Bachelor's Thesis

Bachelor's Degree in Information Technology

Specialization: Information Technology

2013

Ramesh Karki

THE HEALTH RISKS OF WI-FI

TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

BACHELOR´S THESIS | ABSTRACT
TURKU UNIVERSITY OF APPLIED SCIENCES

Information Technology

2013| 37

Granholm Patric

Ramesh Karki

THE HEALTH RISKS OF WI-FI

Recent studies have shown the dramatic effects of Wi-Fi radiation on people's lives. Detection and diagnosis of Wi-Fi-related issues are becoming increasingly important in today's society.

We are surrounded by electro-magnetic radiation and we rarely realize this until someone comes up with the issue. In this technological era, Wi-Fi represents the invisible collective internet consciousness which has become the backbone of the society. Wi-Fi is indisputably one of the miracle inventions in human species. The thesis discusses how wireless systems affect human health. It endeavors to provide the overview on the implications caused by the continuous exposure to Wi-Fi based on a literature review of relevant research.

The overall result of the findings in the thesis is a matter of further discussion because of the discrepancies among various research and experiments.

KEYWORDS:

Detection, Electro-magnetic radiation, Exposure, Physiology

CONTENTS

FIGURES

TABLES

LIST OF ABBREVIATIONS (OR) SYMBOLS

RF	Radio Frequency
ELF	Extremely Low Frequency
Wi-Fi	Wireless Fidelity
A.C.	Alternating current
IEEE	Institute of Electrical and Electronic Engineers
WLAN	Wireless local area network
ICNIRP	International Commission on Non-Ionizing Radiation Protection
DECT	Digital Enhanced Cordless Telecommunications
EHS	Electromagnetic Hypersensitivity Syndrome
IARC	International Agency for Research on Cancer
DNA	De-oxy Ribonucleic Acid
FDA	Food and Drug Administration
GHz	Gigahertz
Ca++	Calcium ion

1. INTRODUCTION

In general, we are exposed to two types of Electromagnetic Radiations:

1.1 Extremely Low Frequency (ELF) EMF

It is an electromagnetic field having a frequency significantly lower than the frequencies utilized in communications. Recently, ELF fields have become an issue of concern in computing applications where cathode-ray tube displays are employed. These displays produce electromagnetic fields because of the strong, changing currents in the electron-beam deflecting coils. The frequencies of these fields are very low.

Sources of ELF mainly include electrical and electronic appliances and power lines.

1.2 Radio Frequency (RF) from wireless devices

Radio frequency (RF) has a range of about 3 kHz to 300 GHz, which matches to the frequency of radio waves, and the alternating current (A.C.) which carries radio signals. RF generally refers to electrical rather than mechanical oscillations; on the other hand, mechanical RF models can be found.

Sources of RF mainly include cellphones, cellular antennas and towers, Wi-Fi & IMAX.

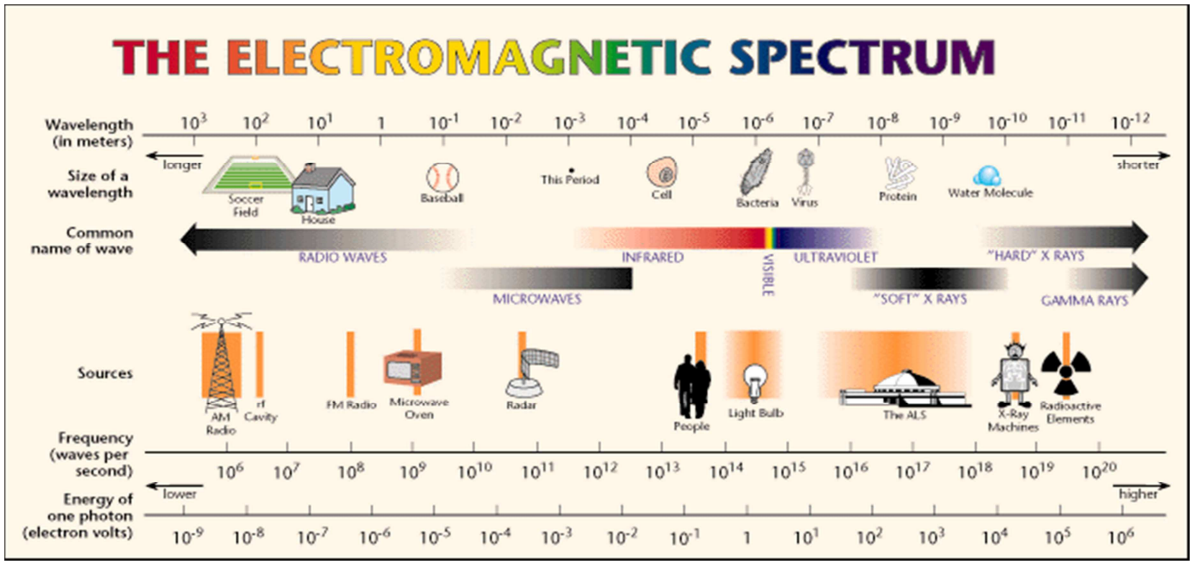

Figure 1. Electromagnetic Spectrum

(Source: http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html)

Electromagnetic spectrum, in principle, is infinite and continuous with the range of all possible frequencies of electromagnetic radiation. The visible spectrum covers a very small portion of the total spectrum. When the frequency increases, the energy of photon also increases with the decrease in wavelength. The above figure shows that the microwaves, radio waves and infrared radiation have very low energy per photon in comparison to ultraviolet and gamma rays. This means that the Wi-Fi radiation has a low intensity and is less harmful.

2. WI-FI

Wi-Fi systems basically consist of two entities that interact without the utilization of any cables. They comply with a standard set of rules to attain their connection, the standard is known as IEEE 802.11 or just 802.11. The name Wi-Fi comes from the Wi-Fi Alliance.

Wi-Fi certified equipment, tested and approved by the Wi-Fi Alliance, bears the Wi-Fi logo as shown in Figure 1.1.1. Primarily, Wi-Fi certified products are guaranteed to be interoperable, even though non-certified products also abide by the standard set out by IEEE. The 802.11 standard was initially completed in 1997. In 1999, it was made an international standard. Its implementation is still increasing and is regarded as a huge accomplishment in terms of adaptation. In 1999, two new versions, 802.11a and 802.11b, were launched to make it possible for increased data rates.

Figure 2. The Wi-Fi Alliance Logo (Source: http://www.wi-fi.org/)

Figure 3. A Wi-Fi Access Point

2.1 How does Wi-Fi Work?

The most common modes for Wi-Fi connectivity are as follow:

-Infrastructure Mode

- Ad hoc Mode

2.1.1 Infrastructure mode

Infrastructure mode a method for connecting to wireless systems with Wi-Fi-facilitated devices like laptops, PDA's etc. They are connected to wireless network with the aid of Access point (AP). Wireless Access Points are often routers or switches that are linked to internet by Ethernet interface.

