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Mahesh Neupane

Exposure of Electromagnetic fields

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Instructors	Matti Fischer,Principal Lecture,Metropolia UAS

The main objective of this study is to examine the exposure of electromagnetic fields on human body and to understand the regulation of safety in general public and occupational exposure. The electromagnetic field information was collected using devices to find the exposure level of magnetic and electric field of some of the home appliances. This study aims to focus and analyze the effects of electromagnetic field on human health. The measured data is compared across the standards of different parts of the world.

This research was carried out to evaluate the exposure of electromagnetic fields in various places. This report is a result of the study where information was collected from materials published by related authority, and web pages and research reports from various EMF regulation authorities.

This thesis includes the information about electromagnetic spectrum and classification of frequency range and their uses by the electronic component, medical devices and power lines.

Keywords	EMF, Electromagnetic field, Static frequency, Extremely low Frequency range Intermediate Frequency Radio Frequency.

Content

List of Abbreviations

EMF	Electromagnetic field
Hz	Hertz
kHz	Kilo Hertz
MHz	Mega Hertz
WHO	World Health Organization
HF	High Frequency
LF	Low Frequency
RF	Radio Frequency
AC	Alternating Current
DC	Direct Current
MF	Magnetic Field
ECG	Electrocardiogram
ICNIRP	International Commission for Non- Ionizing Radiation Protection
SAR	Specific Absorption Rate
MRI	Magnetic Resonance Imaging
CNS	Central Nervous System

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1 Introduction

An electromagnetic field is a generic term for fields of force generated by electrical charged particles or magnet.

This study project focuses on the exposure of EMF around our environment and their effects on human health. There are two types of effects of electromagnetic fields, namely, direct and indirect effects. The general public is exposed to electromagnetic fields daily, irrespective of whether they want or not. The dense electromagnetic environment is continuing to increase because of the new development of science and technology. Every day, the people are in search of sophisticated technical products for easier life which will have a direct or an indirect effect to general human health.

Modern technology and science are going beyond imagination creating and launching new technological devices that have been going on for many years. Technology has already been an essential part of our life. Our day to day activities can't be complete without using technical products. Different companies are producing different technological products every year. On the other hand, the electromagnetic fields generated by these types of devices have direct and indirect effects on our health.

On the other hand, occupational exposure to EMF is always a concern as people working in professional fields are exposed to electromagnetic fields more than the general public. The regulation of EMF level has been monitored by normally two organizations ICNIRP (International Commission for Non-Ionizing Radiation Protection) and European commission directive 2013/35/EU which set the EMF standard for general and public exposure.

This thesis will be helpful to understand the natural and human-made sources of electric and magnetic fields in the environment and their impacts in our daily life depending upon the level of exposure of EMF.

2 Theoretical background

Theoretical background mainly includes theoretical knowledge which is required to accomplish this thesis. The fundaments of electromagnetic fields are defined below,

2.1 Maxwell equation

Maxwell equations are the equation that governs electromagnetism. (The behavior of electric and magnetic fields). These equations describe how electric and magnetic fields propagate, interact and how they are influenced by objects.

Maxwell equation is a combination of four equations:

- Gauss law or Maxwell first equation

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \quad (1)$$

The equation 1 where ∇. E is the divergence of electric field and ϵ_0 is the permittivity of vacuum and ρ is the total electric charge density tells that the total electric fields flux which emerges from a finite region of space filled with electric charge is proportional to the net charge in the region.

- Gauss law of magnetism or Maxwell second equation

$$\nabla \cdot B = 0 \quad (2)$$

The equation 2 where ∇. B is the divergence of magnetic field shows that the total magnetic flux coming from any finite region of space is zero.so there is no magnetic monopole or charge of source.

- Faradays law or Maxwell third equation

$$\nabla \cdot E = \frac{\partial \boldsymbol{B}}{\partial t} \qquad 3$$

The equation 3 tells the electric field E is proportional to the magnetic field B. So the time varying electric field can create magnetic fields.

- ampere law or Maxwell fourth equation

$$\nabla \, \mathrm{X} \, \boldsymbol{B} = \mu_o \left(\mathbf{J} + \epsilon_{\boldsymbol{o}} \frac{\partial \mathbf{E}}{\partial \mathrm{t}} \right) \qquad 4$$

The equation 4 describes that the magnetic field in the region of any closed loop is proportional to the electric current and displacement of current around the enclosed surface. Also states that the generation of magnetic fields B can be done with the change in electric field.

