

# **CHAPTER ONE**

## **General Introduction**

### **1.1. Introduction**

Radiation is energy in the form of waves or streams of particles. There are many kinds of radiation all around us. When people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms. Sound and visible light are familiar forms of radiation; other types include ultraviolet radiation (that produces a suntan), infrared radiation (a form of heat energy), and radio and television signals. Uncontrolled use of man-made radiation carries potential risks to the health and safety of workers and the public.

The purpose of this study is to provide clear and simple information about effects of radiofrequency on water: What is radiofrequency, where it comes from and how it is used. It also presents information on radiation health effects.

### **1.2. Radiofrequency**

Radiofrequency (RF) is a rate of oscillation in the range of around 3 kHz to 300 GHz, which corresponds to the frequency of radio waves and the alternating currents which carry radio signals. RF usually refers to electrical rather than mechanical oscillations. (ISO/IEC 14443-2:2001)

#### **1.2.1. Special properties of RF current**

- Electric currents that oscillate at radio frequencies have special properties not shared by direct current or alternating current of lower frequencies.

- RF current does not penetrate deeply into electrical conductors but tends to flow along their surfaces; this is known as the [skin effect](#). For this reason, when the human body comes in contact with high power RF currents it can cause superficial but serious burns called RF burns.
- RF currents applied to the body often do not cause the painful sensation of electric shock as do lower frequency currents. This is because the current changes direction too quickly to trigger depolarization of nerve membranes.
- RF current can easily ionize air, creating a conductive path through it. This property is exploited by "high frequency" units used in electric [arc welding](#), which use currents at higher frequencies than power distribution uses.
- Another property is the ability to appear to flow through paths that contain insulating material, like the [dielectric](#) insulator of a capacitor. (Curtis, Thomas Stanley, 1916)
- When conducted by an ordinary electric cable, RF current has a tendency to reflect from discontinuities in the cable such as connectors and travel back down the cable toward the source, causing a condition called standing waves, so RF current must be carried by specialized types of cables called [transmission line](#),(Mieny, 2003)

### 1.3. Water

Water is a transparent fluid which forms the world's streams, lakes, oceans and rain, and is the major constituent of the fluids of living bodies. As a [chemical compound](#), a [water molecule](#) contains one [oxygen](#) and two hydrogen [atoms](#) that are connected by [covalent bonds](#).

Water is a [liquid](#) at standard ambient temperature and pressure, but it often co-exists on [Earth](#) with its [solid](#) state, [ice](#); and [gaseous](#) state, [steam](#) ([water vapor](#)). It plays an important role in the [world economy](#), as it functions as a [solvent](#) for a wide variety of chemical substances and facilitates industrial cooling and transportation. Approximately 70% of the fresh water used by humans goes to [agriculture](#) (CIA-the world factbook, 2008).

### 1.3.1. Chemical and physical properties

Water is the [chemical substance](#) with [chemical formula](#)  $H_2O$ : one molecule of water has two [hydrogen atoms covalently bonded](#) to a single [oxygen](#) atom.

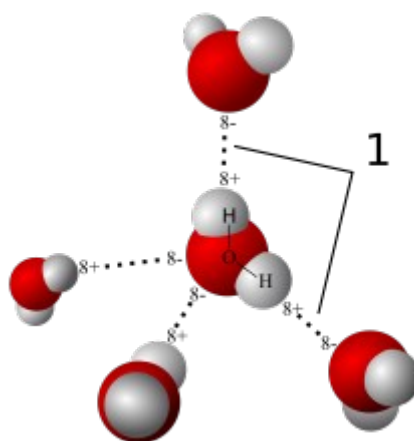


Fig (1-1) [hydrogen bonds](#) (1) between molecules of water.

#### **The major chemical and physical properties of water are:**

- Water is a liquid at standard temperature and pressure. It is tasteless and odorless. The intrinsic [color of water](#) and ice is a very slight blue hue, although both appear colorless in small quantities. Water vapor is essentially invisible as a gas.(Braun, 1993)
- Water is [transparent](#) in the visible [electromagnetic spectrum](#). Thus [aquatic plants](#) can live in water because [sunlight](#) can reach them. Infrared light is strongly [absorbed](#) by the hydrogen-oxygen bonds (Campbell, 2006).

- Water is a good polar [solvent](#) and is often referred to as the universal [solvent](#). Substances that dissolve in water, e.g., [salts](#), [sugars](#), [acids](#), [alkalis](#), and some [gases](#) – especially oxygen and [carbon dioxide](#) ([carbonation](#)) – are known as [hydrophilic](#) (water-loving) substances, while those that are [immiscible](#) with water (e.g., [fats and oils](#)), are known as [hydrophobic](#) (water-fearing) substances.
- All of the components in cells ([proteins](#), [DNA](#) and [polysaccharides](#)) are dissolved in water, deriving their structure and activity from their interactions with the water.
- Pure water has a low [electrical conductivity](#), but this increases with the [dissolution](#) of a small amount of ionic material such as [sodium chloride](#).
- The [density](#) of liquid water is 1,000 kg/m<sup>3</sup> at 4 °C, where ice has a density of 917 kg/m<sup>3</sup>. (Kotz, 2005)
- Water can be [split by electrolysis](#) into hydrogen and oxygen. The [energy](#) required to split water into hydrogen and oxygen by [electrolysis](#) or any other means is greater than the energy that can be collected when the hydrogen and oxygen recombine (Ball Philip, 2007).
- As an oxide of hydrogen, water is formed when hydrogen or hydrogen-containing compounds [burn](#) or [react](#) with oxygen or oxygen-containing compounds. Water is not a [fuel](#); it is an end-product of the combustion of hydrogen.
- [Elements](#) which are more [electropositive](#) than hydrogen such as lithium, sodium, calcium, potassium and cesium displace hydrogen from water, forming hydroxides. Being a flammable gas, the hydrogen given off is dangerous and the reaction of water with the more

electropositive of these elements may be violently explosive (Clavin, 2011).

#### **1.4. Problem of study:**

RF is used in many applications e.g. communication (mobile, tower) and medical (MRI), and may have an effect on human body.

Consider the water needs to be evaluate after expose to RF to prove or despite the effect.

#### **1.5. Objectives:**

##### **General objective:**

Study the effect of radiofrequency radiation on water using uv-spectrophotometer and other techniques.

##### **Specific objectives:**

- To measure the change in temperature using thermometer (0.1<sup>0</sup> Kelvin).
- To study the optical properties of water using uv-spectrophotometer.
- To study electrical properties using conductivity meter.

#### **1.6. Thesis outline:**

This thesis is concerned the effect of radiofrequency on water; it is divided into five chapters. Chapter one is the introduction and the objectives, chapter two is about Theoretical back ground and literature review, chapter three focuses on methods and materials, chapter four contains the results, analysis and discussion, while chapter five contains the conclusions, recommendations.

## Chapter Two

### Literature Review

## 2.1 Theoretical background

### 2.1.1 Electromagnetic spectrum

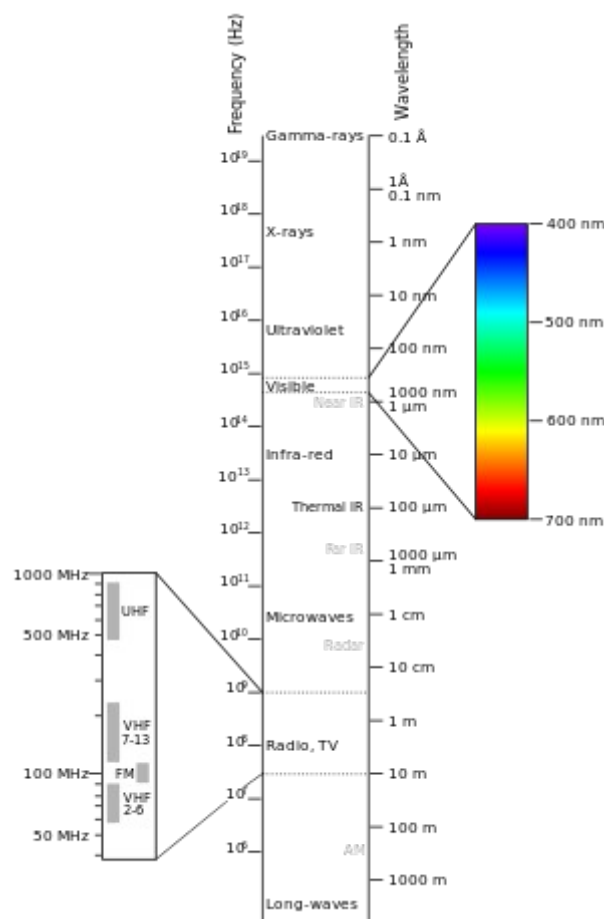
It is the range of all possible frequencies of electromagnetic radiation. It extends from low frequencies used for modern [radio](#) communications to gamma and x-ray radiation at the short-[wavelength](#) (high-frequency), thereby covering wavelengths from thousands of [kilometers](#) down to a [fraction](#) of the size of an atom. The limit for long wavelengths is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length.

Most parts of the electromagnetic spectrum are used in science for spectroscopic and other probing interactions, as ways to study and characterize matter. In addition, radiation from various parts of the spectrum has found many other uses for communications and manufacturing. (Bakshi, 2009).

[Spectroscopy](#) can detect a much wider region of the EM spectrum than the visible range of 400nm to 700nm. A common laboratory spectroscope can detect wavelengths from 2nm to 2500nm. Detailed information about the physical properties of objects, gases, or even stars can be obtained from this type of device. Spectroscopes are widely used in [astrophysics](#). (Condon, 2008)

Whenever electromagnetic waves exist in a [medium](#) with [matter](#), their wavelength is decreased. No matter what medium they are traveling through, they are usually quoted in terms of the vacuum wavelength, although this is not always explicitly stated. The behavior of EM radiation depends on its wavelength. When EM radiation interacts with single atoms and molecules, its behavior also depends on the amount of energy per [quantum](#) (photon) it carries.

Generally, electromagnetic radiation is classified by wavelength into [radio wave](#), microwave, infrared, the visible region is perceived as light, ultraviolet, X-rays and gamma rays.



**Fig (2-1) shows electromagnetic spectrum**

This spectrum of radiant energy can be divided into ionizing and non-ionizing, according to whether it ionizes or does not ionize the atoms in ordinary chemical matter.