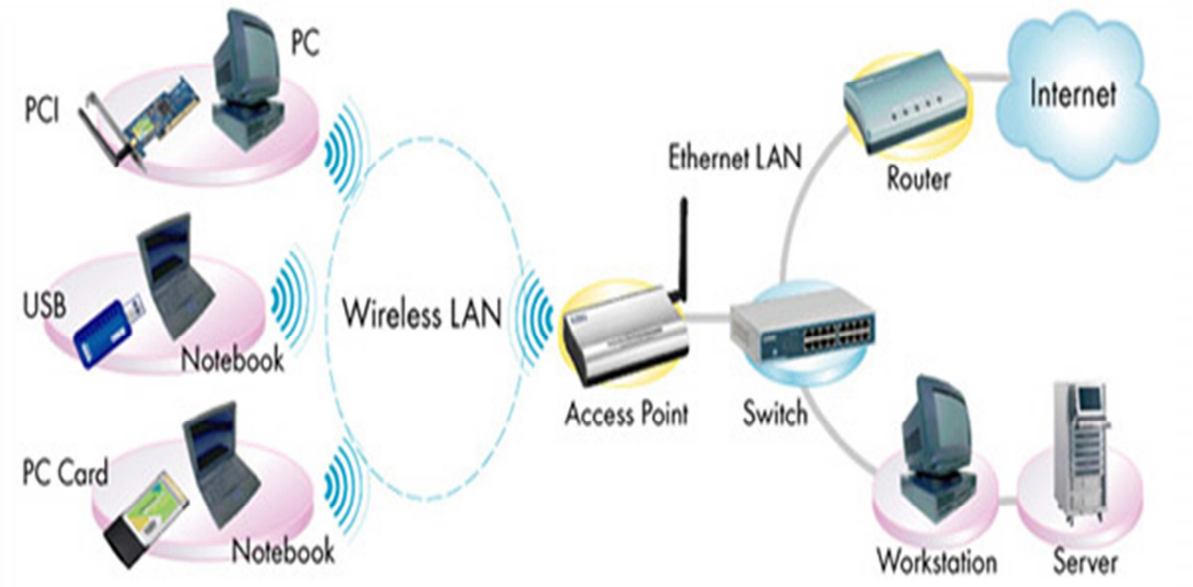

Figure 4. Infrastructure mode (eusso model diagram)

(Source: http://www.eusso.com/Models/Wireless/UGL2454-U2Z/UGL2454-U2Z.htm)

Infrastructure mode of connectivity has the higher risk of exposures in comparison to ad-hoc mode because of the greater number of devices/access points involved in communication.

2.1.2 Ad-hoc mode

Figure 5. Ad-hoc Mode (eusso model diagram)

(Source: http://www.eusso.com/Models/Wireless/UGL2454-U2Z/UGL2454-U2Z.htm)

There is an additional mode of connectivity readily available for Wi-Fi connection. This mode is known as ad hoc mode. With the use of ad hoc mode, devices are in the position for communicating immediately with one another. No Access point is needed for transmission between instruments and all instruments in the range link in peer to peer communication mode.

3. WI-FI EXPOSURES AND FREQUENCIES

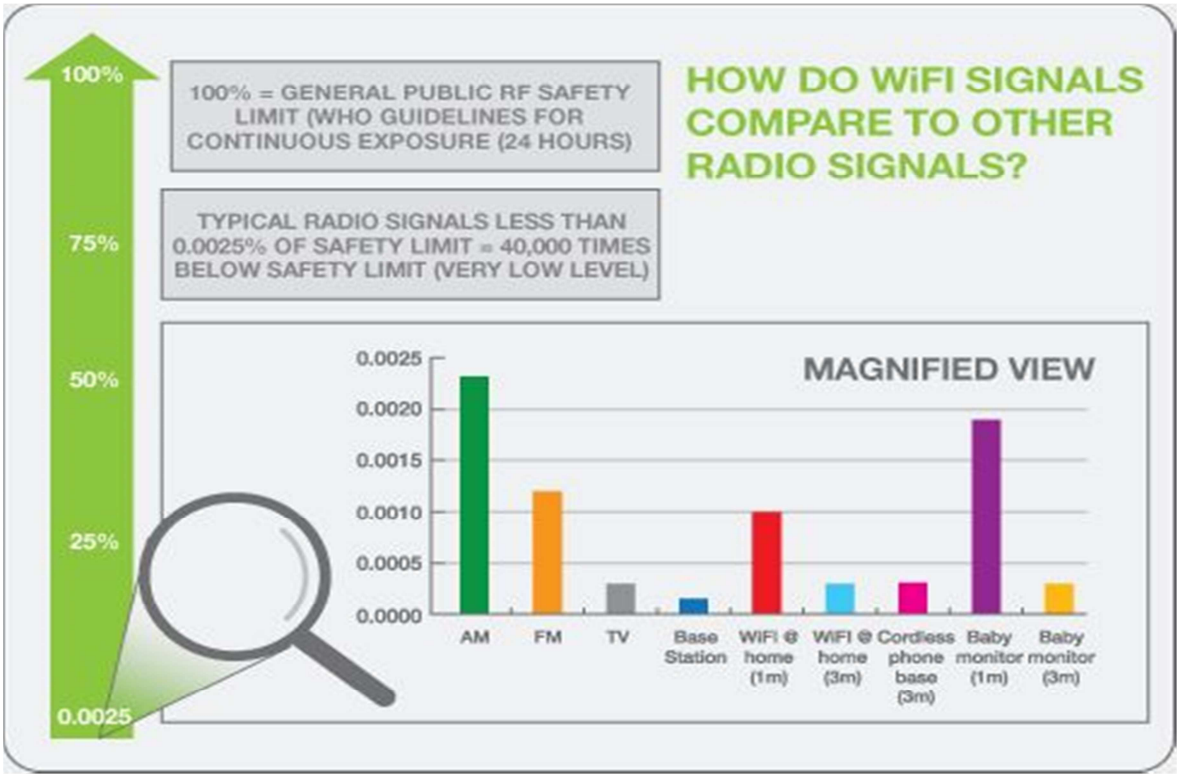

Figure 6. Environmental radio signal level comparison inside a home

(Source: RadHaz Consulting Wi-Fi Home Pilot Study - Report 01043 October 2007)

The above figure shows that Wi-Fi signal at home (1meter distance) has less than 0.0010% of safety limit which is pretty remarkable. Baby monitor seems to impose more risks than Wi-Fi.

Wi-Fi-enabled computers are generally claimed to expose the user(s) to electrical field strengths of 0.1 - 6 V/m .Generally Wi-Fi exposures range between 0.1 - 3 V/m (can go up to 6 V/m) for individuals in areas with WLAN hubs. The greater exposures often occur when downloading documents or delivering e-mails because of the high packet traffic and the power density of radiation.

