39.17	3.64	97.44
850	8	20	37.44	3.73	98.95
900	20	35	37.95	3.67	96.92
950	1	156	30.55	3.39	90.00
1000	5	65	40.92	3.89	103.10
1350	1	60	46.33	4.18	110.86
700	6	Un-known age	13.74	1.54	53.95
800	5		36.71	3.68	97.63
850	1		41.45	3.95	105.00
900	1		44.39	4.09	109.00
1000	1		48.51	4.28	113.44

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

The Average power density of EMR leakages from ovens is much less than the recommended values in table (3.1), at distances 5 cm and 20 cm far from ovens. The magnitudes of electric and magnetic field of radiation leakages from all ovens in tables (4.2) and (4.3) are less than the standard values of general public in table (3.1). It is clear that the electric field is < 61.4 V/m and the magnetic field is < 0.163 A/m. The values of average power density, electric field and magnetic of radiations at distances 5 cm is larger than the values at 20 cm far from ovens, however it is still less than the standard values according to table (3.1)

The relation between the power density of radiation leakage from ovens and age of ovens are shown in Figs. (4.3) and (4.4). These figures show the averaged measured power density leakage as a function of age for groups of ovens of the same operating power 700 W (14 ovens of unknown age were excluded), at distances 5 cm and 20 cm from ovens. Data of Figs. (4.3) and (4.4) are given in tables (b_1) and (b_2) in Appendix (B).

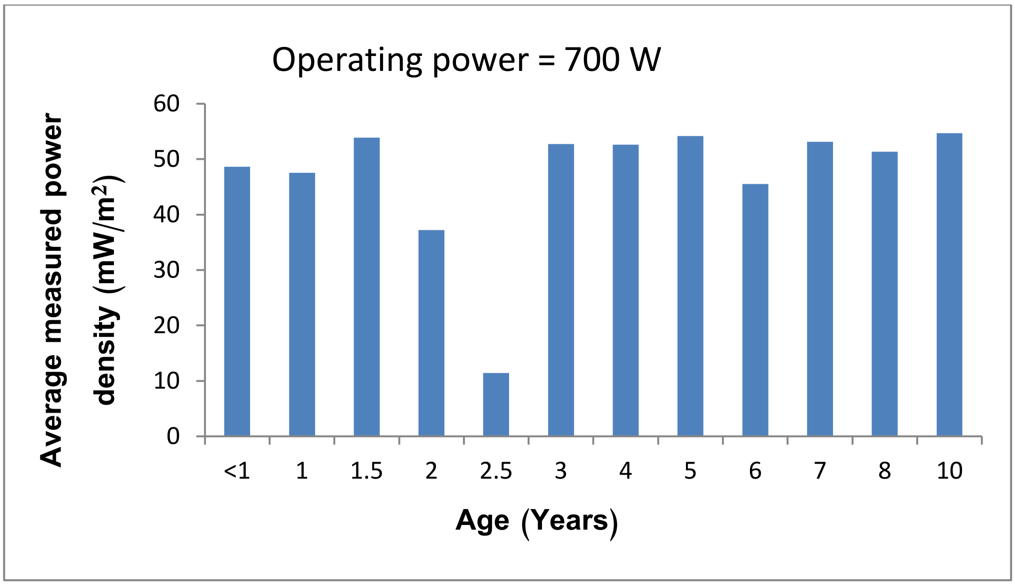

Fig. (4.3): The average of the measured power density leakage as a function of age for groups of ovens at the same operating power 700 W (14 ovens of unknown age were excluded) at distance 5 cm from ovens

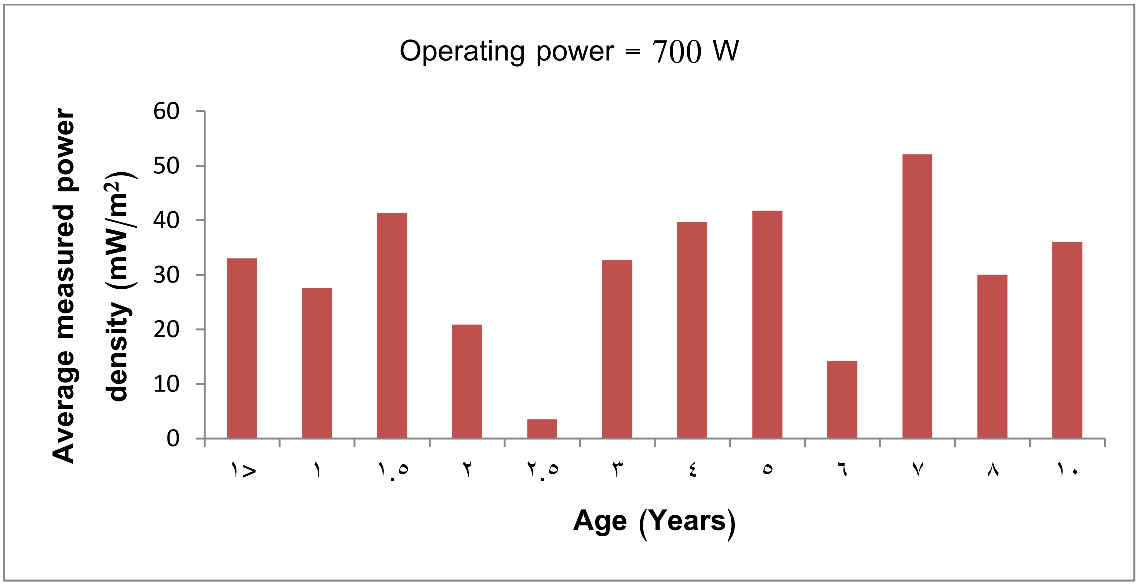

Fig. (4.4): The average of the measured power density leakage as a function of age for groups of ovens at the same operating power 700 W (14 ovens of unknown age were excluded) at distance 20 cm from ovens