#### **2.1.1.1 Ionizing radiation**

It is radiation that carries enough energy to liberate [electrons](#) from [atoms](#) or molecules, thereby ionizing them. Ionizing radiation comprises [subatomic particles](#), ions or [atoms](#) moving at [relativistic speeds](#), and electromagnetic waves on the short wavelength end of the electromagnetic spectrum. Gamma rays, X-rays, and the upper vacuum ultraviolet part of the ultraviolet spectrum are ionizing. (Stallcup, James, 2006).

It is invisible and not directly detectable by human senses, so radiation detection instruments such as Geiger counters are required. However, in some cases ionizing radiation may lead to secondary emission of visible light upon interaction with matter, such as in [Cherenkov radiation](#) and radio luminescence

It arises from a variety of sources, such as bombardment of the environmental of Earth by [cosmic rays](#), the decay of [radioactive](#) materials, matter at extremely high temperatures, or acceleration of charged particles by electromagnetic fields. Ionizing radiation can also be generated by the production of high-energy particles in [X-ray tubes](#) and [particle accelerators](#). It is applied in a wide variety of fields such as [medicine](#), research, manufacturing, construction, and many other areas, but presents a health hazard if proper measures against undesired exposure are not followed. Exposure to ionizing radiation may damage to



living tissue, and can result in mutation, radiation sickness, [cancer](#), and [death](#).

## **Ultraviolet radiation**

Ultraviolet of wavelengths from 10nm to 125nm ionizes air molecules, in some aspects occupies the overlap in a middle ground, as it has some features of both ionizing and non-ionizing radiations. Although nearly ultraviolet spectrum that penetrates the Earth's atmosphere is non-ionizing, this radiation does far more damage to many molecules in biological systems than can be accounted for by heating effects, such as (sunburn). These properties derive from ultraviolet's power to alter chemical bonds, even without having quite enough energy to ionize atoms, Some of the ultraviolet spectrum that does reach the ground (the part that begins above energies of 3.1eV, or wavelengths less than 400nm) is non-ionizing, but is still biologically hazardous due to the ability of single photons of this energy to cause electronic excitation in biological molecules, and thus damage them by means of unwanted reactions. This property gives the ultraviolet spectrum some of the dangers of ionizing radiation in biological systems without actual ionization occurring. (Mehta, 2011)

## **X-rays**

Are electromagnetic waves with wavelengths less than about  $10^{-9}\text{m}$  (greater than  $3 \times 10^{17}$  Hz and 1,240eV). Due to their higher energies, X-rays can also interact with matter by means of the [Compton](#), [photoelectric and pair production](#) [Effect](#). Hard X-rays have shorter wavelengths than soft X-rays. As they can pass through most substances

with some absorption, X-rays can be used to 'see through' objects with thicknesses less than equivalent to a few meters of water. One notable use in this category is diagnostic X-ray images in medicine (a process known as [radiography](#)). X-rays are useful

as probes in high-energy physics. In astronomy, the accretion disks around [neutron stars](#) and [black holes](#) emit X-rays, which enable them to be studied. X-rays are also emitted by the coronas of stars and are strongly emitted by some types of [nebulae](#). (Retrieved 2009-11-12)

## **Gamma rays**

Gamma ( $\gamma$ ) radiation consists of photons with a wavelength less than  $3 \times 10^{-11}$  meters. These are the most energetic [photons](#), having no defined lower limit to their wavelength. In [astronomy](#) they are valuable for studying high-energy objects or regions, however like with X-rays this can only be done with telescopes outside the Earth's atmosphere. Gamma rays are useful to physicists thanks to their penetrative ability and their production from a number of [radioisotopes](#). Gamma rays are also used for the [irradiation](#) of food and seed for sterilization, and in medicine, they are occasionally used in [radiation cancer therapy](#). More commonly, gamma rays are used for diagnostic imaging in [nuclear medicine](#), with an example being [PET scans](#). The wavelength of gamma rays can be measured with high accuracy by means of [photo peak](#). Gamma rays are first and mostly blocked by Earth's magnetosphere then by the atmosphere. (Retrieved, 2010)

### 2.1.1.2 Non-ionizing radiation

This refers to any type of [electromagnetic radiation](#) that does not carry enough [energy](#) to [ionize](#) atoms or molecules to completely remove an [electron](#) from an [atom](#) or [molecule](#). The energy of particles of non-ionizing radiation is low, and instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has only sufficient energy to change the rotational, vibrational or electronic valence configurations of molecules and atoms. This produces thermal effects. The possible non-thermal effects of non-ionizing forms of radiation on living tissue have only recently been studied. (Kwan-Hoong, 2003)

Much of the current debate is about relatively low levels of exposure to radio frequency (RF) radiation from mobile phones and base stations producing "non-thermal" effects. Some experiments have suggested that there may be biological effects at non-thermal exposure levels, but the evidence for production of health hazard is contradictory and unproven. The scientific community and international bodies acknowledge that further research is needed to improve our understanding in some areas. Meanwhile the consensus is that there is no consistent and convincing scientific evidence of adverse health effects caused by RF radiation at powers sufficiently low that no thermal health effects are produced. (Kwan-Hoong,2003).

Non-ionizing radiation can produce [non-mutagenic](#) effects such as inciting thermal energy in biological tissue that can lead to burns. Recently, the International Agency for Research on Cancer (IARC) from the WHO (World Health Organization) released a statement indicating

that radiofrequency electromagnetic fields (including microwave and millimeter waves) are possibly carcinogenic to humans. (IARC, 2011)

In terms of potential biological effects, the non-ionizing portion of the spectrum can be subdivided into:

1. The optical radiation portion, where electron excitation can occur (visible light, infrared light)
2. The portion where the wavelength is smaller than the body.  
Heating via induced currents can occur. In addition there are claims of other adverse biological effects. Such effects are not well understood and even largely denied. (MW and higher-frequency RF).
3. The portion where the wavelength is much larger than the body, and heating via induced currents seldom occurs (lower-frequency RF, power frequencies, static fields).( John E. Moulder,2003)

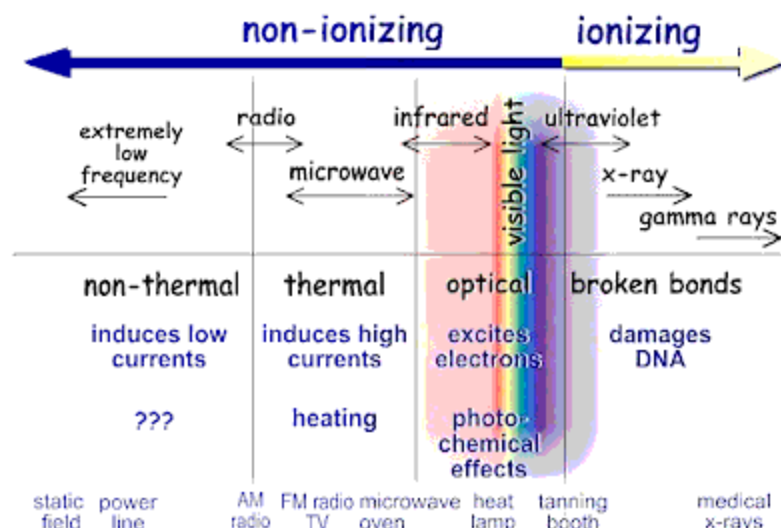


Fig (2-2) shows different types of [electromagnetic radiation](#)

## **Mechanisms of interaction of non ionizing radiation with matter**

Visible and near ultraviolet electromagnetic radiation may induce [photochemical reactions](#), or accelerate [radical reactions](#). Near ultraviolet radiation, although technically non-ionizing, may still excite and cause photochemical reactions in some molecules. This happens because at ultraviolet photon energies, molecules may become electronically-excited or promoted to free-radical form, even without ionization taking place. (Helv, 2000)

The energy of particles of non-ionizing radiation is low, and instead of producing charged ions when passing through matter, it has only sufficient energy to change the rotational, vibrational or electronic valence configurations of molecules and atoms. This produces thermal effects. The possible non-thermal effects of non-ionizing forms of radiation on living tissue have only recently been studied. Much of the current debate is about relatively low levels of exposure to radio frequency (RF) radiation from mobile phones and base stations producing "non-thermal" effects. (Kwan-Hoong , 2003)

**Table (2-1): shows types of non-ionizing radiation (John, 2000)**

	Source	Wavelength	Frequency	Biological effects
<a href="#">UVA</a>	Black light, Sunlight	318–400 nm	750–950 THz	Eye – <a href="#">photochemical</a> cataract; skin – erythema, inc. pigmentation
<a href="#">Visible light</a>	<a href="#">Sunlight</a> , <a href="#">fire</a> , LEDs, light bulbs, <a href="#">Lasers</a>	400–780 nm	385–750 THz	Skin photo aging; eye – photochemical & thermal retinal injury
<a href="#">IR-A</a>	Sunlight, thermal radiation, incandescent light bulbs, Lasers, remote controls	780 nm – 1.4 $\mu$ m	215–385 THz	Eye – thermal retinal injury, thermal cataract; skin burn
<a href="#">IR-B</a>	Sunlight, Thermal radiation, Incandescent light bulbs, Lasers	1.4–3 $\mu$ m	100–215 THz	Eye – <a href="#">corneal burn</a> , cataract; skin burn
<a href="#">IR-C</a>	Sunlight, Thermal radiation, Incandescent light bulbs, <a href="#">Far-infrared laser</a>	3 $\mu$ m – 1 mm	300 GHz – 100 THz	Eye – corneal burn, cataract; heating of body surface
<a href="#">Microwave</a>	PCS phones, some mobile/cell phones, microwave ovens, cordless phones, millimeter waves, airport millimeter scanners, motion detectors, long-distance telecommunications, radar, <a href="#">Wi-Fi</a>	1 mm – 33 cm	1–300 GHz	Heating of <a href="#">body tissue</a> and possible carcinogenic.