Table 1. Table showing the Maximum Field Strength generated by various devices/radiation

Agencies/Organizations	Maximum Field Strength	Devices/radiation	Distance
UK Health Protection Agency	0,72-1,31 V/m	Single wireless laptop	1m(single wireless laptop) Exposure shall be higher at 20-50 cm.
ICNIRP	61V/m(acute heating from microwaves)	microwaves	
Public Health Department of the Government of Salzburg	0,06V/m(outdoor exposure limit) 0,02V/m/indoor exposure limit)	Radio frequency	
Bio-Initiative Report(2007)	0,194V/m	Radio frequency	
Scientific Panel on Electromagnetic Health Risks(2010)	0,25-0,8V/m	Electromagnetic radiation	
Swiss Agency for the Environment, Forests and Landscape	0.7 - 3 V/m 1.1 - 4.9 V/m	WLAN access points	1m 50cm

Wi-Fi or WLANs transmit at 2.4 - 2.48GHz or 5.1 - 5.7GHz carrier wave frequencies. Most Wi-Fi computers in schools use 2.45GHz. The computer communicates making use of its wireless card with a base station which in turn is linked to the computer network. According to Swiss Federal Office for the Environment (2005), when in standby mode, the signal is pulsed with a frequency of 10 to 100Hz, and during data transfer, it is pulsed with a frequency of 10 to 250Hz. When the computer is active and Wi-Fi-enabled, it will likely be transmitting signals, whether or not the access point is turned off. For that reason, the wireless service has to be disabled in the computer if not in use.

Besides the carrier wave frequency, the pulse frequencies are strongly related to the biological effects of wireless network devices. Many functions in the body also have frequencies within these pulse ranges. For instance, impulse frequencies of nerve cell in the brain start from less than 1Hz to as much as around 350Hz.

4. HEALTH RISKS OF WI-FI

Wi-Fi incorporates dangerous radiation when transmitting its signals via walls. Many organizations, such as the Council of Europe, the European Environment Agency, UK Trades Union Congress, the International Commission for Electromagnetic Safety, and the Russian Commission for Electromagnetic Safety (Vidya 2013) have also provided strong warnings about all technology that emits radiation identical to that of Wi-Fi.

The World Health Organization (WHO) and the National Toxicology Program (Vidya 2013) discovered that the radiation can significantly increase the chance of glioma, a lethal brain tumor. They have labeled radio frequency as a possible carcinogen.

4.1 Guidelines for various countries

Different countries have set up radiation exposure limits based on power density. Power density is the amount of power per unit area in a radiated microwave field or other type of electromagnetic field which is usually expressed in milli- or microwatts per square centimeter (mW/cm2 or µW/cm2) (Stewart 2000). In the following diagram, we can observe detrimental biological effects caused by the exposure of radio frequency radiation of various power densities.

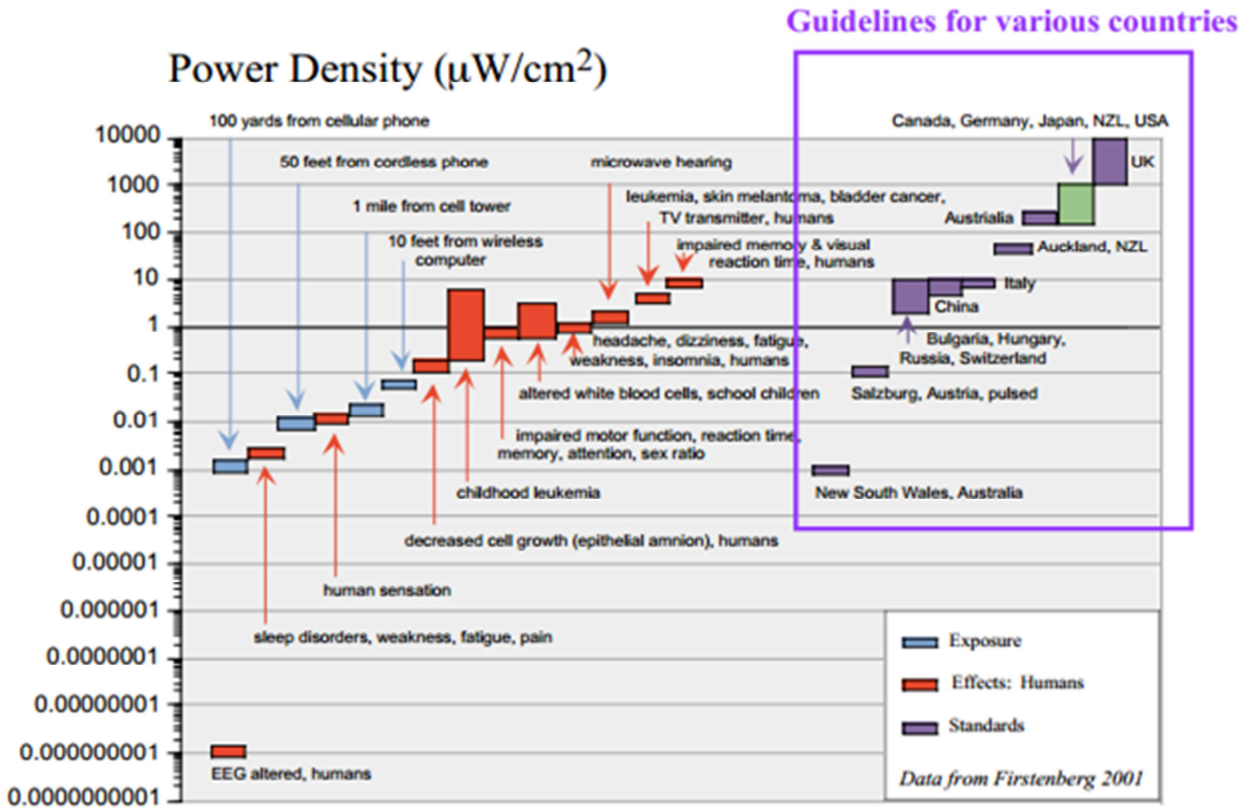

Figure 7. Guidelines, exposures and effects of radio frequency radiation at various power densities (Firstenberg 2001)