Figures (4.3) and (4.4) show the independent of leakages on age of oven for ovens operating at same power 700 W, at 5 cm and 20 cm distances from ovens. From these figures, there is no statistically significant relation between power density leakages from ovens and age. The independent of power density on age is clear in figure (4.4).

4.3 Results of power density measurements with operating power

The operating powers of all ovens in this study ranging from 700 W to 1350 W of different types, models and manufacturers. The average of the measured power density, the average of the calculated electric field, magnetic field of radiations leakage from all ovens of the same age, are given in tables (4.4) and (4.5) at distances 5 cm, and 20 cm far from ovens.

Table (4.4): The measured and calculated parameters* for microwave ovens of the same age at 5 cm distance from oven

Age in Months	**No. of Ovens**	**Avg. Operating power (W)**	**Avg. P (mW/m^2)**	**Avg. E (V/m)**	**Avg. H (A/m) X 10^{-4}**
1-12	17	774	49.12	4.24	112.54
12	12	796	51.00	4.34	115.22
18	6	767	58.48	4.68	124.23
24	9	789	44.03	4.04	107.18
30	1	700	11.41	2.07	55.02
36	24	777	54.48	4.48	118.60
44	11	800	49.42	4.26	112.89
60	9	844	53.31	4.45	117.97
72	2	800	49.18	4.30	114.17
84	2	800	60.94	4.78	127.02
96	3	767	51.45	4.40	116.33
120	1	700	54.69	4.54	120.00
144	1	800	56.81	4.63	123.00
156	3	900	56.73	4.61	122.26
Un-known age	14	782	47.32	4..07	108.01

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

Table (4.5): The measured and calculated parameters* for microwave oven of the same age at 20 cm distance from oven

Age in Months	No. of Ovens	Avg. Operating power (W)	Avg. P (mW/m^2)	Avg. E (V/m)	Avg. H (A/m) X 10^{-4}
1-12	17	774	33.17	3.35	88.85
12	12	796	34.03	3.50	92.73
18	6	767	48.49	4.26	113.02
24	9	789	31.18	3.30	89.02
30	1	700	3.51	1.15	30.50
36	24	777	37.96	3.68	97.67
48	11	800	33.24	3.34	88.53
60	9	844	39.20	3.79	100.54
72	2	800	26.15	3.05	81.22
84	2	800	44.63	4.09	108.41
96	3	767	30.79	3.34	87.67
120	1	700	36.05	3.69	98.00
144	1	800	49.33	4.31	114.00
156	3	900	27.56	2.64	70.11
Un-known age	14	782	28.59	2.85	81.38

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

The magnitudes of average power density, average electric and magnetic field of radiation leakages from all ovens of the same age in tables (4.4) and (4.5) were much less than the standard values of general public in table (3.1). Average power density, Average electric and magnetic field of EMR leakages from all ovens of the same age at distance 5 cm are larger than at 20 cm far from ovens, nevertheless it is still less than the standard values in table (3.1).

The measured power density leakage from microwave oven as a function of operating power are shown in figures (4.5) and (4.6), at 5 cm and 20 cm distances from group of ovens have the same age which is one year. Data of these figures are given in tables (b_3) and (b_4) in Appendix B.