2.2 Frequency

Frequency which is represented by F is used to characterize periodic signal over the duration which indicates how many times an identical event occurs per second. A static field which is constant at time has zero frequency. The range of frequency is Hz (hertz)-GHz (gigahertz). [1]

Frequency is an important parameter of electromagnetic fields it influences the design of electric and electronic circuit, the propagation and the measurement methods. Frequency is physical quantity used in telecommunication and spectral analysis.

The mechanism of interaction with matter and biological effect depends greatly on it. A field of equal strength can either have no effect or be dangerous to the health depending on its frequency. The range of frequencies is classified according to their wave length.[1]

2.3 Wavelengths

Wavelength is the distance travelled by the wave during one period. So, it depends on the frequency. Wavelength is calculated from propagation of speed of the wave in the medium and the frequency, according to the equation,

$$\lambda = \frac{v}{f}\ (m) \qquad 5$$

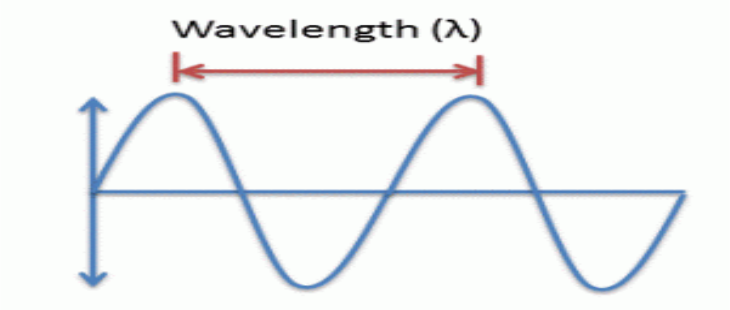

Figure 1.Wavelength

Whereas$v$represents the propagation speed (m/s) and f is frequency of the wave in hertz.

Wavelength also comes into play in the study of the interaction between electromagnetic fields and living organisms. The interaction depends heavily on the relationship between the wavelength and the size of the organism at certain frequency.

2.4 Power density

Power density s is defined as the quantity of energy per unit of time crossing a unit surface or as the power per surface unit. Which is expressed in (W/m^2). Power density can be obtained by normalizing the power radiated by the surface of a sphere of a radius d according to the equation, [1]

$$S = \frac{P}{4 \cdot \pi .\ D^2}\ (W.m^{-2}) \qquad 6$$

Where P is the power radiated by the source.

The figure 2 shows that man standing at a distance from a source of an electromagnetic field at a distance. The exposure is spherical when the man is near to the source, but the exposure starts to change when the man moves away from the source. [1]

Figure 2. Exposure from far away from the source **[1]**

Power density is considered homogeneous over a large surface area. All the points are seen at equal distance from the source. The electric and magnetic fields are perpendicular to one another and the direction of propagation which can be seen in fig 6.

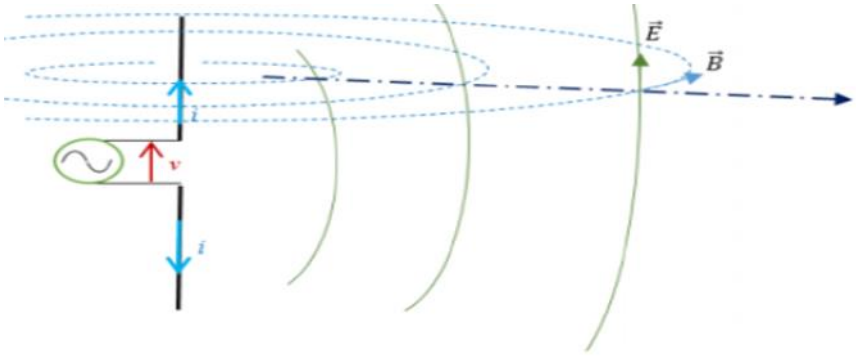

Figure 3.Dipole antenna with electric and magnetic field**[1]**

The poynting vector supplements field E and field H to form a right-angle dihedron. This vector is oriented in the same direction as the propagation. This represents the magnitude of the power density S which is also the product of the electric field E and magnetic field H. [1]

$$S = E.H(W.m^{-2}) \quad (7)$$

The relative representation of electromagnetic wave in far field can be seen in figure 5.