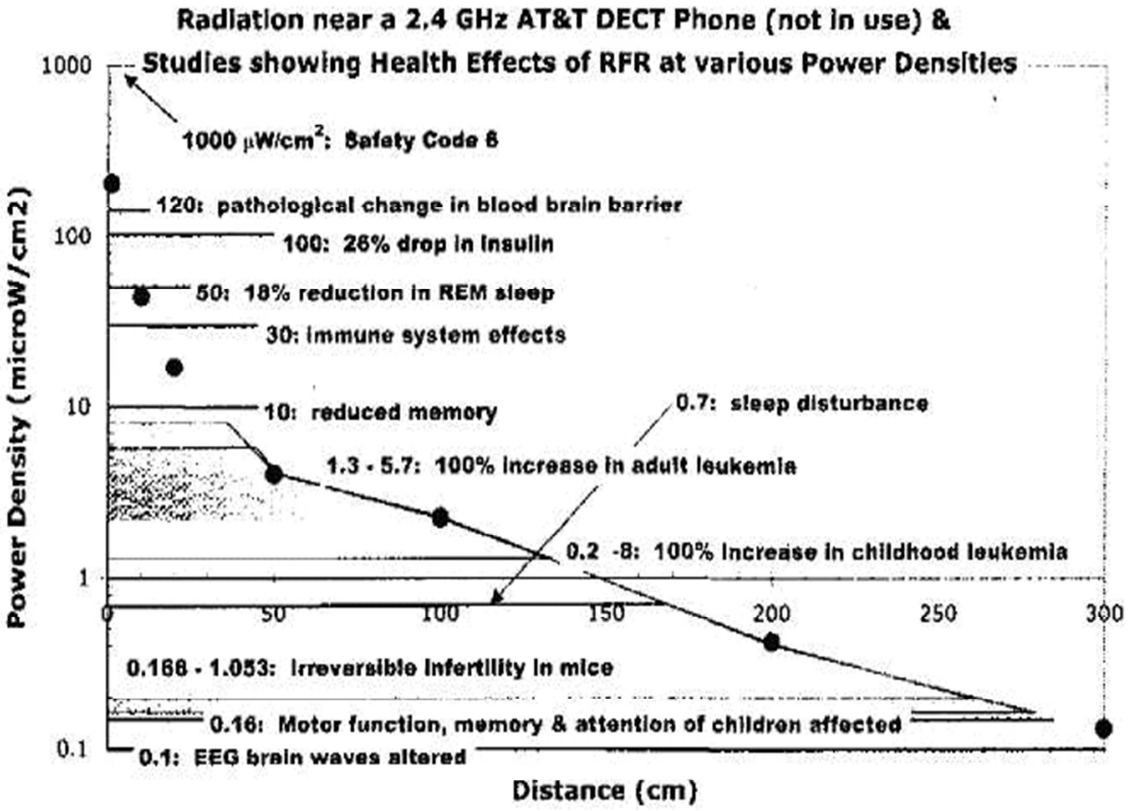

Figure 8. Radiation near a 2.4GHz AT & T DECT phone

(Source: www.oag-bvg.gc.ca)

4.2 General effects of Wi-Fi

Based on the above diagrams and other sources (Bio-Initiative report 2012), the general effects of Wi-Fi can be outlined as below:

Cardiac: The cardiac system performs vital functions that maintain homeostasis of all living components. Failure of any related organs can lead to serious consequences or even death. Continuous Wi-Fi exposure can cause complications as below:

- cardiac arrhythmias,
- shortness of breath and hypertension,

- palpitation

Neurological: The nervous system is a complex network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body and includes both the central nervous system (brain and spinal cord) and peripheral nervous system (somatic and the autonomic nervous systems). Long exposure to Wi-Fi signals can cause:

- headaches,
- nausea,
- dizziness,
- memory concentration difficulties,
- insomnia,
- depression,
- fatigue,
- muscle and joint pains, etc.

In addition, the negative effects of Wi-Fi can be seen in various organs of the body causing several anomalies like:

- deteriorating vision,
- cataracts,
- pain and discomfort,
- ringing in the ear,
- hearing impairment,
- genetic effects including reproductive health issues,
- asthma,
- skin problems and various cancer

5. RESEARCH AND STUDIES

There has been considerable number of researches done in finding out the harmful effects of Wi-Fi radiation. Some research is independently-funded while the others are industry-funded. The statistics on their findings are explained in the later chapter.

Roughly 3-8 percent of populations in western world experience severe electro-hypersensitivity conditions, while 35 percent go through moderate symptoms, as outlined by Dr. Thomas Rau, medical director of the Paracelsus Clinic in Switzerland (Mercola 2011). Dr. Rau also claims that 'electromagnetic loads' result in cancer, concentration issues, attention deficit disorder (ADD), ringing in the ears, headaches, sleeplessness, arrhythmia, Parkinson's and in many cases lumbar pain.

For individuals with Electromagnetic Hypersensitivity Syndrome (EHS), merely walking into a cafe which is WI-FI-equipped may be devastating, initiating a wide range of discomforts which include headache, exhaustion, nausea or vomiting, burning and scratchy skin, and muscle pains .

5.1 Effect of 2.45 GHZ microwave radiation on peroxidation in Wistar rats *(Aweda, Gbenebitse & Meidinyo 2003)*

One hundred twenty rats were divided into groups with 5 rats in each group. Six groups served as control group, six groups were microwave exposed, six groups were treated with ascorbic acid, six groups were treated with alpha-tocopherol (form of vitamin E) and the lipid peroxidation (breaking down of lipid) was monitored for a period of 8 weeks.

Outcome of the study:

The microwave exposure triggered a slight increase in the fat peroxidation (oxidative degradation of lipids) within the first twenty four hours after exposure, after which it steadily lowered to the value of the control group just after about 1 week. Ascorbic acid and alpha-tocopherol (form of vitamin E) administration induced a reduction in the control value of the lipid peroxidation during the first week after irradiation.

The data indicated that microwave exposure induced substantial surge in the lipid peroxidation condition and there were shielding effects of the anti-oxidants ascorbic acid and alpha-tocopherol.

5.2 Effect of 2.45 GHz radiation in heat shock proteins 90 and 70 in rat thyroid gland keeping apoptotic (programmed cell death) process constant *(Misa Agustino, Leiro, Jorge, Rodriguez-Gonzalez, Jorge Barreiro, Ares-Pena & Lopez-Martin 2012)*

Female rats were distributed equally into two groups (6 in each group).The first group was exposed for 90 minute with different specific absorption rates: 0 W, 1.5 W, 3 W and 12 W. Similarly the other group was exposed for 24 hour with different absorption rates: 0 W, 1.5 W, 3 W and 12 W.

Outcome of the study:

One hour thirty minutes following the exposure to 1.5 W, a substantial reduction in Hsp70 levels took place. Hsp90 levels were considerably reduced 90 minutes following the exposure at power of 1.5 W and 3 W, and also 24 hours after the exposure at a power of 3 W compared to the control. Tissue slices of the thyroid gland of subjected animals did not demonstrate any morphological variations in comparison to unexposed animals. No sign of apoptosis was detected in tissue slices from exposed animals.

The outcomes propose that exposure to a 2.45 GHz electromagnetic field may possibly influence levels of cellular strain in rat thyroid gland.

The exposure to the radiation of 2.45 GHz could possibly produce oxidative stress in the dorsal root ganglion (nodule on a dorsal root of the spine that contains cell bodies of nerve cells that carry signals from sensory organs toward the appropriate integration center) and therefore melatonin (hormone regulating reproductive cycle) could avert this kind of reaction. The International Agency for Research on Cancer (IARC 2011) also confirmed that subjection to Wi-Fi radiation is a potential carcinogen. Dr. Blank (Mercola 2011) mentioned on the impact of electromagnetic fields on cells and DNA. The attributes of DNA promote greater reactivity to electromagnetic fields than other tissues, generating the long-term implications.