Both ionizing and non-ionizing radiation can be harmful to organisms and can result in changes to the natural environment

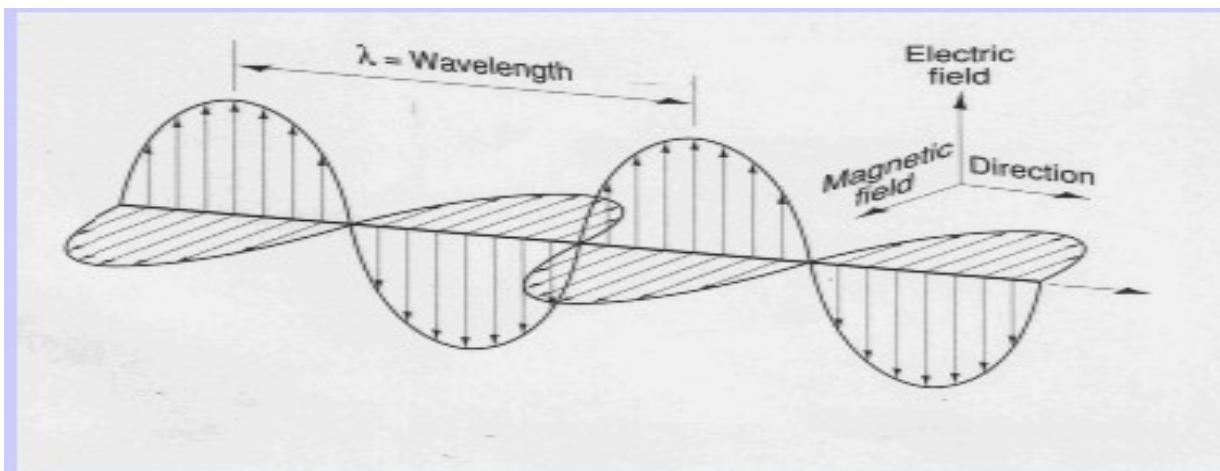
The question of harm to biological systems due to low-power ionizing and non-ionizing radiation is not settled. Controversy continues about possible non-heating effects of low-power non-ionizing radiation, such as non-heating microwave and radio wave exposure. Non-ionizing radiation is usually considered to have a safe lower limit; especially as thermal radiation is unavoidable and ubiquitous.

## **Radiofrequency Electromagnetic Waves 2.1.2**

### **:Definitions 2.1.2.1**

RF waves are electromagnetic (EM) waves used for radio transmission. They carry electromagnetic energy as they propagate in free air and dense media. A changing electric field will create a changing magnetic field, and a changing magnetic field will create a changing electric field.

(( National Weather Service, 2012



**Fig (2-3) “TEM wave” courtesy of Wikibooks (CC BY-SA)**

### **Continuous RF Wave**

:RF wave(s) with

successive identical oscillations • 1

(constant height (amplitude • 2

(constant repetition (frequency • 3



constant output power equal to the average power • 4

.varying sinusoidally with time • 5

(National Radiation Protection Board, 2004) 6

**Examples:** power supplies, plasma etching, welding/cutting arcs, continuous wave NMR, antennas, mobile phone communication, cordless phones, AM and FM broadcasting, anti-theft devices, RF heat sealers, portable radio systems, burglar alarms, microwave ovens, etc.

(( RfCom.ca, 2012

### **Pulsed RF Wave**

:RF waves that are pulsed

The transmitter is pulsed, i.e., “on” for a short time and turned “off” • 1  
.for a longer time

Best example: radar • 2

Common radar frequencies: 50–330 MHz, 300–1,000 MHz, 1–2 • 3  
GHz, 2–4 GHz, 4–8 GHz, 8–12 GHz, 12–18 GHz, 18–27 GHz, 27–40

(GHz, 40–100+ GHz , (Airborne Early Warning Association, 2012

Human exposures to radar systems are from police speed control • 4  
radar, airplane and ship radar, meteorological precipitation  
.monitoring, and ground-penetrating radar for geological observations

Examples of pulsed RF devices: keyless entry pulsed NMR systems, • 5  
analog or digital radar from airports, ships, speed detection, military  
.devices, satellites, electronic test equipment, etc

### **Sources of RF 2.1.2.2**

#### **Natural Sources of RF 2.1.2.2.1**

:Natural RF emitters

earth • 1

sun • 2

thunderstorm activity • 3

the ionosphere • 4

deep-space extraterrestrial sources • 5

:Thunderstorm RF

MHz 300–30 • 1

(Very High Frequency (VHF)( Yasuda, 2009 • 2

:Characteristics of Natural RF

Does not pass through hills or large structures • 1

Cannot be transmitted beyond the horizon • 2

Does not bend readily around the earth's curvature • 3

#### **Biological Sources of RF/EMF 2.1.2.2.2**

Humans and mammals emit EMF energy

:A human body, at 37°C, emits an EMF of

(Frequency: 31 THz (31,000 GHz • 1

Wavelength: 9.66 μm 2

#### **Consumer Products 2.1.2.2.3**

##### **Wireless Phone Evolution**

**First generation** (1G) mobile phones – 1980s (Mobile Phone Directory, (2012

Frequency: 450 MHz, 800–900 MHz • 1

(Radiated power: 600mW (0.6 W • 2

Analogue circuit-switched technology • 3

**Second generation** (2G) mobile phone systems – 1990s

(Frequency: 800, 900, 1500, 1800, 1900 MHz (US • 1

Pure digital technology • 2

Caller identity and text messaging • 3

**Third generation** (3G) mobile phone systems – 2001

Frequencies: 1885–2025, 2110–2200 MHz • 1

Added broadband internet and high-tech video calls • 2

Able to use 2G and 2.5G networks where the 3G service • 3

(unavailable.( Literral M, 2008 4

## **Baby Monitors**

Frequencies: 16 MHz, 9.3–49.9 MHz, 900 MHz, 2.4 GHz • 1

(Range: up to 300 m.( Anonymous, 2012 • 2

Power: 0.010 W to 3 W • 3

## **Bluetooth Devices**

Frequencies: 2.4 to 2.485 GHz – Industrial, Scientific and • 1

Medical (ISM) band

No license required • 2

Range: short range of 5–100 m • 3

.Power at head: 100 mW • 4

Bluetooth products: Over 500 products including hands-free • 5

calling, GPS navigation, portable music players, wireless headsets, wireless speakers, wireless hands-free car systems, printers, laptops, cameras, health and fitness device computers, heart rate monitors, phones, (home security systems, etc. (Kirkland, 2012

Frequencies: 902–928 MHz, 1880–1900 MHz, 1920–1930 MHz • 1

(Range: 91 m in open area.( Kowalk W, 2012 • 2

## **Cordless Phones**

Frequency: 43–49 MHz, 900 MHz, 2.4 GHz and 5.8 GHz • 1

Range: 12–75 m, 20–200 m, 60–450 m, 90–600 m • 2

Long Range: Up to 10 km • 3

Power: 1–5 watts • 4

Emitted Power: 0.2–1.0 mW/cm<sup>2</sup> • 5

Older cordless phone constant power: 10 mW • 6

Digital cordless phones – millisecond transmissions, average • 7

(power: 0.01 mW.( Shop-WiFi.com, 2012

## **Wireless Head Phones**

Frequency: 86–108 MHz, 863 MHz, 900 MHz, 913.5 MHz, 914 • 1

MHz, 914.5 MHz, 925 MHz, 926.0 MHz, 926.5 MHz, 2.4 GHz

:Range • 2

+ o Home use: 1–3 m, 3–9 m, 10 m 3

(o Industrial: 6–100 m.( Sennheiser, 2012 4

Uses: listening to music, watching a video

### **Wireless Home Security**

Frequencies: 43–49 MHz, 433 MHz, 902–928 MHz, 2.4 GHz– • 1

2.4835 GHz, 5.725 GHz and 5.850 GHz

(Typical output power: 10 to 100mW (0.01–0.1 watts • 2

RF emissions: 0.1% of HC SC 6 allowable exposure limits. • 3

(( Health Canada, 2009

### **Wi-Fi Systems**

Frequency: 2.4 GHz, 915 MHz, 5.8 GHz • 1

Power density: <0.003 W/m<sup>2</sup> to 0.03 W/m<sup>2</sup> • 2

Typical exposures: 1.8–4.6 V/m • 3

HC SC6 exposure limit: typical exposures 0.03% to 0.3% of HC • 4

SC6 limits

Health Protection Agency: typical exposure 100mW (0.1 W). • 5

(( Verloock, 2010

### **Smart Meters**

Frequency: 902–928 MHz • 1

End point power: ¼ Watt or 0.25 W • 2

Maximum power (cell relays): <0.5 W • 3

Instantaneous power density: at 30 cm: 0.02 to 0.04 W/m<sup>2</sup> (2 to • 4

(4µW/cm<sup>2</sup>

Typical accumulated emission duration: approximately 60 • 5

seconds per day

RF emissions from Smart Meters: Far below HC SC 6 exposure • 6

(limits at 900 MHz: 600µW/cm<sup>2</sup>.( BC Hydro, 2012

Example of measured instantaneous peak power densities from Smart  
:Meters

One Smart Meter at 30 cm–3.2μW/cm <sup>2</sup> •	1
One Smart Meter at 1 m–2.0μW/cm <sup>2</sup> •	2
One Smart Meter at 3 m–1.2μW/cm <sup>2</sup> •	3
Ten operating Smart Meters at 30 cm–4.0μW/cm <sup>2</sup> •	4
Ten operating Smart Meters at 1 m–2.6μW/cm <sup>2</sup>	
Ten operating Smart Meters at 3 m–1.8μW/cm <sup>2</sup>	

### **AM Radio, FM Radio, and TV Transmissions**

Amplitude modulation (AM) radio frequency: 550 to 1600 kHz •	1
Frequency modulated (FM) radio frequency: 88 to 108 MHz •	2
Airborne television (TV) transmission frequency: 300 to 400 •	3
MHz	
Humans absorb up to five times more RF from FM radio and TV •	4
.than from mobile phone base stations	
SC 6 exposure limits exceeded 1–2 m from AM radio antennae •	5
SC 6 exposure limits exceeded 1–2 m from FM radio antennae •	6
High powers present danger of electrocution with contact •	7
Work Safe BC regulates permissible exposures to workers.( Work •	8
(Safe BC, 2012	



**Fig (2-4) (left) “Super turnstile Antenna” courtesy of Hans-Peter School, Wikipedia (CC BY-SA) (Middle) “ENOME Anywhere!” courtesy of Coolmitch, Flickr (CC BY-NC-ND) (Right) “Broadcast antenna” courtesy of HerPhotographer, Flickr (CC BY-NC-SA)**