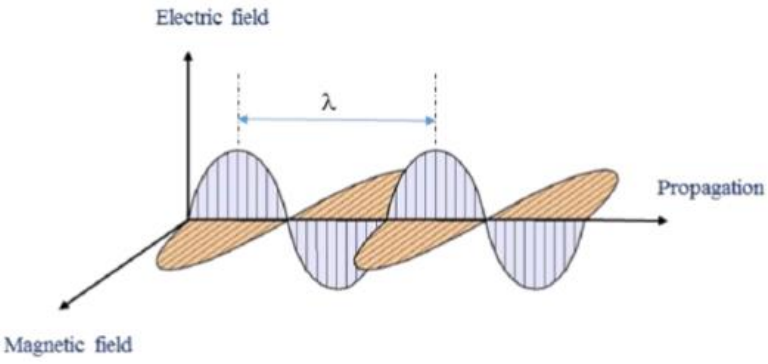

Figure 4. Relative representation on electric and magnetic wave in far field **[1]**

3 Types of radiation

The range of frequency in electromagnetic fields is from static to infinite frequency fields. The radiation is differentiated into two groups depending upon the fundamentals of the matter.

Ionizing radiation is located in the domain of very small wavelength. They are able to break atomic bonds of molecule. This kind of radiation have highest frequency on the other hand non-ionizing radiation are much safer than ionizing radiation.

3.1 Ionizing radiation

The range frequency of ionizing radiation is very high, and its wave length is very small like the size of an atom. Physicist use electron volt (eV), which can be a convenient energetic value, as the unit of measure. Where the relation between energy and frequency is connected by the value of h (planks constant).[1]

$$E = h\,V(eV) \qquad 8$$

Where the value of h is $6.62 * 10^{-34}$ J.s, and V is the symbol for frequency (Hz).

The common sources of ionizing radiation are X ray gamma rays and cosmic rays which can alter the matter dramatically. Their effect on our health are recognized even when the doses of effect is very small. Some electromagnetic waves carry large quantity of energy that can ionize particles of matter and consequently breaks down the chemical bonds between molecules.

3.2 Non-ionizing radiation

The frequency range of non-ionizing radiation starts from 0 hertz. This kind of radiation has long wave length. This does not have enough energy to ionize atoms or molecules. The common sources of non-ionizing radiation are microwaves, radio waves, infrared radiation.

3.3 Electromagnetic spectrum

Electromagnetic spectrum is the entire distribution of electromagnetic radiation according to the frequency and its wave length. All the electromagnetic wave travels at a speed of light in a vacuum so they have wide range of frequency and wave length. Electromagnetic spectrum comprises the span of all electromagnetic radiation and consist of many sub ranges. The various frequency range have their different names based on their behaviors and emission transmission and absorption. Figure 5 shows that the classification of frequency and wavelength of different ionizing and non-ionizing radiation.