The diagrams shown below represent the biological effects in the health of human being from radiofrequency radiation at low-intensity exposure such as cell tower, Wi-Fi, etc. at various power densities based on various experiments and research (Bio-Initiative Report 2012).

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure
(Cell Tower, Wi-Fi, Wireless Laptop and 'Smart' Meter RF Intensities)

Power Density (Microwatts/centimeter2 - uW/cm2)		Reference
As low as (10^{-13}) or 100 femtowatts/cm2	Super-low intensity RFR effects at MW reasonant frequencies resulted in changes in genes; problems with chromatin conformation (DNA)	Belyaev, 1997
5 picowatts/cm2 (10^{-12})	Changed growth rates in yeast cells	Grundler, 1992
0.1 nanowatt/cm2 (10^{-10}) or 100 picowatts/cm2	Super-low intensity RFR effects at MW reasonant frequencies resulted in changes in genes; problems with chromatin condensation (DNA) intensities comparable to base stations	Belyaev, 1997
0.00034 uW/cm2	Chronic exposure to mobile phone pulsed RF significantly reduced sperm count,	Behari, 2006
0.0005 uW/cm2	RFR decreased cell proliferation at 960 MHz GSM 217 Hz for 30-min exposure	Velizarov, 1999
0.0006 - 0.0128 uW/cm2	Fatigue, depressive tendency, sleeping disorders, concentration difficulties, cardio- vascular problems reported with exposure to GSM 900/1800 MHz cell phone signal at base station level exposures.	Oberfeld, 2004
0.0009 uW/cm2	RFR induced 10%-40% increase in DNA synthesis in glioma cells (brain)	Stagg, 1997
0.003 - 0.02 uW/cm2	In children and adolescents (8-17 yrs) short-term exposure caused headache, irritation, concentration difficulties in school.	Heinrich, 2010
0.003 to 0.05 uW/cm2	In children and adolescents (8-17 yrs) short-term exposure caused conduct problems in school (behavioral problems)	Thomas, 2010
0.005 uW/cm2	In adults (30-60 yrs) chronic exposure caused sleep disturbances, (but not significantly increased across the entire population)	Mohler, 2010
0.005 - 0.04 uW/cm2	Adults exposed to short-term cell phone radiation reported headaches, concentration difficulties (differences not significant, but elevated)	Thomas, 2008
0.006 - 0.01 uW/cm2	Chronic exposure to base station RF (whole-body) in humans showed increased stress hormones; dopamine levels substantially decreased; higher levels of adrenaline and nor-adrenaline; dose-response seen; produced chronic physiological stress in cells even after 1.5 years.	Buchner, 2012
0.01 - 0.11 uW/cm2	RFR from cell towers caused fatigue, headaches, sleeping problems	Navarro, 2003

Stress proteins, HSP, disrupted immune function	Brain tumors and blood-brain barrier
Reproduction/fertility effects	Sleep, neuron firing rate, EEG, memory, learning, behavior
Oxidative damage/ROS/DNA damage/DNA repair failure	Cancer (other than brain), cell proliferation
Disrupted calcium metabolism	Cardiac, heart muscle, blood-pressure, vascular effects

Figure 9. Biological Effects from Radiation at Low-Intensity Exposure (Bio-Initiative Report, 2012)

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure
(Cell Tower, Wi-Fi, Wireless Laptop and 'Smart' Meter RF Intensities)

Power Density (Microwatts/centimeter2 - uW/cm2)		Reference
0.01 - 0.05 uW/cm2	Adults (18-91 yrs) with short-term exposure to GSM cell phone radiation reported headache, neurological problems, sleep and concentration problems.	Hutter, 2006
0.005 - 0.04 uW/cm2	Adults exposed to short-term cell phone radiation reported headaches, concentration difficulties (differences not significant, but elevated)	Thomas, 2008
0.015 - 0.21 uW/cm2	Adults exposed to short-term GSM 900 radiation reported changes in mental state (e.g., calmness) but limitations of study on language descriptors prevented refined word choices (stupified, zoned-out)	Augner, 2009
0.05 - 0.1 uW/cm2	RFR linked to adverse neurological, cardio symptoms and cancer risk	Khurana, 2010
0.05 - 0.1 uW/cm2	RFR related to headache, concentration and sleeping problems, fatigue	Kundi, 2009
0.07 - 0.1 uW/cm2	Sperm head abnormalities in mice exposed for 6-months to base station level RF/MW. Sperm head abnormalities occurred in 39% to 46% exposed mice (only 2% in controls) abnormalities was also found to be dose dependent. The implications of the pin-head and banana-shaped sperm head. The occurrence of sperm head observed increase occurrence of sperm head abnormalities on the reproductive health of humans living in close proximity to GSM base stations were discussed."	Otitoloju, 2010
0.38 uW/cm2	RFR affected calcium metabolism in heart cells	Schwartz, 1990
0.8 - 10 uW/cm2	RFR caused emotional behavior changes, free-radical damage by super-weak MWs	Akoev, 2002
0.13 uW/cm2	RFR from 3G cell towers decreased cognition, well-being	Zwamborn, 2003
0.16 uW/cm2	Motor function, memory and attention of school children affected (Latvia)	Kolodynski, 1996
0.168 - 1.053 uW/cm2	Irreversible infertility in mice after 5 generations of exposure to RFR from an 'antenna park'	Magras & Zenos, 1997
0.2 - 8 uW/cm2	RFR caused a two-fold increase in leukemia in children	Hocking, 1996
0.2 - 8 uW/cm2	RFR decreased survival in children with leukemia	Hocking, 2000
0.21 - 1.28 uW/cm2	Adolescents and adults exposed only 45 min to UMTS cell phone radiation reported increases In headaches.	Riddervold, 2008

Figure 10. Biological Effects from Radiation at Low-Intensity Exposure (Bio-Initiative Report, 2012)

Power Density (Microwatts/centimeter2 - uW/cm2)		Reference
0.5 uW/cm2	Significant degeneration of seminiferous epithelium in mice at 2.45 GHz, 30-40 min.	Saunders, 1981
0.5 - 1.0 uW/cm2	Wi-FI level laptop exposure for 4-hr resulted in decrease in sperm viability, DNA fragmentation with sperm samples placed in petri dishes under a laptop connected via WI-FI to the internet.	Avendano, 2012
1.0 uW/cm2	RFR induced pathological leakage of the blood-brain barrier	Persson, 1997
1.0 uW/cm2	RFR caused significant effect on immune function in mice	Fesenko, 1999
1.0 uW/cm2	RFR affected function of the immune system	Novoselova, 1999
1.0 uW/cm2	Short-term (50 min) exposure in electrosensitive patients, caused loss of well-being after GSM and especially UMTS cell phone radiation exposure	Eltiti, 2007
1.3 - 5.7 uW/cm2	RFR associated with a doubling of leukemia in adults	Dolk, 1997
1.25 uW/cm2	RFR exposure affected kidney development in rats (in-utero exposure)	Pyrpasopoulou, 2004
1.5 uW/cm2	RFR reduced memory function in rats	Nittby, 2007
2 uW/cm2	RFR induced double-strand DNA damage in rat brain cells	Kesari, 2008
2.5 uW/cm2	RFR affected calcium concentrations in heart muscle cells	Wolke, 1996
2 - 4 uW/cm2	Altered cell membranes; acetycholine-induced ion channel disruption	D'Inzeo, 1988
4 uW/cm2	RFR caused changes in hippocampus (brain memory and learning)	Tattersall, 2001
4 - 15 uW/cm2	Memory impairment, slowed motor skills and retarded learning in children	Chiang, 1989
5 uW/cm2	RFR caused drop in NK lymphocytes (immune function decreased)	Boscolo, 2001
5.25 uW/cm2	20 minutes of RFR at cell tower frequencies induced cell stress response	Kwee, 2001
5 - 10 uW/cm2	RFR caused impaired nervous system activity	Dumansky, 1974
6 uW/cm2	RFR induced DNA damage in cells	Phillips, 1998