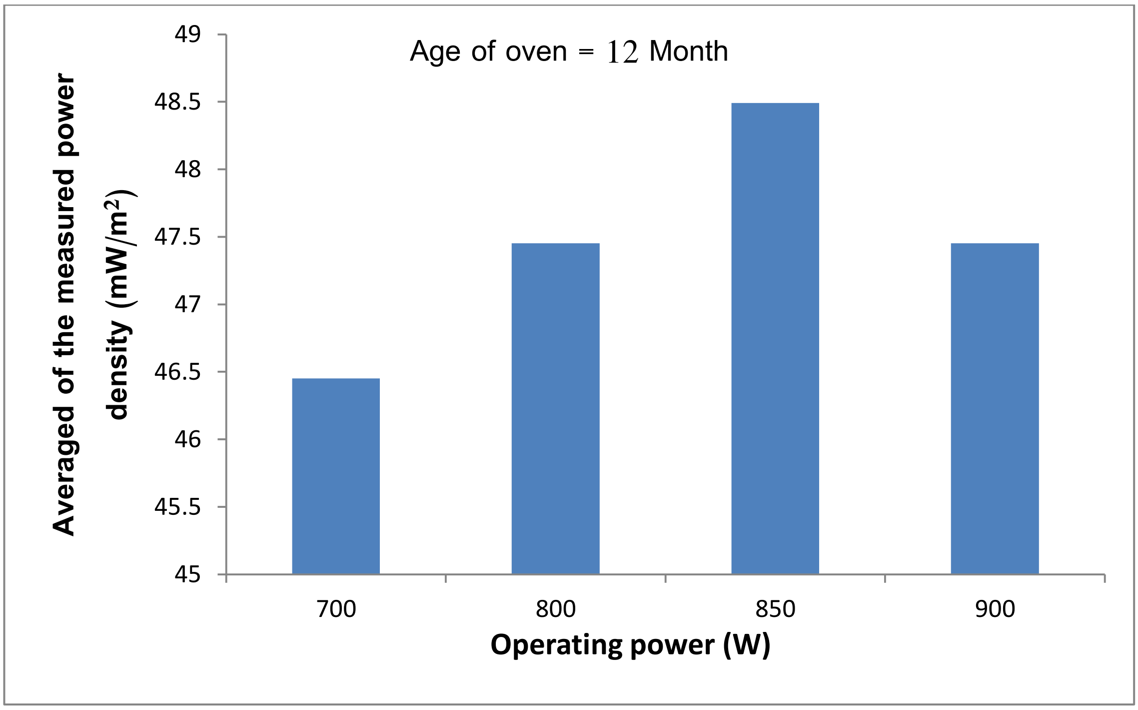

Fig. (4.5): Average power density leakage as a function of operating power at distance 5 cm from oven

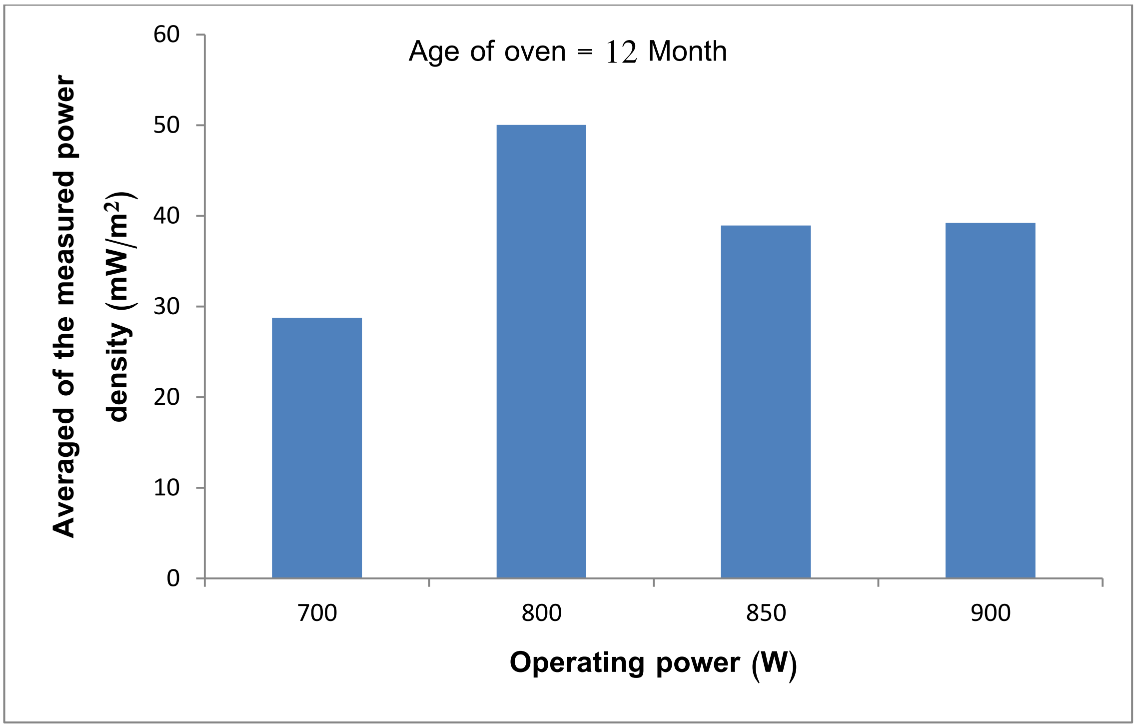

Fig. (4.6): Average power density leakage as a function of operating power at distance 20 cm from oven

The figures (4.5) and (4.6) show the independent of leakages on operating power of ovens at distance 5 cm and 20 cm, no statistically significant relation was observed between the power density of radiation leakage and operating power of ovens from figures (4.5) and (4.6). It is more pronounced in figure (4.8) for all ovens and in figures (4.7) for group of ovens at the same age.

The measured power density of all ovens with operating power are shown in figure (4.7), data of this figure is shown in table (b_5) in Appendix (B).