**CB and FRS Radio**

Frequency: CB – 27 MHz, Family Radio Service (FRS) – • 1  
462/467 MHz

(Power: CB: 4 W; FRS: 500 mW–2 W.( Industry Canada,2007 • 2

### **Microwave Ovens**

Frequency: home 2.45 GHz; industrial 915 MHz • 1

Power: home 400–1400 W • 2

Typical microwave oven leakage: up to 1 mW/cm<sup>2</sup> • 3

Average microwave oven leakage 0.17–0.52 mW/cm<sup>2</sup> • 4

Physical/structural damage of microwave may result in RF • 5

(leakage.( Department of Justice Canada,2006

### **Table of power densities from common RF sources**

Power density,” in units of microwatts per square centimeter“ • 1  
 (( $\mu\text{W}/\text{cm}^2$ ), may be converted to watts per square meter ( $\text{W}/\text{m}^2$

Table 1 describes the typical RF emissions from various RF • 2  
 (sources.( Industry Canada, 2012

**Table (2-2) RF source, frequency, power, and power density**

RF Sources	Frequencies	Power	Typical Average Power Density Exposure	2.1.2.3
Mobile Phone	GMS 850, 1900 MHz	0.3–3 W	1000 to 5000 $\mu\text{W}/\text{cm}^2$ (at ear)	2.1.2.3
Microwave Oven	2450 MHz	400–1200 W	5000 $\mu\text{W}/\text{cm}^2$ (at 5 cm)	2.1.2.3
WiFi	2.4 GHz and 5.0 GHz	less than 1.0 W (FCC) less than SC 6 (HC)	0.001–20 $\mu\text{W}/\text{cm}^2$ Max average RF exposure level 0.232% of SC 6 limits	2.1.2.3
TV Broadcast VHF	54–216 MHz	10–100 kW	0.005–1.0 $\mu\text{W}/\text{cm}^2$	2.1.2.3
TV Broadcast UHF	470–698 MHz	500–5000 kW	0.005–1.0 $\mu\text{W}/\text{cm}^2$	2.1.2.3
Smart Meter at 1 m	902–928 MHz	0.25 W	0.0001–0.002 $\mu\text{W}/\text{cm}^2$	2.1.2.3
FM AM	88–108 MHz 535 kHz–1.7 MHz	FM 33 kW AM 50 kW	0.005 to 1 $\mu\text{W}/\text{cm}^2$ 500 $\mu\text{W}/\text{cm}^2$	2.1.2.3

## application of RF

### RF Sources Used in Industry 2.1.2.3.1

Frequencies: 135–6 MHz, 27.12 MHz, and 40.68 MHz • 1

Heat sealer power: 1,500 W to 60,000 W • 2

Exposures: Unprotected worker exposures are often • 3

five to eight times above allowable exposure limits 4

(Body to ground currents: >200 mA (Stuchly MA,1980 • 5

### Induction Heating (IH) Cooking Hotplates

Frequency: 20–50 kHz, 26.1 kHz • 1

Power: commercial hobs: 1–3 kW • 2

(Electric field strength: 10–20 V/m at 10 cm. (Suzuki Y,2005 • 3

### **RF Sources Used in Medicine 2.1.2.3.2**

#### **Magnetic Resonance Imaging (MRI) in Radiology**

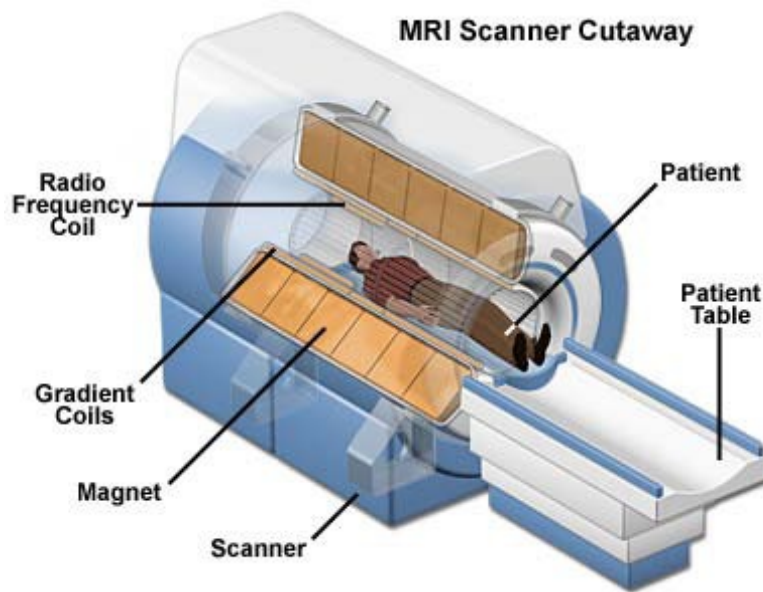
Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to visualize detailed internal structures. An MRI :machine uses three different fields to generate images

A static magnetic field (average magnetic flux density of 1.5 to 3 • 1 Tesla) produced by a large magnet for the alignment of hydrogen nuclei .(protons) inside the body

Low power time-varying magnetic field gradients (100 Hz to 1 • 2 kHz) generated by small magnets in three orthogonal directions to provide the spatial position of the protons. These MF gradients allow .image slicing by focusing on the patient body part under examination

RF fields (10 to 400 MHz) to excite the protons (in the body) and • 3 .cause them to emit radio waves for the acquisition of anatomical images





**Fig( 2-5) “MRI Scanner” courtesy of onlinedocturs, Flickr (CC BY)**

### **RF Ablation in Interventional Cardiology**

Cardiac ablation is a procedure that can correct heart rhythm problems (arrhythmias). It works by scarring or destroying tissue in the heart that triggers abnormal heart rhythms. ( Lencioni RA, 2003

Frequency: 485 kHz, 915 MHz • 1

Power: 40 W, 50 W, 150 W • 2

### **Physiotherapy: Short-Wave Diathermy**

Frequency: 27.12 MHz • 1

Power: 500 W • 2

In diathermy, the heat generated by RF waves increases blood flow and speeds up metabolism and the rate of ion diffusion across cellular membranes. The fibrous tissues in tendons, joint capsules, and scars are more easily stretched when subjected to heat, thus facilitating the relief of stiffness of joints and promoting relaxation of the muscles and decrease .(of muscle spasms ( Stuchly MA, 1982

## RF Tumor Therapy

Frequency: 461 KHz • 1

Nominal power: 200 W • 2

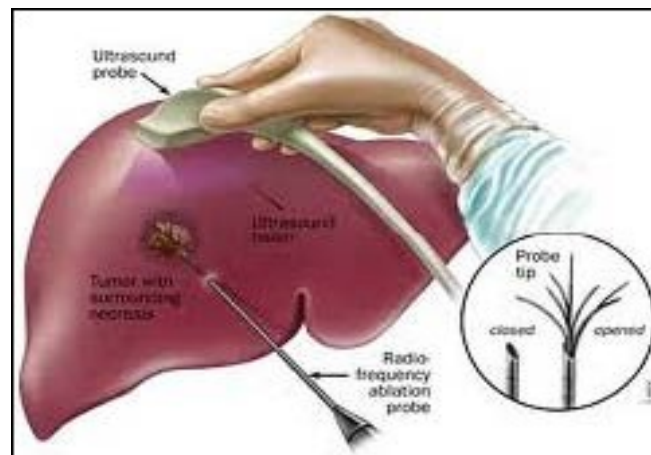
Radiofrequency ablation – treats tumors in lung, liver, kidney • 3  
and bone

Needle-like RF ablation probe placed inside tumor • 4

RF waves increase temperature and destroy tumor • 5

May be combined with chemotherapy treatment.( Assenheim • 6  
(HM, 1979

7



**Fig (2-6) Radiofrequency ablation (RFA) in liver cancer (hepatocellular carcinoma)” courtesy of Hopkins Medicine.org (CC BY-NC)**

**Table (2-3). RF sources: frequency, power, and power density (Fuchs  
(VR, 2001**

RF Medical Source	Frequencies	Power/Strength
Magnetic Resonance Imaging (MRI)	0 Hz	Main Magnetic Field operating field 1-7 Tesla
	100 Hz to 1 kHz	Gradient Magnetic Field 1-5 mT (millitesla)
	Radiofrequency fields 10-400 MHz	Up to a few KW Not radiative
Cardiac Ablation	485 kHz, 915 MHz	40, 50, 150, 200 W
Shortwave Diathermy	27 MHz	500 W
Tumour Therapy	461 kHz	200 W

### 2.1.3. Water

Water is a molecule made up of two hydrogen atoms and one oxygen atom. It has the formula  $H_2O$ . When oxygen and hydrogen combine (H-O-H) they form a v-shaped triangular molecule. While water molecules are electrically neutral, the oxygen atom holds a small negative charge and the two hydrogen atoms hold Small positive charges.

Water molecules are attracted to each other, creating hydrogen bonds. These strong bonds determine almost every physical property of water and many of its chemical properties too. Scientists believe this unusual electrical balancing, called polarity, gives water some of its remarkable properties.

A large part of the mass of most organisms is simply water. In human tissues the percentage of water ranges from 20% in bones to 85% in brain cells. The water content is greater in embryonic and young cells and decreases as aging occurs. About 70% of our total body weight is water; as much as 95% of jellyfish or certain plants is water. Water is not only the major component of organisms but also one of the principal environmental factors affecting them.

Many organisms live within the sea or in freshwater rivers, lakes, and puddles. The physical and chemical properties of water have permitted living things to appear, to survive, and to evolve on this planet.

Water the Universal Solvent Scientists often call water the “universal solvent” because water can **dissolve** more substances than any other liquid. This property of water allows for the transport of nutrients vital to life in animals and plants.