Figure 11. Biological Effects from Radiation at Low-Intensity Exposure (Bio-Initiative Report, 2012)

Power Density (Microwatts/centimeter2 - uW/cm2)		Reference
8.75 uW/cm2	RFR at 900 MHz for 2-12 hours caused DNA breaks in leukemia cells	Marinelli, 2004
10 uW/cm2	Changes in behavior (avoidance) after 0.5 hour exposure to pulsed RFR	Navakatikian, 1994
10 - 100 uW/cm2	Increased risk in radar operators of cancer; very short latency period; dose response to exposure level of RFR reported.	Richter, 2000
12.5 uW/cm2	RFR caused calcium efflux in cells - can affect many critical cell functions	Dutta, 1989
13.5 uW/cm2	RFR affected human lymphocytes - induced stress response in cells	Sarimov, 2004
14.75 uW/cm2	RFR increased biomarker for cell division in glioma brain tumor cells	Stagg, 1997
20 uW/cm2	Increase in serum cortisol (a stress hormone)	Mann, 1998
28.2 uW/cm2	RFR increased free radical production in rat cells	Yurekli, 2006
37.5 uW/cm2	Immune system effects - elevation of PFC count (antibody producing cells	Veyret, 1991
45 uW/cm2	Pulsed RFR affected serum testosterone levels in mice	Forgacs, 2006
50 uW/cm2	Cell phone RFR caused a pathological leakage of the blood-brain barrier in 1 hour	Salford, 2003
50 uW/cm2	An 18% reduction in REM sleep (important to memory and learning functions)	Mann, 1996
60 uW/cm2	RFR caused structural changes in cells of mouse embryos	Somozy, 1991
60 uW/cm2	Pulsed RFR affected immune function in white blood cells	Stankiewicz, 2006
60 uW/cm2	Cortex of the brain was activated by 15 minutes of 902 MHz cell phone	Lebedeva, 2000
65 uW/cm2	RFR affected genes related to cancer	Ivaschuk, 1999
92.5 uW/cm2	RFR caused genetic changes in human white blood cells	Belyaev, 2005
100 uW/cm2	Changes in immune function	Elekes, 1996
100 uW/cm2	A 24.3% drop in testosterone after 6 hours of CW RFR exposure	Navakatikian, 1994

Figure 12. Biological Effects from Radiation at Low-Intensity Exposure (Bio-Initiative Report, 2012)

5.3 Reproductive Health

Recent research (Hough 2011) shows the effect of Wi-Fi on the reproductive health of individuals. In the experiment, 29 men aged 26 to 45 volunteered the sperm which then was placed near the laptop connected to the wireless networks. The laptop was then used to download files from the internet for four hours.

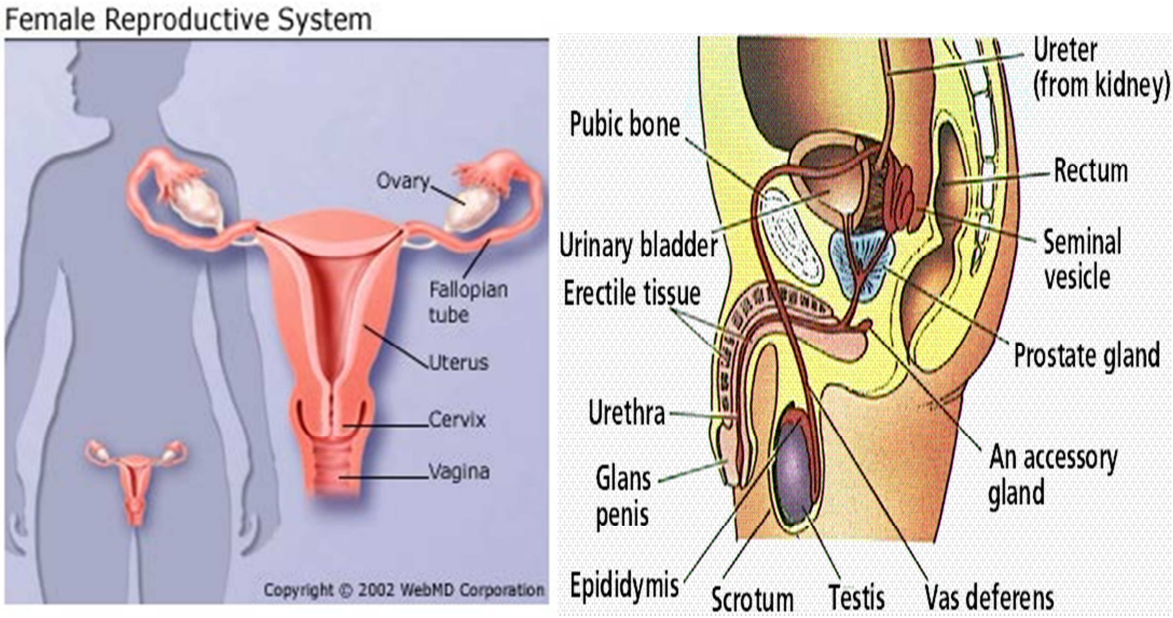

Figure 13. Male and Female Reproductive system

(Source: http://www2.estrellamountain.edu/faculty/farabee/biobk/biobookreprod.html)

Figure 14. Sperm fertilizing with Ovum

(Source: http://sayskakodkar.blogspot.fi/2012/08/fertility-treatment-ideas-does-sex.html)

According to the report provided at the end of the experiment, it was found that 25 per cent of the sperm stopped moving and 9 percent was damaged. On the other hand, only 14 percent of the sample not exposed to Wi-Fi stopped moving and 3 percent showed DNA damage. Lead researcher Conrado Avendano, of Nascentis Medicina Reproductiva located in Cordoba suggested that the continuous use of laptop connected to the internet wirelessly may decrease the sperm quality and count.