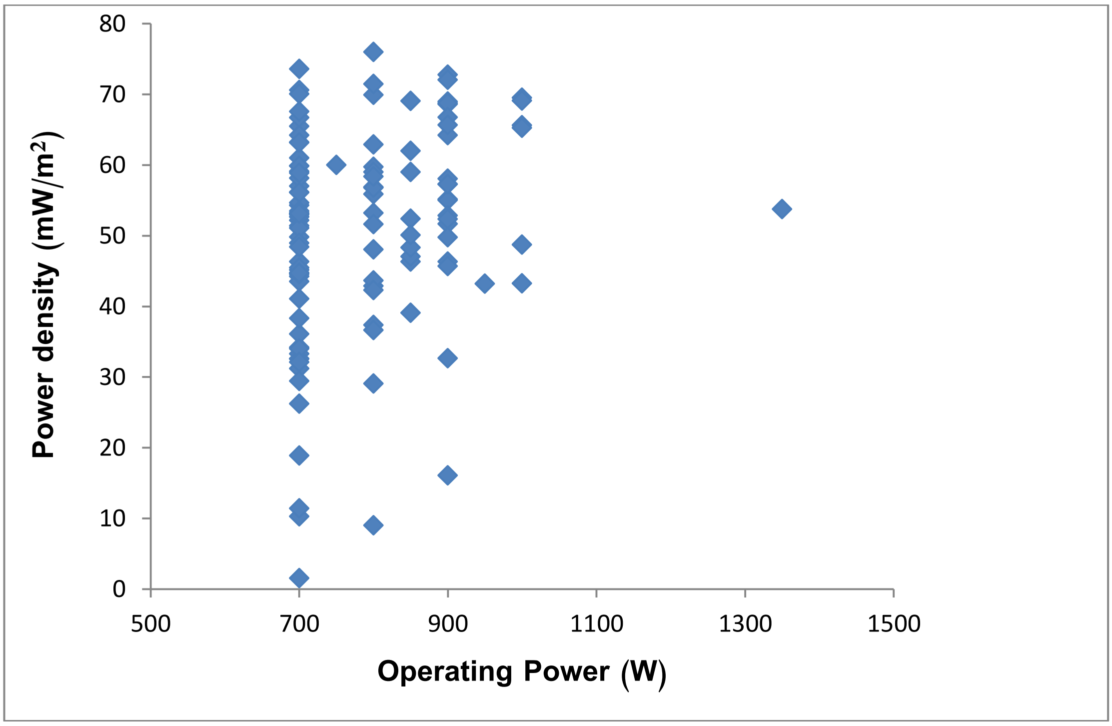

Fig. (4.7): The measured power density for 115 microwave ovens versus operating power at distance 20 cm

The averaged of the measured power density leakage as a function of average operating power for groups of ovens at the same age (14 ovens of unknown age were excluded), are shown in figure (3.8), data of this figure are given in table (b_6) in Appendix (B).

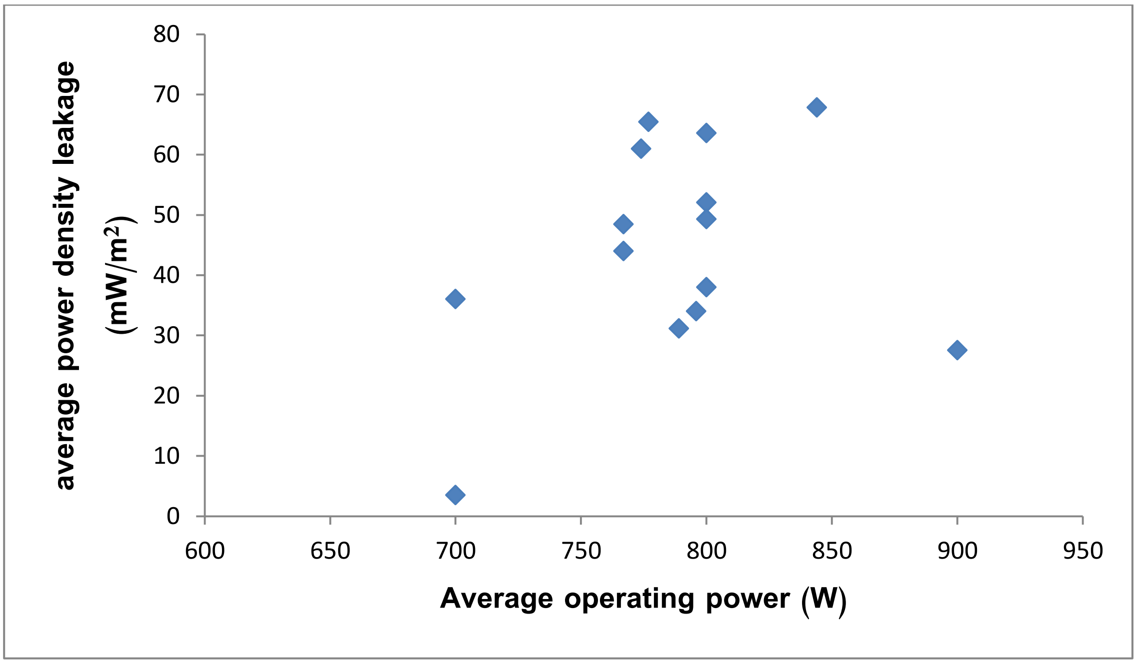

Fig. (4.8): Average power density leakage as a function of average operating power for group of ovens at the same age (14 ovens of unknown age were excluded) at distance 20 cm from oven

4.4 Results of power density measurements with different manufacturers

The type, daily use and manufacturer of ovens are parameters that affect on the value of radiation emissions from microwave ovens. The average electric field magnetic field of all ovens of different manufacturers are calculated and given in tables (4.6) and (4.7) at distances 5 cm, and 20 cm far away from ovens.