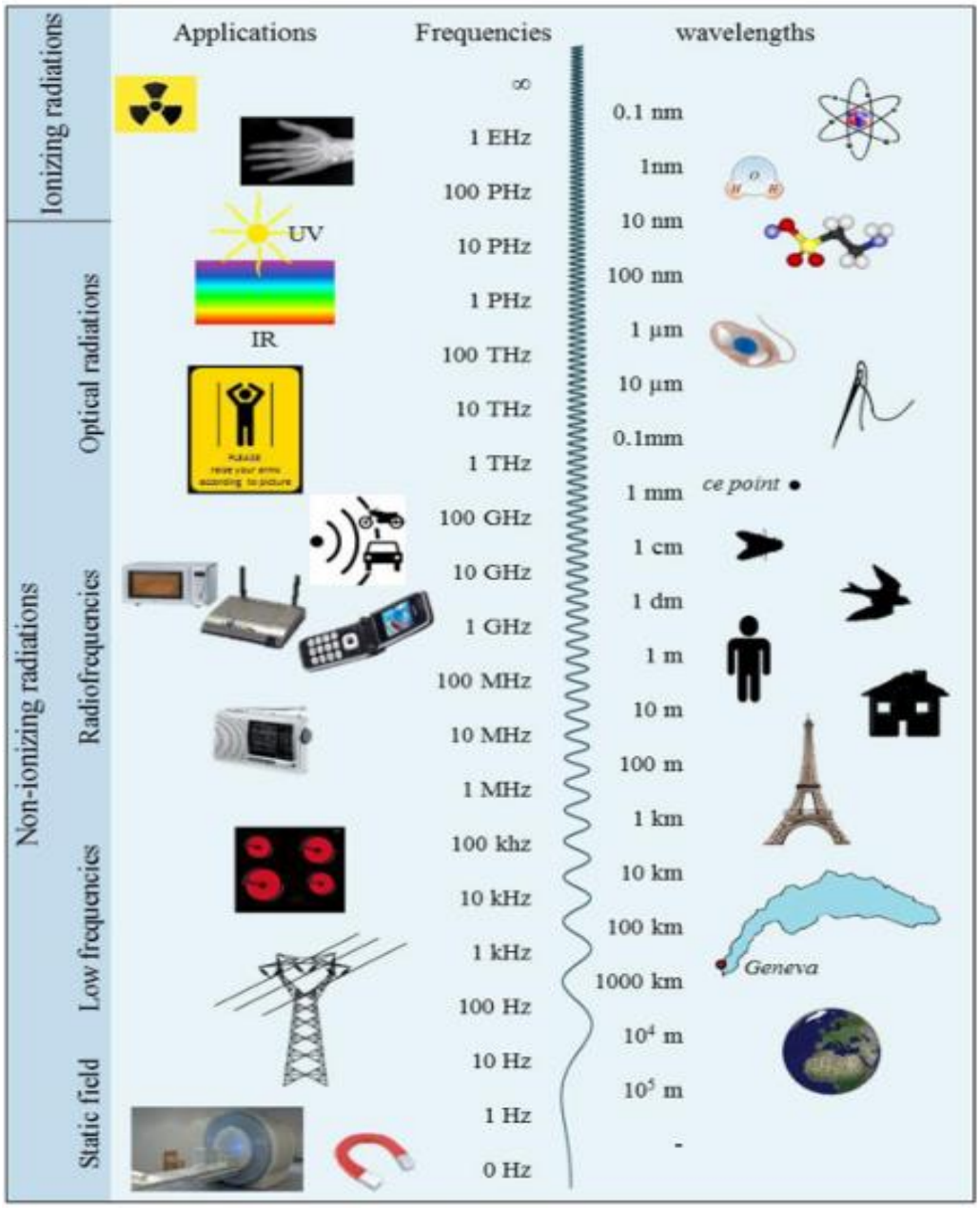

Figure 5. Electromagnetic spectrum and its applications **[1]**

3.4 Classification of frequency bands

Frequencies are classified by the decade of wavelength based on definitions from the International Telecommunication Union (ITU).The relationship between frequency and wavelength is inversely proportional so the increase in frequency meaning less wavelength and high wavelength has low frequency.[2]

Table 1. Classification of frequency bands [2]

Band name	Frequency range	Wave length	Abbreviation	Example uses
Static frequency	Below 3 Hz	>100,000 KM	SF	Static electricity, communication with submarines
Super low frequency	30 – 300 HZ	10,000 – 1000 KM	SLF	Communication with submarines
Ultra-low frequency	300 Hz – 3kHz	1000 – 100km	ULF	Underwater and underground telecommunication
Very low frequency	3 – 30 kHz	100 – 10 km	VLF	Navigation, wireless heart rate monitors, geophysics
Low frequency	30 – 300 kHz	10 – 1 km	LF	Time signals, RFID, anti-theft system, radio synchronization
Medium frequency	300 – 3000 kHz	10km – 100m	MF	Short wave radio, military communication, avalanche victim detector
High frequency	3 – 30 MHz	100 – 10 m	HF	RFID, radio connection, trans horizon transmission and radar
Very high frequency	30 – 300 MHz	10 – 1m	VHF	FM, television broadcast, aeronautical and maritime radio, weather radio
Ultra-high frequency	300 – 3000MHz	1 – 0.1m	UHF	DTT, mobile telephones, Wireless LAN, Bluetooth, GPS, satellite radio
Super high frequency	3 – 30 GHz	100 – 10mm	SHF	Private networks, radar, satellite telecommunication, microwave devices
Extremely high frequency	30 – 300GHz	10 – 1mm	EHF	Radio astronomy, onboard automotive radar, high frequency microwave radio relay, remote sensing, directed energy weapon security scanner gate
Terahertz or tremendously high frequency	300 – 3000GHz	1 – 0.1mm	THz or THF	Remote sensing, radiotherapy, spectroscopy, terahertz computing\communications

4 Sources of EMF

There are various sources of electromagnetic fields. Some are generated through natural sources while some are generated through manmade sources. The picture below illustrates the basic sources of EMF around our environment.