In spite of the commonly negative outcomes of these scientific studies, it will be a challenge to draw solid conclusions on reproductive risk without in-depth epidemiological details on highly exposed people and accurate exposure evaluation.

Microwave exposures have also been discovered to considerably raise the percentage of sperm head abnormalities. Otitoloju et al. (2009) observed that after subjection of mice for 6 months to 0.49V/m fields, 40% of sperm, respectively, had abnormal form. Long-term exposures at low intensity microwave fields have been found to reduce sperm count, mobility, increase defective sperm morphology and increase oxidative tension in animals.

Some of the studies (Nakamura, Nagasa, Ogino, Hatta and Matsuzaki 2000) also suggest that continuous exposure of microwave radiation can reduce utero-placental blood flow and cause ovarian/placental dysfunction during pregnancy.

5.4 Genetic Anomalies

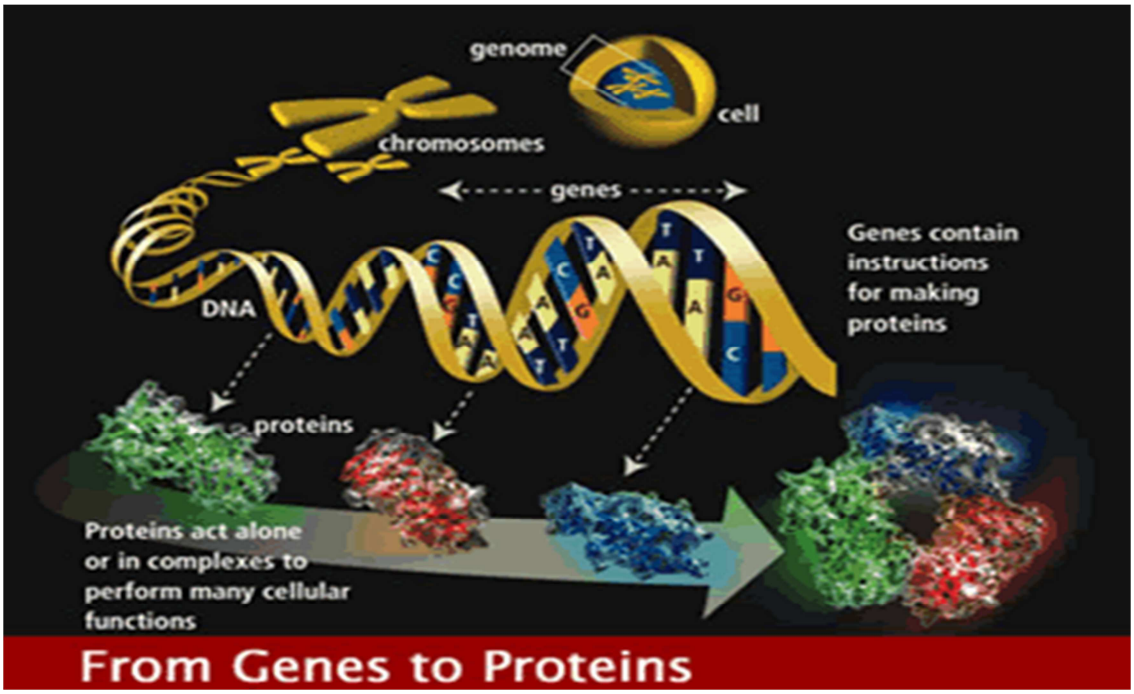

Figure 15. Genetic Transcription (National Human Genome Research Institute)

The problem with the hereditary information in cells has been observed with subsequent subjection to microwaves. The review by Lai (2007b, Bio-initiative report) explains several experiments confirming DNA impairment, alterations in chromosomal conformation, as well as the development of micronuclei subsequent to microwave exposure. Microwave seems to be toxic only in some situations. Instances of DNA impairment was found in human fibroblasts, lymphocytes, leukocytes, rat and mouse brain cells, mouse sperm, etc.

Microwave exposure of lymphocyte cells shows the alteration in the number of chromosomes leading to Aneuploidy (a mutation that can cause genetic instability).

According to Atasoy (2005), wireless exposure for 24 hours per day/20 weeks can cause increased DNA anomalies and potential effect on fertility. Kesari (2010) found the increase in the cell death also called apoptosis at 2.45GHz when exposed for 35 days or longer at 0.11 W/Kg. Panagopulous (2012) found a significant decrease in ovarian development and size due premature cell death and follicles in ovaries.

Considering the fact that cell phone use is linked with substantially increased possibility of cancer in several researches, it is not detrimental to assume that there is the chance of Wi-Fi also posing a risk in time. Wireless computing devices can be employed for longer durations than phones, and are more likely used by young people. Studies are essential to make sure that long-term exposure to Wi-Fi and similar technologies does not maximize cancer threat.

6. BIASED RESEARCH

Not all the studies show the consistent outcome. There has been the anomalies especially when comparing the result of independently funded research with that of industry funded.

Of the studies that show a biological or health effect from Wi-Fi (Jeffry Fawcett 2007), 14% are industry funded while 86% are independently funded. Of studies showing no effect (Jeffry Fawcett), 49% are industry funded while 51% are independently funded.

To make the point another way, of industry-funded studies, only 27% found an RFR effect. Independently-funded studies found an RFR effect 68% of the time. This discrepancy is consistent among the effects listed. Of studies that found an effect on cancer, 11% were industry-funded, 47% were independently funded. Cellular and molecular effects: 19% industry, 69% independent. Electrophysiology effects: 33% industry, 77% independent. Physiological and behavioral effects: 57% industry, 83% independent.

The discrepancies between the industry funded studies and the independently funded studies indicate bias. The way a study is fashioned, the techniques used in the study, data collection process, and the way results are interpreted can cause these discrepancies. Some independently funded experts are biased since they are concerned with the elimination of RFR exposures or even destruction of the reputation of the wireless industry. They may have purposely or instinctively designed their experiments, selected methods, gathered facts, and interpreted the outcomes to indicate health consequences from RFR.

Inside each group, outcomes do not always come to an agreement -some research shows an effect whilst others do not irrespective of who did the financing. This kind of inconclusiveness provides the wireless industry with an advantage in advertising their wireless products to be safe. The FDA also seems to be on their side stating that the presented scientific explanation does not indicate that any health issues are linked with employing wireless devices. There is no evidence, nevertheless, that wireless devices are completely secure.

7. SAFETY AND PRECAUTION

It is the general consensus of the scientific community that the level of RF exposure due to wireless networks is so low compared to other RF sources that health concerns from Wi-Fi exposure are not an issue. But we cannot ignore the fact presented by various researchers on the harmful implications caused by the long-term exposure of Wi-Fi.