Table (4.6): The measured and calculated parameters* for microwave ovens of different manufacturers at 5 cm distance from oven

Manuf-acturer	No. of Ovens	Avg. Operating power (W)	Avg. Age (months)	Avg. P (mW/m^2)	Avg. E (V/m)	Avg. H (A/m) X 10^{-4}
LG	41	777	34	51.92	4.41	116.93
Kennedy	9	744	35	38.63	3.74	99.24
Daeivoo	8	850	29	56.95	4.51	119.59
Konka	4	850	16	55.25	4.56	120.85
Pilot	4	700	19	54.99	4.51	119.73
Universal	4	775	51	53.30	4.47	118.47
Crystal	3	900	37	57.85	4.66	123.65
Electra	3	800	18	47.38	4.20	111.29
Hemilton	3	767	34	45.79	4.01	109.11
Gold star	3	800	24	38.65	3.60	95.51
Hyundai	3	700	24	36.84	3.69	97.91
Sharp	2	750	24	68.50	5.08	134.76
Sanyo	2	900	90	63.18	4.87	129.41
Prestige	2	775	102	58.62	4.70	122.25
Galanz	2	900	54	55.09	4.57	120.86
Morphy richards	1	900	36	72.79	5.24	138.95
Panasonic	1	1000	156	65.65	4.98	131.96
Prisma	1	700	60	56.11	4.60	122.00
Typhoon	1	700	3	51.42	4.40	117.00
Mega	1	700	12	48.99	4.30	113.99
Technolax	1	1000	48	48.72	4.29	113.68
Kenon	1	700	96	43.56	4.05	107.00
compact	1	950	156	43.22	4.04	107.00

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

Table (4.7): The measured and calculated parameters* for microwave ovens of different manufacturers at 20 cm distance from oven

Manuf-acturer	No. of Ovens	Avg. Operating power(W)	Avg. Age (months)	Avg. P (mW/m^2)	Avg. E (V/m)	Avg. H (A/m) X 10^{-4}
LG	41	777	34	36.70	3.63	95.89
Kennedy	9	744	35	25.80	2.98	78.98
Daeivoo	8	850	29	47.26	4.10	110.51
Pilot	4	700	19	42.22	3.94	104.43
Konka	4	850	16	38.61	3.80	100.83
Universal	4	775	51	30.27	3.19	84.93
Crystal	3	900	37	382.00	3.78	100.24
Electra	3	800	18	32.75	3.39	91.19
Hemilton	3	766	34	29.16	2.93	77.64
Gold star	3	800	24	27.62	3.02	79.96
Hyundai	3	700	24	20.49	3.69	97.91
Sanyo	2	900	90	48.02	4.25	112.66
Sharp	2	750	24	46.87	4.20	111.43
Galanz	2	900	54	36.01	3.68	97.70
Prestige	2	775	102	19.17	2.57	68.11
Morphy richards	1	900	36	65.55	4.97	131.86
Panasonic	1	1000	156	52.09	4.43	117.54
Typhoon	1	700	3	46.20	4.17	112.00
Prisma	1	700	60	40.62	3.91	103.80
Technolax	1	1000	48	32.47	3.50	92.80
compact	1	950	156	30.55	3.39	90.00
Mega	1	700	12	21.01	2.82	74.66
Kenon	1	700	96	16.03	2.46	65.00

Parameters*: P = Power density leakage, E = Electric field, H = Magnetic field

The type, model, usage time and manufacturer are parameters that affect on the values of power density of radiation emissions from microwave ovens. The average power density of all ovens of different manufacturers is shown in tables (4.5) and (4.6); from these tables Morphyrichards have the highest values of average power density, average electric and magnetic field at distances 5 cm and 20 cm far from oven. However, it is still much below than the recommended values in table (3.1).

The measured power density, calculated electric and magnetic field of radiation leakages from all ovens with different manufacturer according to table (4.6) and (4.7) were less than the standard values of general public as shown table (3.1).

4.5 Calculation the specific absorption rate

SAR values were calculated using equation (2.5) according to ρ and σ values as follows; SAR for human's brain, $\rho = 1030\ kg/m^3$ and $\sigma = 0.77\ 1/\Omega m$, while SAR for human's skin $\rho = 1100\ kg/m^3$ and $\sigma = 0.872\ 1/\Omega m$, and SAR for human's eye sclera $\rho = 1100\ kg/m^3$ and $\sigma = 1.173\ 1/\Omega m$ (Angelone *et al*., 2004). SAR values are given in tables (4.8), (4.9), (4.10), (4.11), (4.12) and (4.13).

Tables (4.8) and (4.9) show the average SAR of some human tissues that exposure to EMR leakages from microwave ovens of the same age at distances 5 cm and 20 cm from ovens. SAR was calculated for some tissues of human body; human's skin, human's brain and human's eye sclera.