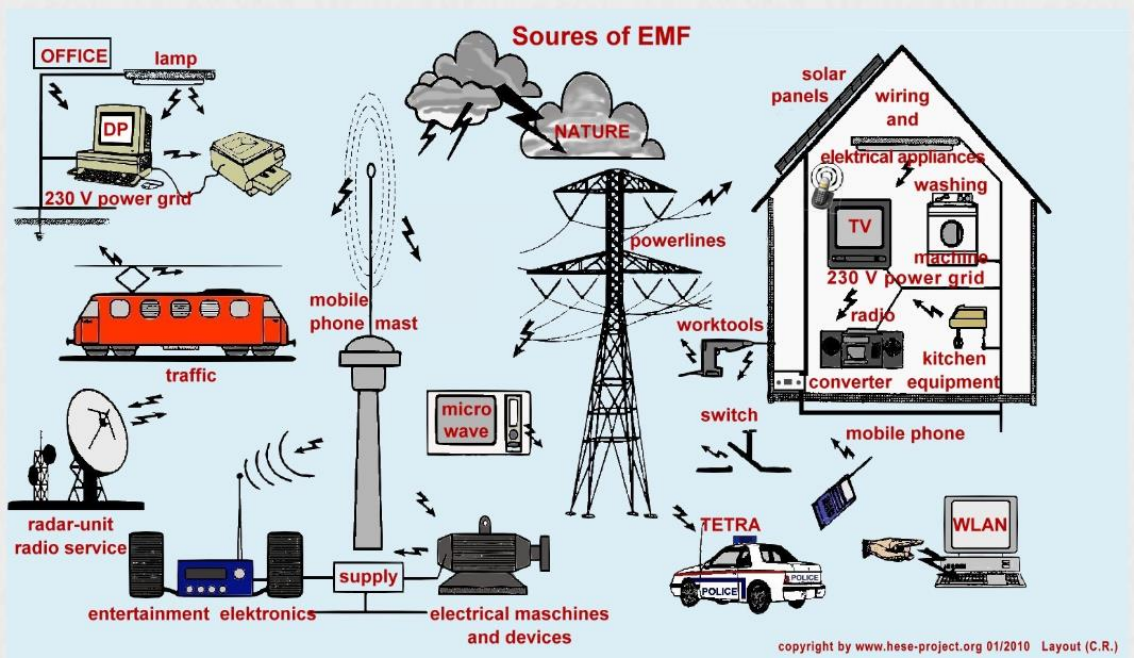

Figure 6. Common sources of ionizing and non-ionizing radiation **[3]**

4.1 Natural sources of electromagnetic fields

Earth is encircled with a huge magnetic field form its south pole to North Pole. The shape of its lines is identical to a bar magnet. The strength of earth geomagnetic fields varies from about 30 to 70 µT depending upon the places around the earth normally 70 µT around both magnetic poles. Some other natural sources of electromagnetic fields are

- Lightning, the electrical discharge produces and electromagnetic pulse.

- Sun
- Cosmic radiation

4.2 Static electric fields

Static electric field is constant fields. The strength of electric fields is expressed in (V/m). The strength of natural electric field in atmosphere varies from 100 V/m in good weather to several thousand V/m in the thunder clouds.

Static electric fields can be generated naturally when an object is rubbed which removes electrons from the object and polarizing it.

4.3 Static magnetic fields

Static magnetic fields are constant fields, whose intensity and direction do not change over time, in contrast to low and high frequency fields. So, they have the frequency of 0 Hz.

Static magnetic fields can be found in medical devices such as MRI (Magnetic Resonance Imaging). MRI produces high resolution 3D image of a body which is formed by layering up cross-section (2D images). MRI is only way to where central nervous system can be studied in detail and cerebral activity is visualized in quasi-real time. MRI equipment uses strong magnetic fields sources that expose the patient to strong fields. The effect of those fields can also be observed on the people who assist them.

MRI scanner normally generates three types of fields a static magnetic field, three gradient magnetic fields and electromagnetic fields in the radiofrequency.