### 2.1.3.1. Chemical and physical properties

**Table (2-4). The major chemical and physical properties of water are: (Clavin, 2011)**

	<b>Remarks</b>	<b>Importance to the environment</b>

Physical state	Only substance occurring naturally in all three phases as solid, liquid, and gas on Earth's surface	Transfer of heat between ocean and atmosphere by phase change
Dissolving ability	Dissolves more substances in greater quantities than any other common liquid	Important in chemical, physical, and biological process
Density: mass per unit volume	Density is determined by (1) temperature, (2) salinity, and (3) pressure, in that order of importance. The temperature of maximum density for pure water is 4 °C. For seawater, the freezing point decreases with increasing salinity	Controls oceanic vertical circulation, aids in heat distribution, and allows seasonal stratification
Surface tension	Highest of all common liquids	Controls drop formation in rain and clouds; important in cell physiology
Conduction of heat	Highest of all common liquids	Important on the small scale, especially on cellular level
Heat capacity	Highest of all common solids and liquids	Prevents extreme range in Earth's temperatures (i.e., great heat moderator)
Latent heat of fusion	Highest of all common liquids and most solids	Thermostatic heat-regulating effect due to the release of heat on freezing and absorption on melting

Latent heat of vaporization	Highest of all common substances	Immense importance: a major factor in the transfer of heat in and between ocean and atmosphere, driving weather and climate
Refractive index	Increases with increasing salinity and decreases with increasing temperature	Objects appear closer than in air
Transparency	Relatively great for visible light; absorption high for infrared and ultraviolet	Important for photosynthesis
Sound transmission	Good compared with other fluids	Allows for sonar and precision depth recorders to rapidly determine water depth, and to detect subsurface features and animals; sounds can be heard great distances underwater
Compressibility	Only slight	Density changes only slightly with pressure/depth
Boiling and melting points	Unusually high	Allows water to exist as a liquid on most of Earth

## 2.2 Previous studies

Chou et al (1992) studied low-level microwave irradiation of rats. To investigate effects of long-term exposure to pulse microwave radiation. An exposure facility was developed that enabled 200 rats to be maintained under specific-pathogen-free (SPF) conditions while housed individually in circularly-polarized waveguides. The exposure facility consisted of two rooms, each containing 50 active waveguides and 50 waveguides for sham (control) exposures. The experimental rats were

exposed to 2,450-MHz pulsed microwaves at 800 pps with a 10-microseconds pulse width. The pulsed microwaves were square-wave modulated at 8-Hz. Whole body calorimetry, thermographic analysis, and power-meter analysis indicated that microwaves delivered at 0.144 W to each exposure waveguide resulted in an average specific absorption rate (SAR) that ranged from 0.4 W/kg for a 200-g rat to 0.15 W/kg for an 800-g rat. Two hundred male, Sprague-Dawley rats were assigned in equal numbers to radiation-exposure and sham-exposure conditions. Exposure began at 8 weeks of age and continued daily, 21.5 h/day, for 25 months. Animals were bled at regular intervals and blood samples were analyzed for serum chemistries, hematological values, protein electrophoretic patterns, thyroxine, and plasma corticosterone levels. In addition to daily measures of body mass, food and water consumption by all animals, O<sub>2</sub> consumption and CO<sub>2</sub> production were periodically measured in a sub-sample (N = 18) of each group. Activity was assessed in an open-field apparatus at regular intervals throughout the study. Their result was After 13 months, 10 rats from each group were euthanatized to test for immunological competence and to permit whole-body analysis, as well as gross and histopathological examinations. At the end of 25 months, the survivors (11 sham-exposed and 12 radiation-exposed rats) were euthanatized for similar analyses. The other 157 animals were examined histopathologically when they died spontaneously or were terminated in extremis.

Dubreuil et al (2002) studied Does head-only exposure to GSM-900 electromagnetic fields affect the performance of rats in spatial learning tasks? Their study was the first using a head-only exposure system emitting a 900-MHz GSM electromagnetic field (pulsed at 217 Hz). The two behavioral tasks that were evaluated here have been used previously to demonstrate performance deficits in spatial learning after

electromagnetic field exposure: a classical radial maze elimination task and a spatial navigation task in an open-field arena (dry-land version of the Morris water maze). The performances of rats exposed for 45 min to a 900-MHz electromagnetic field (1 and 3.5 W/kg) were compared to those of sham-exposed and cage-control rats. Their results showed no differences among exposed, sham, and cage-control rats in the two spatial learning tasks. The discussion focuses on the potential reasons that led previous studies to conclude that learning deficits do occur after electromagnetic field exposure.

Haarala et al (2003).studied the Effects of 902 MHz mobile phone on cerebral blood flow in humans Studied fourteen healthy right-handed subjects were scanned using PET with a [15O] water tracer during exposure to electromagnetic field (EMF) emitted by a mobile phone and a sham-exposure under double-blind conditions. During scanning, the subjects performed a visual working memory task. Exposure to an active mobile phone produced a relative decrease in regional cerebral blood flow (rCBF) bilaterally in the auditory cortex but no rCBF changes were observed in the area of maximum EMF. It is possible that these remote findings were caused by the EMF emitted by the active mobile phone. A more likely interpretation of the present findings were a result of an auditory signal from the active mobile phone. Therefore, it was ``not reasoned to attribute this finding to the EMF emitted by the phone.

Verschaeve et al (2006) Effects of Radiofrequency Electromagnetic Fields In Vivo they investigated the possible combined genotoxic effects of radiofrequency (RF) electromagnetic fields (900 556MHz, amplitude modulated at 217 Hz, mobile phone signal) with the drinking water mutagen and carcinogen 3-chloro-4-(dichloromethyl)-5-



hydroxy-2(5H)-furanone (MX). Female rats were exposed to RF fields for a period of 2 years for 2 h per day, 5 days per week at average whole-body specific absorption rates of 0.3 or 0.9 W/kg. MX was given in the drinking water at a concentration of 19 µg/ml. Blood samples were taken at 3, 6 and 24 months of exposure and brain and liver samples were taken at the end of the study (24 months). DNA damage was assessed in all samples using the alkaline comet assay, and micronuclei were determined in erythrocytes. They did not find significant genotoxic activity of MX in blood and liver cells. However, MX induced DNA damage in rat brain. Co-exposures to MX and RF radiation did not significantly increase the response of blood, liver and brain cells compared to MX exposure only. In conclusion, this 2-year animal study involving long-term exposures to RF radiation and MX did not provide any evidence for enhanced genotoxicity in rats exposed to RF radiation.

Mooney et al (2007) Studied” Nonequilibrium molecular dynamics simulations of hen egg “white lysozyme have been performed in the canonical ensemble at 298 K in the presence of external electromagnetic fields of varying intensity in the microwave to far-infrared frequency range. Significant non thermal field effects were noted, such as marked changes in the protein's secondary structure which led to accelerated incipient local denaturation relative to zero-field conditions. This occurred primarily as a consequence of alignment of the protein's total dipole moment with the external field, although the enhanced molecular mobility and dipolar alignment of water molecules is influential on sidechain motion in solvent-exposed regions. The applied field intensity was found to be highly influential on the extent of denaturation in the frequency range studied, and 0.25-0.5 V A(rms) (-1) fields were found to induce initial denaturation to a comparable extent to thermal denaturation

in the 400 to 500 K range. In subsequent zero-field simulations following exposure to the e/m field, the extent of perturbation from the native 140 fold and the degree of residual dipolar alignment were found to be influential on incipient folding.

Finnie et al (2009) Expression of the water channel protein, to determine whether exposure to mobile telephone radiofrequency (RF) fields, either acutely or longterm, produces up-regulation of the water channel protein, aquaporin-4 (AQP-4). They were Used a purpose designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate of 4 W/kg for 60 minutes or a similar exposure on 5 successive days/week for 104 weeks. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. A positive control group was given a clostridial toxin known to cause microvascular endothelial injury, severe vasogenic oedema and upregulation of AQP-4. Brains were perfusion fixed with 4% paraformaldehyde, coronal sections cut from six levels, and immunostained for the principal water channel protein in brain, AQP-4. Their Results were no increase in AQP-4 expression in brains exposed to mobile phone microwaves compared to control (sham exposed and freely moving caged mice) brains after short or protracted exposure, while AQP-4 was substantially upregulated in the brains of mice given the clostridial toxin. Conclusion: Brains exposed to mobile telephone RF fields for a short (60 minutes) or long (2 years) duration did not show any immunohistochemically detectable up-regulation of the water channel sprtein, AQP-4, suggesting that there was no significant increase in blood-brain barrier permeability.

Narayanan et al (2009).” Spatial memory performance of Wistar rats exposed to mobile phone”; they tested the effects of mobile phone exposure on spatial memory performance. Male Wistar rats (10-12 weeks old) were exposed to 50 missed calls/day for 4 weeks from a GSM (900/1800 MHz) mobile phone in vibratory mode (no ring tone). After the experimental period, the animals were tested for spatial memory performance using the Morris water maze test. Their result was both phone exposed and control animals showed a significant decrease in escape time with training. Phone exposed animals had significantly (approximately 3 times) higher mean latency to reach the target quadrant and spent significantly (approximately 2 times) less time in the target quadrant than age- and sex-matched controls. Mobile phone exposure affected the acquisition of learned responses in Wistar rats.

Fragopoulou et al (2010); “Whole body exposure with GSM 900MHz affects spatial memory in mice”. Their Studied was performed worldwide on the effects of mobile phone radiation upon rats' cognitive functions, however there was great controversy to the existence or not of deficits. The present work had been designed in order to test the effects of mobile phone radiation on spatial learning and memory in mice musculus Balb/c using the Morris water maze (a hippocampal-dependent spatial memory task), they had applied a 2h daily dose of pulsed GSM 900MHz radiation from commercially available mobile phone for 4 days at SAR values ranging from 0.41 to 0.98W/kg. Statistical analysis revealed that during learning, exposed animals showed a deficit in transferring the acquired spatial information across training days (increased escape latency and distance swam, compared to the sham-exposed animals, on the first trial of training days 2-4). Moreover, during the memory probe-trial sham-exposed animals showed the expected preference for the target

quadrant, while the exposed animals showed no preference, indicating that the exposed mice had deficits in consolidation and/or retrieval of the learned spatial information. Their results provide a basis for more thorough investigations considering reports on non-thermal effects of electromagnetic fields (EMFs).

## **Chapter Three**

### **Material and Method**

There are many experimental techniques and equipment used in this study. The sample was prepared and put in the different instruments, UV (Ultra Violet Spectroscopy), conductivity meter and Thermocouple meter to study the physical properties of water after exposed to radiofrequency.