Table (4.8): The values of SAR for some tissues of human body exposure to EMR from ovens of the same operating power at 5 cm distance from oven

Operating Power (W)	No. of Ovens	Avg. Age (months)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
700	50	34	73	69	99
750	1	156	92	86	123
800	15	38	75	71	101
850	8	20	77	72	103
900	20	35	84	79	113
950	1	156	65	61	87
1000	5	65	87	82	118
1350	1	60	80	76	108
700	6	Un-known age	52	47	70
800	5		80	75	108
850	1		93	87	125
900	1		82	78	111
1000	1		103	97	139

SAR*: SAR for human skin

SAR:** SAR for human brain

SAR***: SAR for human eye sclera

Table (4.9): The values of SAR for some tissues of human body exposure to EMR from ovens of the same operating power at 20 cm distance from oven

Operating Power (W)	No. of ovens	Avg. Age (months)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
700	50	34	51	47	68
750	1	156	45	42	60
800	15	38	56	53	76
850	8	20	55	52	74
900	20	35	57	53	76
950	1	156	46	43	61
1000	5	65	61	58	82
1350	1	60	69	65	108
700	6	Un-known age	12	11	15
800	5		55	52	74
850	1		62	58	83
900	1		63	63	89
1000	1		72	68	98

SAR*: SAR for human skin

SAR**: SAR for human brain

SAR***: SAR for human eye sclera

All magnitudes of the calculated SAR in tables (4.7) and (4.8) for human's skin, human's brain and human's eye sclera were much less than the recommended levels of exposure in table (3.2). These results were much less than 0.08 W/ Kg for human's skin, 2 W/ Kg for human's brain and human's eye sclera. Values of SAR in table (4.8) are greater than in tables (4.9), nevertheless it is still below than the recommended values according to table (3.2).

Tables (4.10) and (4.11) show the average SAR for some human tissues that exposure to EMR leakages from groups of microwave ovens have the same operating power at distances 5 cm and 20 cm from ovens. SAR was calculated using equation (2.5) for some tissues of human body, human's skin, human's brain and human's eye sclera.

Table (4.10): The values of SAR for some tissues of human body exposure to EMR from ovens of the same age at 5 cm distance from oven

Age in Months	No. of Ovens	Avg. Operating power (W)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
1-12	17	774	73	69	99
12	12	796	76	72	103
18	6	767	87	82	118
24	9	789	66	62	89
30	1	700	17	16	23
36	24	777	81	77	110
48	11	800	74	73	99
60	9	844	80	75	107
72	2	800	73	69	99
84	2	800	91	86	122
96	3	767	77	72	103
120	1	700	82	77	110
144	1	800	85	80	114
156	3	900	85	80	114
Un-known age	14	782	71	67	95

SAR*: SAR for human skin

SAR:** SAR for human brain

SAR***: SAR for human eye sclera

Table (4.11): The values of SAR for some tissues of human body exposure to EMR from ovens of the same age at 20 cm distance from oven

Age in Months	No. of Ovens	Avg. Operating power (W)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
1-12	17	774	104	94	133
12	12	796	101	95	135
18	6	767	145	137	196
24	9	789	93	88	125
30	1	700	10	10	14
36	24	777	114	107	153
48	11	800	99	94	134
60	9	844	117	111	158
72	2	800	78	74	105
84	2	800	133	126	179
96	3	767	92	87	124
120	1	700	108	102	145
144	1	800	147	139	198
156	3	900	124	116	166
Un-known age	14	782	78	73	105

SAR*: SAR for human skin

SAR**: SAR for human brain

SAR***: SAR for human eye sclera

SAR for human skin, human brain and human eye sclera in tables (4.10) and (4.11) were much less than the safety values of SAR as shown in table (3.2).

The average SAR of some tissues of human body that exposure to EMF leakages from ovens of different manufacturers, SAR are calculated and given in tables (4.12) and (4.13) at distances 5 cm, and 20 cm far from ovens.

Table (4.12): The values of SAR for some tissues of human body exposure to EMR from ovens of different manufactures at 5 cm distance from oven

Manuf-acturer	No. of Ovens	Avg. Operating power (W)	Avg. Age (months)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
LG	41	777	34	78	74	105
Kennedy	9	744	35	58	54	78
Daeivoo	8	850	29	85	80	111
Konka	4	850	16	88	78	111
Pilot	4	700	19	82	77	111
Universal	4	775	51	80	75	107
Crystal	3	900	37	86	81	116
Electra	3	800	18	71	67	95
Hemilton	3	767	34	68	65	92
Gold star	3	800	24	56	54	78
Hyundai	3	700	24	55	52	74
Sharp	2	750	24	102	97	138
Sanyo	2	900	90	94	89	127
Prestige	2	775	102	87	82	118
Galanz	2	900	54	83	78	112
Morphy richards	1	900	36	109	103	146
Panasonic	1	1000	156	98	93	132
Prisma	1	700	60	84	79	113
Typhoon	1	700	3	77	72	103
Mega	1	700	12	73	69	98
Technolax	1	1000	48	73	69	98
Kenon	1	700	96	65	61	88
compact	1	950	156	65	61	87

Table (4.13): The values of SAR for some tissues of human body exposure to EMR from ovens of different manufactures at 20 cm distance from oven