4.3.1 Exposure limit for static magnetic field

The individual who are exposed to static magnetic fields as a result of their regular or assigned job activity are under these guidelines, the other terms general public refers to the entire population.[4]

Exposure characteristics	Magnetic flux density
occupational	
exposure of head and trunk	2T
exposure of limbs	8T
general public	
exposure of any parts of body	400mT

Occupational exposures

The recommended limit set for occupational exposure of the head and trunk should not exceed peak magnetic flux of 2T to prevent vertigo and nausea and other sensation, but for the specific work application, when the environment is controlled and appropriate to work, the exposure up to 8T is acceptable.

General public exposures

Based on the scientific knowledge on the direct effect of static fields on human, acute exposure of general public should not exceed 400mT in any parts of body.

4.4 Exposure level EMF around the world at different frequency range

4.4.1 General public exposure

The exposures of emf on general pubic have been monitored by ICNIRP. On the other hand, European Union has its regulation monitored by the EU Directive (2013/35/EU). The exposure has been in two parts: general public exposure and occupational exposure. The level of EMF exposure limit is also different in both categories. Power frequency EMF is generated in transport, production and distribution. Normally the frequency of alternating current and the resulting EMF is 50 Hz in Africa, most parts in Asia, Australia and Europe. However, some countries like Philippines and Korea Japan and Saudi Arabia use 60 Hz frequency. Council of European Union published a recommendation of the limitation of exposure which contains basic restriction for the electric fields and current, the absorption power in the body and the reference level for the strength of EMF.

From the table below it is illustrated that the reference level for general public exposure of electromagnetic fields for the member of European Union and some industrial nation all over the world. [5]

Table 2. Reference levels or exposure limits for the general public for electromagnetic fields **[5]**

	50 Hz		900 MHz			1800 MHz			2100 MHz		
Country:	electric field strength (V/m)	magnetic flux density (µT)	electric field strength (V/m)	magnetic flux density (µT)	equivalent plain wave power density (W/m^2)	electric field strength (V/m)	magnetic flux density (µT)	equivalent plain wave power density (W/m^2)	electric field strength (V/m)	magnetic flux density (µT)	equivalent plain wave power density (W/m^2)
1999/519/EC	**5000**	**100**	**41**	**0.14**	**4.5**	**58**	**0.20**	**9**	**61**	**0.20**	**10**
Austria	[5000]	[100] [1]	[41]	[0.14]	[4.5]	[58]	[0.20]	[9]	[61]	[0.20]	[10]
Belgium	—	10 [2]	21 [3]	—	—	29 [3]	—	—	31 [3]	—	—
Bulgaria	— [4]	— [4]	—	—	0.1	—	—	0.1	—	—	0.1
Croatia	2000 [5]	40 [5]	17 [5]	0.055 [5]	0.72 [5]	23 [5]	0.078 [5]	1.4 [5]	25 [5]	0.084 [5]	1.7 [5]
Cyprus	[5000]	[100]	41	0.14	4.5	58	0.20	9	61	0.20	10
Czech Republic	2000	200	41	0.14	4.5	58	0.20	9	61	0.20	10
Denmark	—	— [6]	—	—	—	—	—	—	—	—	—
Estonia	5000	100	41	0.14	4.5	58	0.20	9	61	0.20	10
Finland	[5000]	[100] [7]	41	0.14	4.5	58	0.20	9	61	0.20	10
France	5000 [8]	100 [8]	41	0.14	4.5	58	0.20	9	61	0.20	10
Germany	5000 [9]	100 [9]	41	0.14	4.5	58	0.20	9	61	0.20	10
Greece	5000	100	32 [10]	0.11 [10]	2.7 [10]	45 [10]	0.15 [10]	5.4 [10]	47 [10]	0.16 [10]	6 [10]
Hungary	5000	100	41	0.14	4.5	58	0.20	9	61	0.20	10
Ireland	5000 [11]	100 [11]	41	0.14	4.5	58	0.20	9	61	0.20	10
Italy	—	3 [12]	6 [13]	0.02 [13]	0.1 [13]	6 [13]	0.02 [13]	0.1 [13]	6 [13]	0.02 [13]	0.1 [13]
Latvia	—	—	—	—	—	—	—	—	—	—	—
Lithuania	500 [14]	20 [14]	—	—	0.45	—	—	0.9	—	—	1
Luxemburg	5000 [15]	100 [15]	41 [16]	0.14	4.5	58 [16]	0.20	9	61 [16]	0.20	10
Malta	[5000]	[100]	41	0.14	4.5	58	0.20	9	61	0.20	10
Netherlands	[5000] [17]	[100] [17]	—	—	—	—	—	—	—	—	—
Poland	1000	75	7	—	0.1	7	—	0.1	7	—	0.1
Portugal	5000	100	41	0.14	4.5	58	0.20	9	61	0.20	10
Romania	5000	100	41	0.14	4.5	58	0.20	9	61	0.20	10
Slovakia	5000	100	41	0.14	4.5	58	0.20	9	61	0.20	10
Slovenia	500 [18]	10 [18]	13 [18]	0.04 [18]	0.45 [18]	18 [18]	0.06 [18]	0.9 [18]	19 [18]	0.06 [18]	1 [18]
Spain	[5000] [19]	[100] [19]	41	0.14	4.5	58	0.20	9	61	0.20	10
Sweden	[5000]	[100]	[41]	[0.14]	[4.5]	[58]	[0.20]	[9]	[61]	[0.20]	[10]
United Kingdom	[9000]	[360]	[41]	[0.14]	[4.5]	[58]	[0.20]	[9]	[61]	[0.20]	[10]
Australia	—	—	41	0.14	4.5	58	0.20	9	61	0.20	10
China	4000	100	12	0.04	0.4	12	0.04	0.4	12	0.04	0.4
India	—	—	13	0.041	0.45	18	0.058	0.9	20	0.063	1.1
Japan	3000 [20]	200 [20]	48	0.16	6	61	0.20	10	61	0.20	10
Russia	500	5 [21]	—	—	0.1	—	—	0.1	—	—	0.1
Switzerland	—	1 [22]	4 [23]	—	—	6 [23]	—	—	6 [23]	—	—
U.S.A.	— [24]	— [24]	—	—	6	—	—	10	—	—	10