#### **3.1 Material**

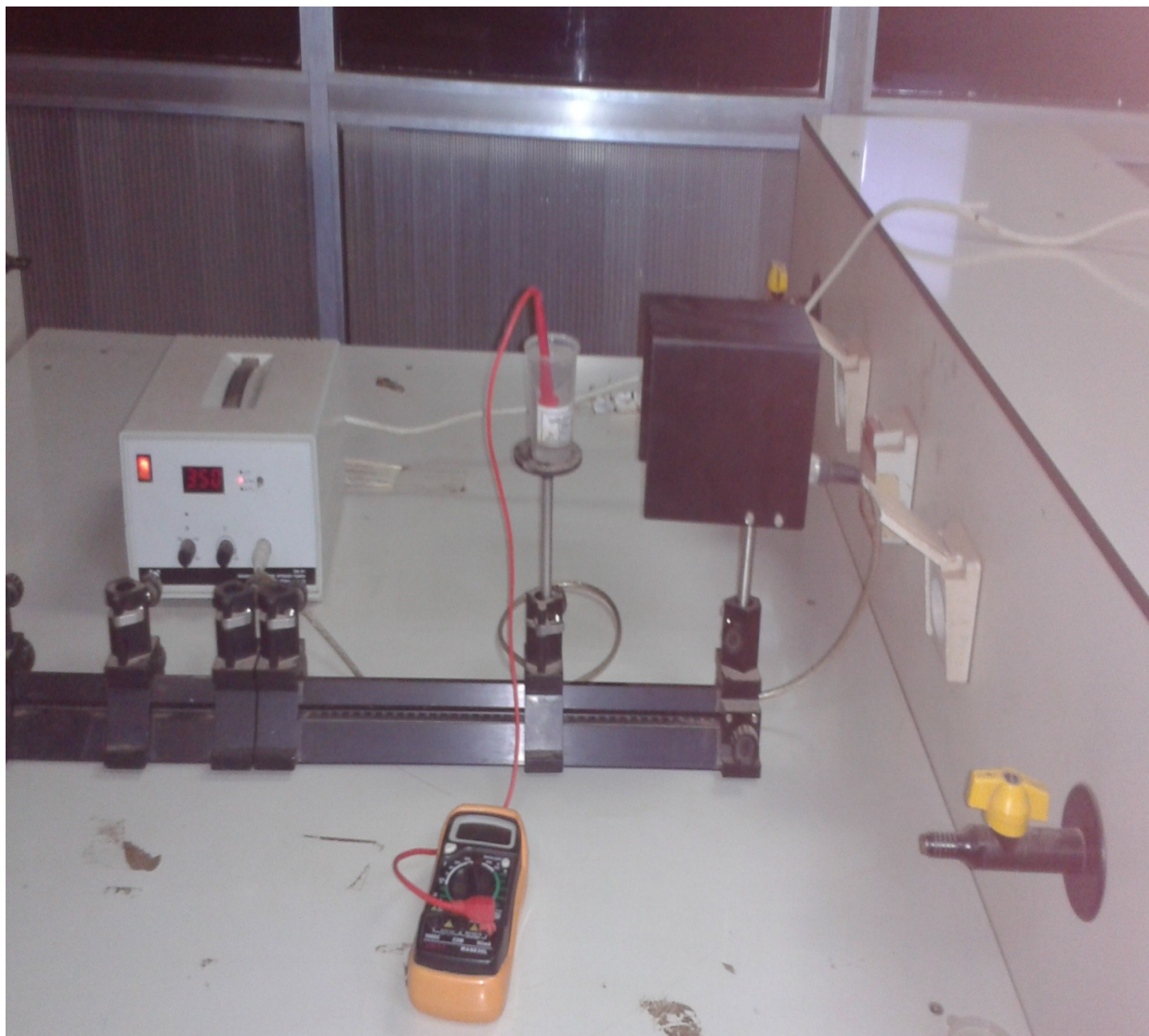
Distill water with initial; temperature ( $33^{\circ}\text{C}$ ), conductivity ( $25.9\mu\text{S/cm}$ ) to use for experiment. It was put in seven tubes at similar conditions and maintained under a control room temperature ( $32^{\circ}\text{C}$ ).

Rubidium high-frequency lamp was used as source of radiofrequency with different frequencies.

#### **3.2 Experimental procedures**

Sample of distill water (350ml) divided into seven groups ; A (50ml) to study the effect of RF expose on(500Mhz which used in MRI for whole body scan) at two hours, B (50ml) were exposed to RF (500Mhz) at four hours, C (50ml) were exposed to RF (900Mhz which used in mobile ) at two hours, D (50ml) were exposed to RF (900Mhz) at four hours, E (50ml) were exposed to RF (1800Mhz which used in Mobile Phone Base Stations) at two hours, F (50ml) were exposed to RF (1800Mhz) at four hours and G (50ml) as a control. The temperature measured (by Thermocouple) every 20 minutes during exposure.

Samples were exposed in an anechoic tube. Control group (G) of water kept under similar conditions (without applying radiation field). The sample away from the source(10 cm), during exposure time.



**Fig (3-1): schematic diagram shows the setup of exposure system**

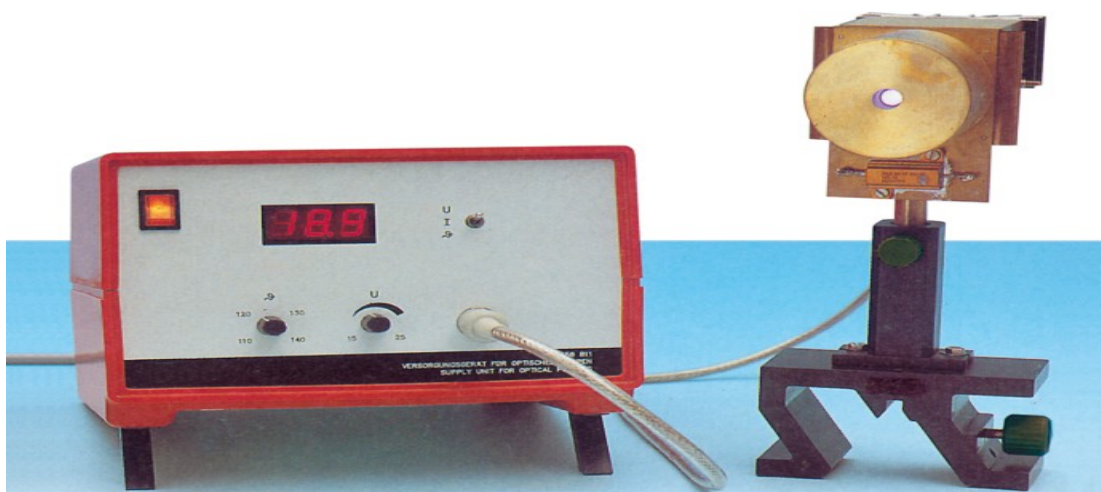
After exposure period immediately, the electrical property is measured (by Electrical conductivity meter). The optical properties measure (by UV-V spectroscopy)

### 3.3 Equipment

#### 3.3.1 Rubidium high-frequency lamp

RHFL contents are; signal source for optical pumping, Rubidium gas discharge lamp with RF transmitter for electrode-free excitation, integrated heating resistance and temperature sensor for temperature control, in brass housing on stem, including 6-core connecting cable with multi-way plugs.

This equipment has properties are; oscillating circuit: 60 MHz, 5 W  
temperature sensor: PT 100, heating resistance: 22 Ohm, 22 W,  
dimensions of housing: 8 cm x 9 cm x 16 cm, diameter of stem: 13 mm



**Fig (3-2) Rubidium high-frequency lamp**

#### 3.3.2 UV-Vis spectroscopy:-

Electronic absorption or UV-visible spectroscopy is one of the simplest and mostly useful optical techniques for studying optical and electronic properties of nanomaterials. Most of the organic molecules and

functional groups are transparent in the portion of the electromagnetic spectrum which we call the ultraviolet and visible regions. That is the .region, where wavelength ranges from 190 nm to 800nm

The basic principle of electronic absorption spectroscopy is based in the measurement of light absorption due to electronic transition in the sample. The energy adsorption due to absorption spectrum, atoms and molecules pass from a state of low energy i.e. ground state to a state of .higher energy i.e. excited state

The electromagnetic radiation that is absorbed has energy exactly equal to the energy difference between the excited and ground state (Pavia et al., 2007). The operating principle is based on Beer's law, the absorbance or optical density as a function of wavelength, is related to the incident light intensity, and transmitted light intensity, concentration of a solution sample, path length of the sample, absorption coefficient, and .(molar absorptivity (formerly known as molar extinction coefficient

Compounds that are colored have absorption in the visible region and are likely to contain a long chain conjugation system or a polycyclic aromatic chromophore. Few functional groups like nitro, azo, nitroso, polybromo,  $\alpha$ -diketo etc containing compounds also exhibits color in .visible region





**Fig (3-2) Ultraviolet Spectroscopy (UV) Device**

### **3.1.3 Electrical conductivity meter**

(EC meter) measures the [electrical conductivity](#) in a [solution](#). It is commonly used in [hydroponics](#), [aquaculture](#) and [freshwater](#) systems to monitor the amount of nutrients, salts or impurities in the water.

The common laboratory conductivity meters employ a potentiometric method and four electrodes. Often, the electrodes are cylindrical and arranged concentrically. The electrodes are usually made of platinum metal. An alternating current is applied to the outer pair of the electrodes. The potential between the inner pair is measured. Conductivity could in principle be determined using the distance between the electrodes and their surface area using the [Ohm's law](#) but generally, for accuracy, a calibration is employed using electrolytes of well-known conductivity.

Industrial conductivity probes often employ an inductive method, which has the advantage that the fluid does not wet the electrical parts of the sensor. Here, two inductively-coupled coils are used. One is the driving coil producing a magnetic field and it is supplied with accurately-known voltage. The other forms a secondary coil of a transformer. The liquid passing through a channel in the sensor forms one turn in the secondary winding of the transformer. The induced current is the output of the sensor.



**Fig (3-3) an electrical conductivity meter**

### **3.3.4 Thermocouple**

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a [voltage](#) when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are a widely used type of [temperature sensor](#) for measurement and control and can also convert a temperature [gradient](#) into electricity. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In

contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree [Celsius](#) (°C) can be difficult to achieve. (IEC 584-2(1982) + A1 (1989), 2010)

Any junction of dissimilar metals will produce an electric potential related to temperature. Thermocouples for practical measurement of temperature are junctions of specific [alloys](#) which have a predictable and repeatable relationship between temperature and voltage. Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Where the measurement point is far from the measuring instrument, the intermediate connection can be made by extension wires which are less costly than the materials used to make the sensor. Thermocouples are usually standardized against a reference temperature of 0 degrees Celsius; practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals. Electronic instruments can also compensate for the varying characteristics of the thermocouple, and so improve the precision and accuracy of measurements.