Manuf-acturer	No. of Ovens	Avg. Operating power (W)	Avg. Age (months)	Avg. SAR* (W/Kg) X 10^{-4}	Avg. SAR** (W/Kg) X 10^{-4}	Avg. SAR*** (W/Kg) X 10^{-4}
LG	41	777	34	52	52	72
Kennedy	9	744	35	47	36	52
Daeivoo	8	850	29	70	67	95
Pilot	4	700	19	63	59	85
Konka	4	850	16	58	54	78
Universal	4	775	51	45	43	68
Crystal	3	900	37	57	54	76
Electra	3	800	18	49	46	66
Hemilton	3	767	34	44	41	59
Gold star	3	800	24	41	39	56
Hyundai	3	700	24	31	29	41
Sanyo	2	900	90	72	68	97
Sharp	2	750	24	70	66	94
Galanz	2	900	54	54	51	72
Prestige	2	775	102	29	27	39
Morphy richards	1	900	36	98	92	132
Panasonic	1	1000	156	78	73	105
Typhoon	1	700	3	96	65	93
Prisma	1	700	60	61	57	82
Technolax	1	1000	48	49	46	65
compact	1	950	156	46	43	61
Mega	1	700	12	31	30	42
Kenon	1	700	96	24	23	32

SAR*: SAR for human skin

SAR**: SAR for human brain

SAR***: SAR for human eye sclera

The maximum values of SAR for human skin, human brain and human eye sclera when expose to EMR leakages are from Morphyrichards oven at distance 5 cm and 20 cm from ovens. However these values are still less than recommended level of SAR in table (3.2).

SAR for human skin, human brain and human eye sclera in tables (4.12), (4.13), were much less than the recommended levels of exposure in table (3.2).

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

This survey tested 115 microwave ovens of domestic use in Palestine. The maximum power density, electric field, magnetic field and SAR of radiation leakages from all ovens at distances 5 cm and 20 cm, were found less than the specified limit for the general public exposure. Values of power density leakage from all tested ovens with different ages, operating power, models, daily use, number of users and manufacturer were less than the specified value, the power density leakages from all ovens at 5 cm is < 10 W/m^2 in table (3.1), there is no concern from EMR leakage from microwave ovens.

Usage time of every microwave oven was recorded. The users of microwave ovens spent short time near these ovens; a slight daily use of microwave ovens at homes was found; the maximum duration of use was for an hour and intermittently. Therefor the power density of radiation leakage from microwave ovens was slight.

The maximum value of SAR for human skin was less when compared to the standard value 0.08 W/Kg, all values of calculated SAR for human brain and human eye sclera were much less than the recommended levels of exposure, which is 2 W/Kg according to table (3.2) for standard values of SAR.

There is no concern about exposure to radiation leakage from microwave ovens when they are used in cooking and heating; because of the short time of use of ovens. The amount of radiation leakage does not depend on oven age. There is no statistically significant relation found between operating power and radiation leakages from ovens.

5.2 Some observations

In this study some survey observations were noted:

- It is found that some people buy used ovens; in this study 14 ovens with unknown age.
- Some ovens had broken doors glasses but no abnormal leakage was detected.
- Some people put a wet towel on the door of the microwave oven when they turn it on; they believe it reduces the radiation leaking from these ovens.
- Some ovens have been damaged and the measurements were not taken, so they did not taken into consideration in this study.
- A few of the ovens had problems with their doors that small piece of paper placed in the door to force the doors to be closed.
- The lower parts of some ovens are damaged.
- Some ovens are found above electrical devices, such as television and refrigerator.
- Some ovens stop working although there is a timer.
- Some ovens have used doors which relate to other ovens.
- Small numbers of people are using plastic and metal pots to heat food in microwave oven.

The above mentioned points made us to exclude these ovens from the sample of ovens.

5.3 Recommendations

The suggestions and recommendations mentioned below may reduce the EMR leakage from microwave ovens and its effect on human health. Even though, the results do not exceed the exposure standard values:

1. It is useful for the manufacturers to make labels of information and warnings in local language, to make it easier for people to understand and read the warnings.
2. It is recommended to stay away from the microwave oven a distance of not less than 20 cm while using it, and to stay away from the oven while it is running, and avoid stand next it to cook the food, especially for the children.
3. It is better in future to avoid putting the microwave ovens near other electrical devices; operating microwave oven may cause an interference of the electromagnetic radiation leakage with other radiation.
4. It is prohibited in future to operate the oven while the door is open; this leads to harmful exposure to microwave radiation. It is particularly important that the oven door close properly.
5. It is recommended in future not to operate the microwave oven completely if it is damaged, or does not close well, and to bring the microwave oven to qualified service personnel in order to repair it in the case of being damaged.

6. Long-term exposure to these radiations will cause thermal health problems, effects and risks of radiation leakages appear after years. Therefore, it is recommended to make awareness bulletins and programs about the dangers of long term exposure to electromagnetic radiation.

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Appendix (A)

Table (a_1): The power density of EMR of one oven and distance from oven (age of this oven is 2 years with 700 W operating power)

Distance from oven (cm)	P (mW/m^2)
0	76.02
2	72.08
5	69.06
15	58.62
20	53.84
25	48.02
30	46.02
40	39.02
45	36.95
50	32.04
70	22.62
90	18.07
100	10.04
130	6.10
150	2.02
200	0.99

Table (a_2): The average power density of EMR of all ovens and distance from ovens

Distance from oven (cm)	Avg. P (mW/m^2)
0	59.50
2	53.90
5	48.08
10	42.54
15	37.55
20	32.86
25	27.54
30	31.21
40	20.48
45	17.40
50	14.31
70	10.18
90	7.65
100	6.15
130	3.58
150	2.49
200	1.78

Appendix (B)

Table (b_1): The average measured power density at distance 5 cm from ovens and age of oven