4.4.2 Occupational exposure

In all the member of European Union, the risk of EMF exposed in occupation and workers risk is monitored by the national legislation based on the European Union 2013/35/EU Directive, which sets the minimum requirement but also gives the member of state to set their own limits and conditionals exemption. This directive also has the level for the electric field strengths magnetic flux and power density outside the body which are related to health effect exposure equivalent to ICNIRP occupational basic restriction for power density and absorption rate. Countries outside EU have their own consideration under the ICNIRP regulation. [4]

The table below shoes that the occupation level of exposure of EMF in the member state of European Union and some selected countries outside EU

Table 3. Occupational reference levels or exposure limits for electromagnetic fields [5]

	50 Hz		900 MHz					
Country:	electric field strength (high AL) (V/m)	magnetic flux density (high AL) (μT)	electric field strength (V/m)	magnetic flux density (μT)	equivalent plain wave power density (W/m^2)	conditional exemption from ELV for MRI	alternative protection system for armed forces	temporary exemption from ELV for specific sectors or activities
2013/35/EU	**20000**	**6000**	**90**	**0.30**	**—**	**yes**	**yes**	**yes**
Austria	20000 [1]	6000 [1]	90 [1]	0.30 [1]	—	yes	no	yes [2]
Belgium	20000	6000	90	0.30	—	yes	no	yes
Bulgaria	20000	6000	90	0.30	—	yes	yes (NATO)	no
Croatia	20000	6000	90	0.30	—	yes	yes	yes
Cyprus	20000	6000	90	0.30	—	yes	yes	yes
Czech Republic	10000	1000	90	0.30	22.5	no	no	no
Denmark	20000	6000	90	0.30	—	yes	no	no
Estonia	20000	6000	90	0.30	—	yes	yes (NATO)	no
Finland	20000	6000	90	0.30	—	yes	yes	yes
France	20000 [3]	6000 [3]	90 [3]	0.30 [3]	—	yes [4]	no	no
Germany	20000	6000	90	0.30	—	yes [4]	no	yes [4]
Greece	20000	6000	90	0.30	—	yes	Yes (NATO)	Yes [5]
Hungary	20000	6000	90	0.30	—	no [6]	yes (NATO)	yes [6]
Ireland	20000	6000	90	0.30	—	yes	no	no
Italy	20000	6000	90	0.30	—	no [7]	yes	yes [7]
Latvia	20000	6000	90	0.30	—	yes	yes	no
Lithuania	20000	6000	90	0.30	—	yes	yes [8]	no
Luxemburg	20000	6000	90	0.30	—	yes [9]	yes (NATO) [9]	yes [9]
Malta	20000	6000	90	0.30	—	yes	yes	yes
Netherlands	20000	6000	90	0.30	—	yes	yes	no
Poland	10000 [10]	2000 [10]	60 [10]	0.20 [10]	—	no	yes	no
Portugal	20000 [11]	6000 [11]	90 [11]	0.30 [11]	—	yes	yes	no
Romania	20000	6000	90	0.30	—	yes	yes	yes
Slovakia	20000	6000	90	0.30	—	yes	yes	yes
Slovenia	20000	6000	90	0.30	—	yes	yes	yes [12]
Spain	20000	6000	90	0.30	—	yes	yes (NATO)	yes
Sweden	20000	6000	90	0.30	—	yes	yes	no
United Kingdom	20000	6000	90	0.30	—	yes	yes	yes [13]
Australia	10000	1000	92	0.31	22.5			
China	5000	—	—	—	50 [14]			
India	—	—	—	—	—			
Japan	— [15]	— [15]	— [15]	— [15]	— [15]			
Russia	—	2000 [16]	—	—	10 [16]			
Switzerland	10000 [17]	500 [17]	90 [17]	0.30 [17]	22.5 [17]			
U.S.A.	— [18]	— [18]	—	—	30			