Thermocouples are widely used in science and industry; applications include temperature measurement for [kilns](#), [gas turbine](#) exhaust, [diesel engines](#), and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in [safety devices](#) for gas-powered major appliances (Ramsden, 2000)



**Fig (3-4) Thermocouple connected to a [multimeter](#) displaying room temperature in [°C](#)**

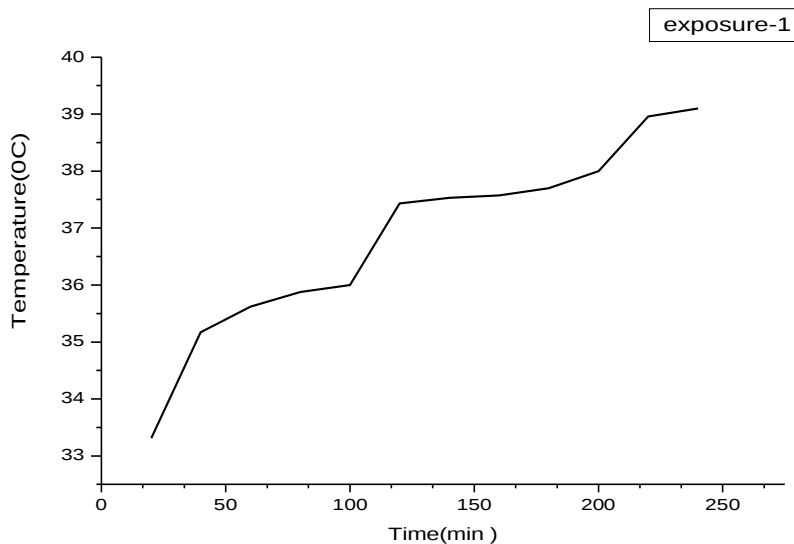
## Chapter Four

### Result and Discussion

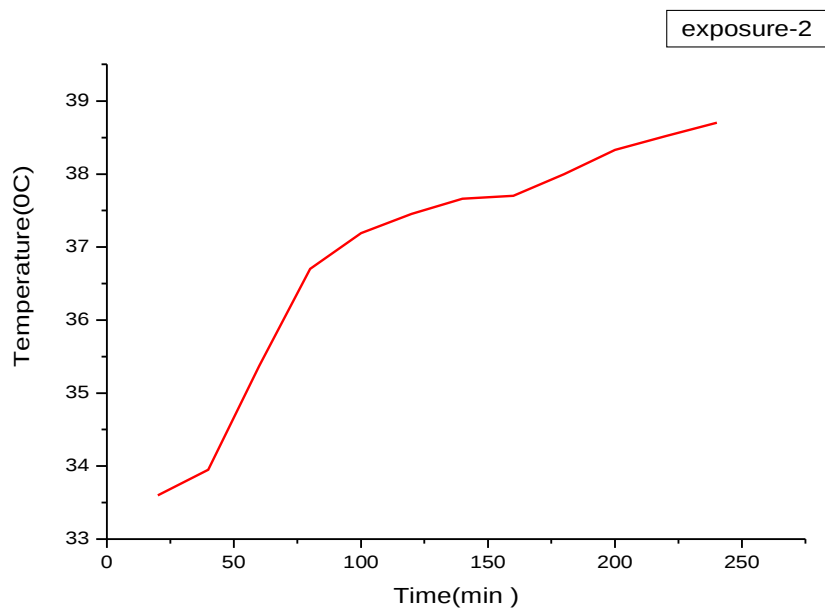
#### 4.1 The Result of temperature

The Result of sample temperatures are calculated and measured every (20 minutes), while the temperatures of samples (50ml) for tube G “control” maintained constant in (33°C).

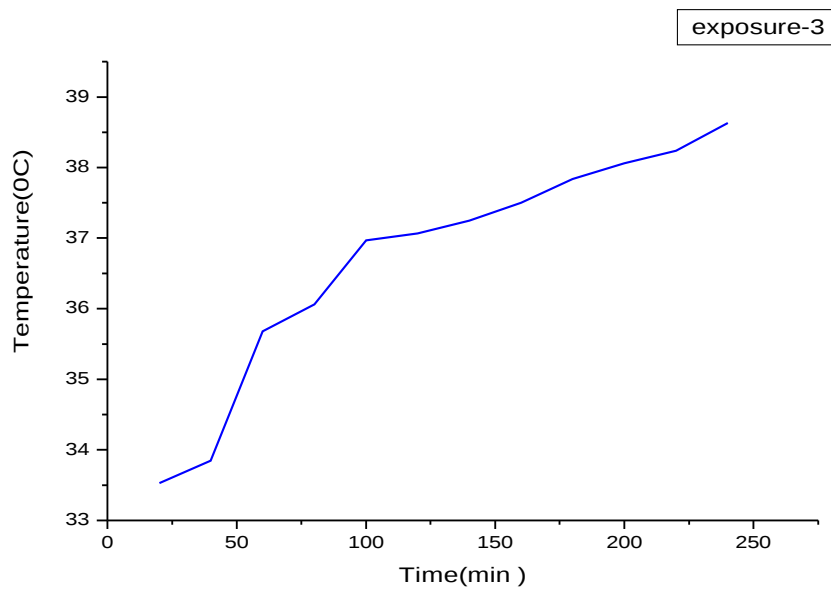
The results of experimental of the temperatures of samples (50ml) for tube A &B (which exposed to RF 500 MHz, distance=10cm)”exposed 1” against time (20 munities) as shows in Fig (4.1), while the temperatures of samples (50ml) for tube C&D (which exposed to RF 900 MHz, distance=10cm) ”exposed 2” against time (20 munities) was shows in Fig (4.2) .And Fig (4.3) shows the temperatures of samples (50ml) for tube E&F (which exposed to RF 1800 MHz, distance=10cm) ”exposed 3” against time (20 munities).In addition Fig (4) shows the comparing between temperatures rising of three exposed frequency.



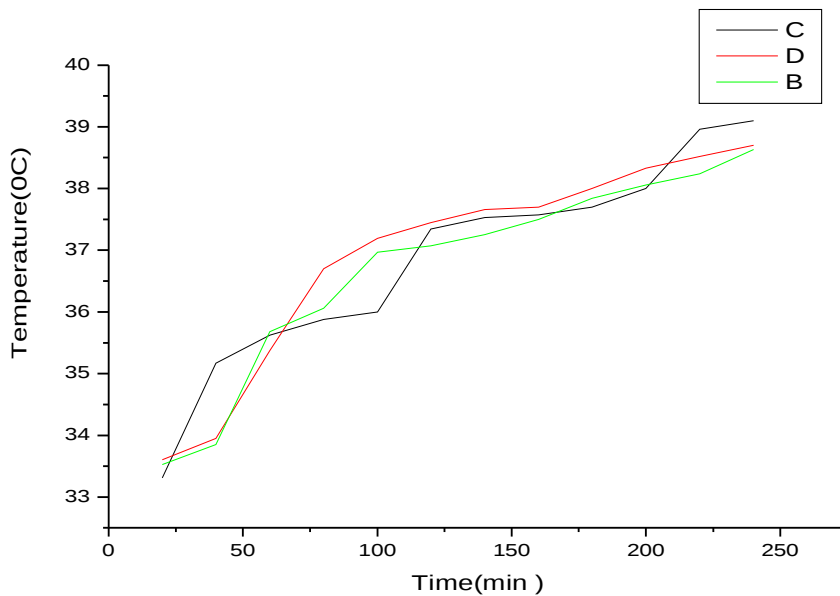
**Fig(4.1)shows the temperatures Vs time for tube A &B (which exposed to RF 500 MHz, distance=10cm) .**



**Fig (4.2) shows the temperatures Vs time for tube C &D (which exposed to RF 900 MHz, distance=10cm).**



**Fig(4.3)shows the temperatures Vs time for tube E &B (which exposed to RF 1800 MHz, distance=10cm)**



**Fig (4.4) shows the comparing between raising temperature of three groups.**

**(C=exposure-1, D=exposure-2 and B=exposure-3).**

#### **Discussion:**

As it mentioned in the previous results, the effects of RF radiation was clearly observed. There are distinguish different in the amount of absorption spectra between the control and exposed sample. There are increases in temperature with increases of exposure time and also increasing of the RF in the irradiated specimen. The difference in temperatures is due to the increasing of motion of water particles ( $H_2O$ ). As it mentioned by the (De Iuliis et al., 2009)

#### **4.2 conductivity results**

The Result of sample conductivity was calculating and detecting using conductivity meter ,while the conductivity of samples (50ml) for tube G “control” was (25.9  $\mu S/cm$ ). Table (4-1) shows the result of conductivity for all samples.

**Table (4.1) Shows the conductivity Vs time for tube A &B (which exposed to RF 500 MHz, distance=10cm).**

<b>Time Hour</b>	<b>Conductivity <math>\mu\text{S/cm}</math></b>
<b>2</b>	<b>26.3</b>
<b>4</b>	<b>27.2</b>

**Table (4.2) shows the conductivity Vs time for tube C &D (which exposed to RF 900 MHz, distance=10cm).**

<b>Time Hour</b>	<b>Conductivity <math>\mu\text{S/cm}</math></b>
<b>2</b>	<b>28.9</b>
<b>4</b>	<b>29.7</b>

**Table (4.3) shows the conductivity Vs time for tube E &B (which exposed to RF 500 MHz, distance=10cm)**

<b>Time Hour</b>	<b>Conductivity <math>\mu\text{S/cm}</math></b>
<b>2</b>	<b>35.9</b>
<b>4</b>	<b>41.8</b>

### **Discussion:**

The results show the effects of RF radiation in the electric conductivity of the exposed sample, and there are clear increasing in conductivity value according to increasing of frequencies values and time; When RF treated water it increase pH and water molecule mobility. The latter was characterized by higher conductivity. . As it mentioned by (T. Wong, (2009

### **4.3 Results of optical properties**

The Result of optical properties was calculating and detecting using UV-Vis spectroscopy. Fig (4.5) shows the absorption of tube A &B



(which exposed to RF 500 MHz, distance=10cm)”exposed 1” against wavelength comparing with control (tube G). Moreover Fig (4.6) shows the absorption of tube C&D (which exposed to RF 900 MHz, distance=10cm)”exposed 2” against wavelength comparing with control (tube G). And Fig (4.7) shows the absorption of tube E&F (which exposed to RF 1800 MHz, distance=10cm)”exposed 3” against wavelength comparing with control (tube G).