Age of Ovens (Years)	Avg. P (mW/m^2)
<1	48.61
1	47.53
1.5	53.87
2	37.18
2.5	11.41
3	52.75
4	52.60
5	54.16
6	45.49
7	53.13
8	51.34
10	54.69

Table (b_2): The average measured power density at distance 20 cm from ovens and age of oven

Age of Ovens (Years)	Avg. P (mW/m^2)
<1	33.02
1	27.58
1.5	41.37
2	20.89
2.5	3.51
3	32.66
4	39.65
5	41.76
6	14.26
7	52.07
8	30.02
10	36.05

Table (b_3): The average measured power density at distance 5 cm from ovens and operating power

Operating Power (W)	Avg. P (mW/m^2)
700	46.45
800	47.45
850	48.49
900	47.45

Table (b_4): The average measured power density at distance 20 cm from ovens and operating power

Operating Power (W)	Avg. P (mW/m^2)
700	28.77
800	50.02
850	38.93
900	39.22

Table (b_5): The measured power density for 115 microwave ovens and operating power at distance 20 cm

P(mW/m^2)	Operating Power(W)
46.32	700
54.30	700
53.13	700
44.27	700
34.21	700
45.15	700
33.31	700
43.56	700
59.12	700
31.20	700
53.23	700
18.91	700
54.69	700
63.22	700
45.49	700
36.11	700
49.81	700
52.17	700
1.54	700
32.62	700

44.57	700
32.56	700
41.09	700
44.77	700
53.00	700
51.42	700
61.03	700
60.00	750
37.38	800
42.91	800
55.91	800
56.89	800
53.24	800
56.81	800
9.04	800
59.76	800
43.67	800
36.66	800
62.02	850
16.09	900
51.67	900
46.32	900
45.70	900
32.64	900
55.17	900
55.02	900
43.22	950
43.24	1000
53.77	1350
65.51	700
70.61	700
56.16	700
10.30	700
38.32	700
59.88	700
64.22	700
29.46	700
44.70	700
34.00	700
59.87	700
32.14	700

52.70	700
26.22	700
51.10	700
48.99	700
57.05	700
53.52	700
70.05	700
66.71	700
48.40	700
58.15	700
67.60	700
73.61	700
11.41	700
58.90	700
53.12	700
63.18	700
56.11	700
62.91	800
59.02	800
58.40	800
42.33	800
29.08	800
76.01	800
51.65	800
48.05	800
69.95	800
71.48	800
46.34	850
47.04	850

P (mW/m^2)	Operating Power (W)
39.09	850
69.06	850
59.02	850
52.39	850
48.32	850
50.11	850
68.60	900
72.79	900
52.88	900
68.97	900
57.32	900
68.75	900
72.07	900
64.23	900
58.05	900
66.76	900
65.66	900
49.78	900
52.39	900
57.31	900
65.65	1000
65.27	1000
69.54	1000
69.11	1000
48.72	1000

Table (b_6): Average power density leakage, average operating power for group of ovens at the same age (14 ovens of unknown age were excluded) at distance 20 cm from oven

Operating power (W)	Avg. P (mW/m^2)
774	60.97
796	34.03
767	48.49
789	31.18
700	3.51
777	65.46
800	63.62
844	67.82
800	38.03
800	52.07
767	44.02
700	36.05
800	49.33
900	27.56

Appendix C

Paper to collect data and information about microwave oven

Ovens number :	Dates of manufacturing :
Country of origin :	Manufacturer :
Age of oven :	Number of users :
Daily use :	Location of the oven at home :
Operating power :	Age of user :
User awareness :	Frequency :
Power density (mW/cm^2) :	Electric field (E): Magnetic field (H) :

Distance from oven (cm)	Leakage ($\mu W/m^2$)
0	
2	
5	
10	
15	
20	
25	
30	
40	
45	
50	
70	
90	
100	
130	
150	
200	

جامعة النجاح الوطنية

كلية الدراسات العليا

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د .محمد ابو جعفر

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس – فلسطين

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الملخص

لقد تم قياس كمية التسرب الإشعاعي، وحساب المجال الكهربائي، والمجال المغناطيسي ومعدل الامتصاص النوعي من 115 فرن ميكروويف للإستخدام المنزلي في نابلس- فلسطين . لقياس كمية التسرب الإشعاعي من الأفران استخدم جهاز Acoustimeter . يتراوح عمر الأفران المقاسة من شهر- 13 سنة (بينهم 14 فرناً مستعمل غير معروف العمر) وقوة تشغيلها تتراوح بين 700-1350 واط، الأفران كانت من أنواع ونماذج مختلفة . وقد تم قياس كثافة تدفق الطاقة للإشعاعات المتسربة من الأفران عند مسافات مختلفة، وحساب المجال الكهربائي، المجال المغناطيسي، ومعدل الامتصاص النوعي على بعد 5 سم و 20 سم من الأفران. كانت هذه القيم أقل بكثير من مستويات المجالات الكهرومغناطيسية (EMF) الموصى بها من اللجنة الدولية للحماية من الإشعاع غير المؤين (ICNIRP) عند تردد 2.45 غيغاهيرتز. وتبين من النتائج أن كثافة تدفق الطاقة للإشعاعات الكهرومغناطيسية لا تعتمد على كل من عمر الفرن وقدرة تشغيل الأفران.