Table 2. Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz (ICNIRP Guidelines, 1998)

Exposure characteristics	Frequency range	Current density for head and trunk (mA m^{-2}) (rms)	Whole-body average SAR (W kg^{-1})	Localized SAR (head and trunk) (W kg^{-1})	Localized SAR (limbs) (W kg^{-1})
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/*f*	—	—	—
	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	*f*/100	—	—	—
	100 kHz–10 MHz	*f*/100	0.4	10	20
	10 MHz–10 GHz	—	0.4	10	20
General public exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/*f*	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	*f*/500	0.08	2	4
	10 MHz–10 GHz	—	0.08	2	4

The table shows the general restrictions on the radiation exposure fields (electric and magnetic) for various frequency ranges. The exposure characteristics are divided into occupational exposure and general public exposure. The current density (the amount of electric current flowing per unit cross-sectional area of a material) produced in the head and trunk region of people exposed to the radiation in the work environment seems to be higher in comparison to the general exposure of public. This means the people who are exposed to the radiation while at work are more prone to harmful radiation.

Table 3. Reference levels for occupational exposure to time-varying electric and magnetic fields (ICNIRP Guidelines, 1998)

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

f is the frequency in hertz.

Because of electrical inhomogeneity of the body, current densities should be averaged over a cross-section of 1 cm^2 perpendicular to the current direction.

For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by $\sqrt{2}$ (~1.414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$.

For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.

All SAR values are to be averaged over any 6-min period.

Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.

For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures in the frequency range 0.3 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 10 mJ kg^{-1} for workers and 2mJ kg^{-1} for the general public, averaged over 10 g tissue.

Some of the ways to minimize the effect of Wi-Fi radiation include:

- Minimizing exposure time
- Keeping a distance from Wi-Fi sources (inverse square law).
- Special attention required to prevent exposure to children under 10 years.
- Constructing a Faraday Cage (an earthed metal screen surrounding a piece of equipment to exclude electrostatic and electromagnetic influences.)

Figure 16. Faraday Cage house

(Source: http://www.pcpro.co.uk/blogs/2011/04/14/whats-killing-your-wi-fi-wrapping-your-house-in-tin-foil/)

8. SUMMARY

Mass acceptance of the reliable and valid research on this area and action to implement the preventive measures could assist in controlling the risks to some degree.

Scientific studies of radio frequency radiation along with epidemiological experiments of individuals who use wireless technology suggest undesirable biological consequences. These issues include rise in cancers, DNA anomalies, impaired fertility, elevated permeability of the blood-brain barrier, changed Ca^{++} flux, modifications in enzyme action, neurological diseases, altered brainwave activity, sleeplessness, lowered memory, reduced reaction time, ringing in the ears, faintness, skin complaints, severe headaches, chronic pain and fatigue, respiratory system difficulties, etc. An increasing number of population is becoming vulnerable to electromagnetic energy.

REFERENCES

BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF). [www-document] Available at: http://www.bioinitiative.org. Accessed 10 September 2013.

Davanipour Z. and Sobel E. 2007. Magnetic field exposure: Melatonin production, Alzheimer's disease, Breast cancer, Bio-initiative Report section 12, http://www.bioinitiative.org/report/docs/section_12.pdf. Accessed 12 August 2013.

Garaj-Vrhovac V. and Orescanin V.. 2008. Assessment of DNA sensitivity in peripheral blood leukocytes after occupational exposure to microwave radiation: the alkaline comet assay and chromatid breakage assay, Cell Biol Toxicol, Online first (53).

Gul A., Celebi H. and Ugras S. (2009) The effects of microwave emitted by cellular phones on ovarian follicles in rats. Arch Gynecol Obstet 280, 729-733.

Hardell L., Hansson Mild K. and Kundi M., 2007a, Evidence for brain tumors and acoustic neuromas, Bio-Initiative Report Section 10.

Health Protection Agency. 2008. http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733779274 Accessed September 2013.

ICNIRP. 1998. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). Health Physics 74 (4), 494-522, http://www.icnirp.de/PubEMF.htm. Accessed 08 May 2013.

Koylu H., Mollaoglu H., Ozguner F., Nazyroolu M., and Delibap N. 2006. Melatonin modulates 900MHz microwave-induced lipid peroxidation changes in rat brain. Toxicol Ind Health 22(5), 211-216.

Krause C. M., Pesonen M., Haarala Bjarnberg C., and Hamalainen H. 2007. Effects of pulsed and continuous wave 902 MHz mobile phone exposure on brain oscillatory activity during cognitive processing. Bioelectromagnetics 28(4), 296-308.

Lai H., 1994, Evidence for effects on Neurology and Behavior, Prepared for the Bio-Initiative Working Group. http://www.bioinitiative.org/report/docs/section_9.pdf. Accessed 15 June 2013.

Lai H. 2007a. Evidence for effects on neurology and behavior. Bio-Initiative Report, Section 9. http://www.bioinitiative.org/report/docs/section_9.pdf. Accessed July 2013.

Lai H. 2007b. Evidence for Genotoxic effects (RFR and ELF genotoxicity). Bio-Initiative Report Section 6. http://www.bioinitiative.org/report/docs/section_6.pdf. Accessed July 2013.

Lai H. and Singh N. P. 1997. Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 18(6), 446-454.

Narayanan S. N., Kumar R. S., Potu B. K., Nayak S. and Mailankot M. 2009. Spatial memory performance of wistar rats exposed to mobile phone. Clinics 64(3), 231-234.

Nittby, H., Grafstrom G., Eberhardt J. L., Malmgren L., Brun A., Persson B. R. R. and Salford L. G. 2008b. Radiofrequency and extremely low-frequency electromagnetic field effects on the blood-brain barrier. Electromagnetic Biology and Medicine, 27, 103-126.

Persson B. R. R., Salford L. G. and Brun A. 1997. Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wireless Networks 3, 455-461.

Powerwatch - International Guidance Levels. 2013. Powerwatch - International Guidance Levels. [www-document] Available at: http://www.powerwatch.org.uk/science/intguidance.asp. Accessed 02 October 2013.

Powerwatch - Electromagnetic Hypersensitivity. 2013. Powerwatch - Electromagnetic Hypersensitivity. [www- document] Available at: http://www.powerwatch.org.uk/health/sensitivity.asp. Accessed 04 September 2013.

Reproductive System – Google Images. 2013 Available at: https://www.google.fi/search?q=reproductive+system&es_sm=93&source=lnms&tbm=isch&sa=X&ei=ph5PUt7CPMjS4QSi5oCADA&ved=0CAkQ_AUoAQ&biw=1366&bih=643&dpr=1. Accessed 01 October 2013.

Sage C. L. 2007. Evidence for breast cancer promotion (melatonin studies in cells and animals), Bio-Initiative Report section 13, http://www.bioinitiative.org/report/docs/section_13.pdf. Accessed Aug 2013.

Vidya. (November 19, 2013). Adrift in a Sea of Electromagnetic Pollution Are WiFi Radiation Dangers Real? . Available at: http://www.earthcalm.com/wifi-radiation/. Accessed 10th Aug 2013.

Zhu Y., Gao F., Yang X., Shen H. and Liu W. 2008. The effect of microwave emission from mobile phones on neuron survival in rat central nervous system. Progress in Electromagnetics Research 82, 287-298.