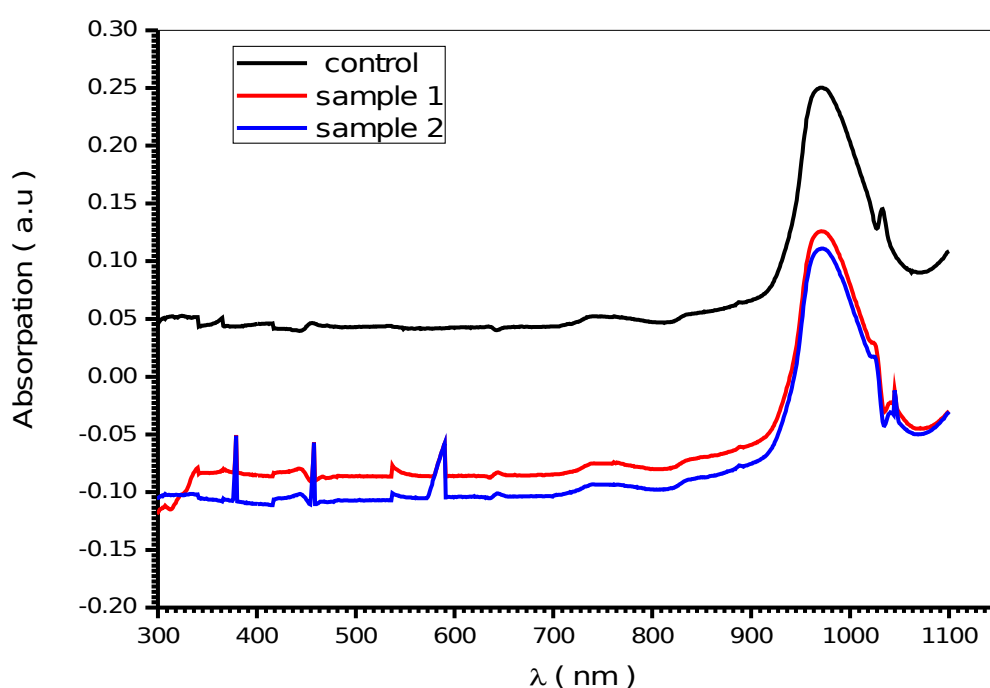


Fig (4.5) shows the absorption of tube A & B (which exposed to RF 500 MHz, distance = 10cm) against wavelength comparing with control (tube G)

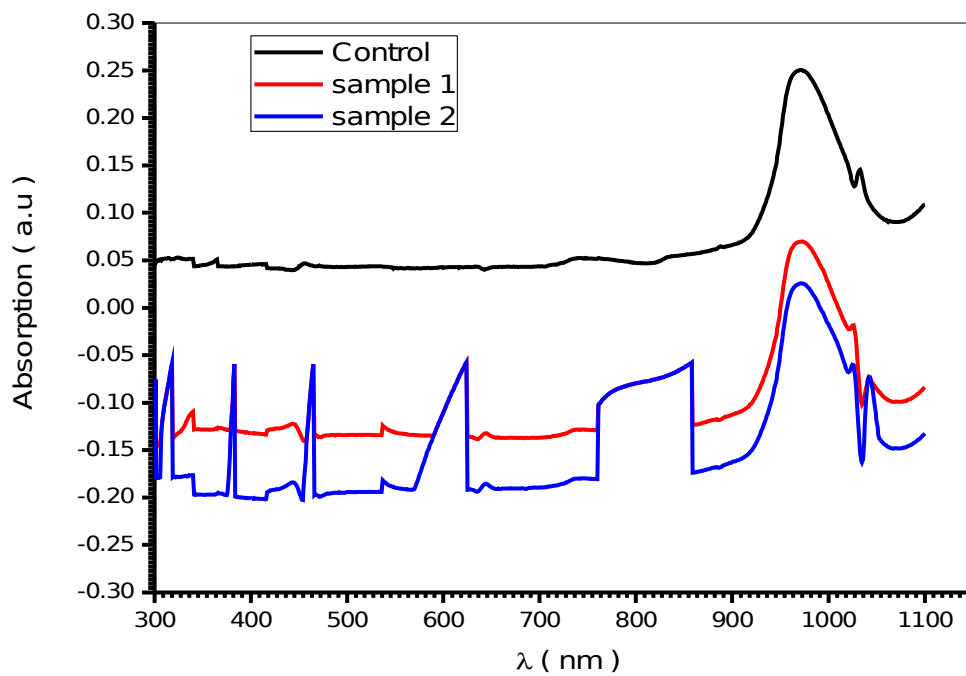


Fig (4.6) shows the absorption of tube C&D (which exposed to RF 900 MHz, distance=10cm)”exposed 2” against wavelength comparing with control (tube G)

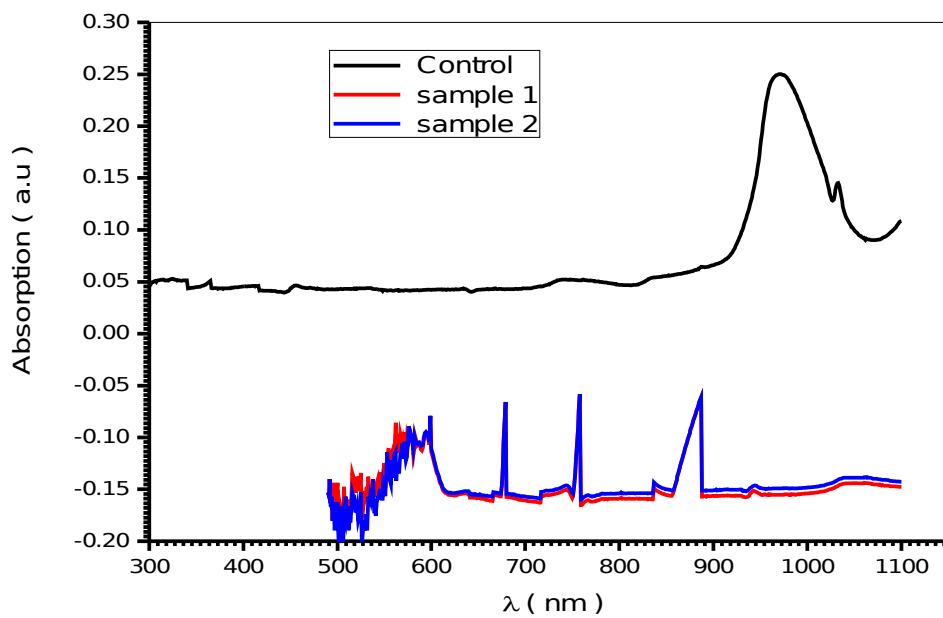


Fig (4.7) shows the absorption of tube E&F (which exposed to RF 1800 MHz, distance=10cm)”exposed 3” against wavelength comparing with control (tube G).

**Discussion:**

The absorption spectra by the ultra violet spectroscopy techniques show the very clear effects of RF radiation on the irradiated sample. There are relatively decrease in the amount of absorption by increasing the value of time, this evidence was clear in the multi graphs which are compare the irradiated sample by each others. This decrease in the amount of absorption is a result of reduce the inter action of radiation with water dye to break down hydrogen bound. It is clear that the RF radiation make shift in the absorption beak of the irradiated sample for higher frequencies as shows in Fig (4.7). We obtain the clear effects of RF radiation in the exposed sample.

## Chapter Five

### Conclusion and Recommendation

#### 5.1 Conclusion

In this study assessment the effect of RF radiation on distilled water (33°C, 25.  $\mu\text{S}/\text{cm}/50\text{ml}$ , and 10cm). The prepared samples were exposed to radiofrequency radiation Which generated from Rubidium high-frequency lamp with different frequencies;; 500MHz (MRI), 900MHz (Mobile telephone) and 1800MHz (Tower communication) exposed at (two hours ,four hours).and measured thermal effect, change in conductivity and optical properties (absorption) . In case of thermal effect; the temperatures is measured every (20 minutes) using thermocouple and found the temperatures is increased (RF500MHz=3.43°C, 1.67°C, RF900MHz=4.19°C, 1.04°C, RF1800MHz=4.07°C, 1.56°C) due to the increasing of motion of water particles ( $\text{H}_2\text{O}$ ), the time is more effected than frequency. Then conductivity is measured after exposed using electrical conductivity meter and found increased in conductivity with increase (RF500MHz=0.4 $\mu\text{S}/\text{cm}$ , 0.9 $\mu\text{S}/\text{cm}$ , RF900MHz=2.8 $\mu\text{S}/\text{cm}$ , 0.8 $\mu\text{S}/\text{cm}$ , RF1800MHz=10 $\mu\text{S}/\text{cm}$ , 5.9 $\mu\text{S}/\text{cm}$ ) of frequency and time. In the end, optical properties (absorption) is measured after exposed using UV-visible spectroscopy and found when frequency increases the absorption decrease.

## **5.2 Recommendations**

- Make more analysis using different analytical methods. Also, to analyze different types samples.
- More study to know the effect of RF radiation on water and then the effect of this exposed water on human body.
- Study the effect of the ionizing radiation on the distilled water.
- The way of avoiding the biological side effects of RF.

## **5.3 Problems**

- The time of the research was not enough in order to investigate all the effects of RF on water.
- Lack of privation equipments to measures other parameter; resistivity, viscosity and other optical properties.

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## Appendices (A)

**Shows the temperatures Vs time for tube A &B (which exposed to RF  
(500 MHz, distance=10cm**

( Time(min	(Temperature( <sup>0</sup> C
20	33.31
40	35.17
60	35.62
80	35.88
100	36.00
120	.4337
140	37.53
160	37.57
180	37.70
200	38.00
220	38.96
240	39.10

**Table shows the temperatures Vs time for tube C &D (which exposed  
.(to RF 900 MHz, distance=10cm**

<b>( Time(min</b>	<b>(Temperature(<sup>0</sup>C</b>
20	33.60
40	33.95
60	35.37
80	36.70
100	37.19
120	37.45
140	37.66
160	37.70
180	38.00
200	38.33
220	38.52
240	38.70

**Table shows the temperatures Vs time for tube E &F (which exposed  
(to RF 1800 MHz, distance=10cm**

<b>( Time(min</b>	<b>(Temperature(<sup>0</sup>C</b>
20	33.53
40	33.85
60	35.68
80	36.06
100	36.97
120	37.07
140	37.25
160	37.50
180	37.84
200	38.06
220	38.24
240	38.63

## Appendices (B)