4.5 Low frequency

The low frequency ranges from 1Hz-100 kHz in the electromagnetic spectrum. Low frequency fields have two main components: electric fields due to electric charge and a related magnetic field.

When people are exposed to LF fields, electric fields and current are generated inside the human body, and they interface with our own electric fields and current, which are related to normal biological functioning.

Potential long- term effects of low frequency fields have been studied over the last decades and some epidemiological studies have suggested that, when people are exposed to low frequency fields for a long time, there can be increased risk of childhood leukemia. Nevertheless, the combination of study is biased; therefore, the current scientific evidence does not lead to prove that exposure to LF is a cause of childhood leukemia.

The table shows that the reference level for occupational exposure for time varying electric and magnetic fields.

4.6 High Frequency

High Frequency (HF) is part of electromagnetic spectrum comprising frequency range from 100 kHz to 300 GHz. Technologies such as mobile communication base station and radio communication use high frequency.

The main effect of HF exposure on human is heating of the body of exposed tissues. HF fields have power to penetrate our body and can cause vibration of charged molecules. Although, above a reference level (referred as threshold), depending upon the duration of exposure, the temperature rise of our body can provoke serious health effects such as heat stroke and tissue damages.

5 Electromagnetic fields in the environment

Due to the electromagnetic field produced by natural and artificial sources, we are always at risk of being exposed to electromagnetic fields every day. We can't avoid being exposed to the electromagnetic field because of the development made by humans in past century products that have magnet and run through electricity that produces EMF. When a child is born, whether in a hospital or somewhere else, he will be exposed to the EMF since his early age. Even before being born, while he is in the mother's womb, he is exposed to EMF because nowadays, various equipment which produced EMF are used to check the condition of baby various times. The technology which is being used in the hospital such as the X-ray machine and the ECG machine and other medical equipment also produce EMF. So, every day and every place, humans are at risk of exposure to EMF. The common sources of EMF in our environment are cell phones, cell phone towers, computer power transmission lines, radar communication towers and so on. Thus, the environment around us is filled with electric and magnetic fields. The level of exposure of EMF can be bigger or smaller depending upon the source of it.

5.1 Electromagnetic fields in everyday life

From early morning to the evening and during the night we are always exposed to the electromagnetic fields every day. When we wake up, we use several electrical appliances such as coffee machine, water kettle, electric razor, toothbrushes, refrigerator and other various electric devices that are used in everyday life. Depending upon the place you spend your time in your home, you are always exposed to emf. When we leave our home to go to work or somewhere else, we are exposed to emf via cell phone which we carry for most of the time. The cars, buses and trains which we use for transportation, the transmission line which might be above us, the cell towers, the railway lines and many other sources of EMF are always there which encounter in everyday life. Patients in the hospitals can be exposed to electromagnetic fields. The common sources of EMF that we have in our homes are such as

- Hair drier

- Refrigerator
- Wi-Fi router
- Computers
- Laptops
- Television
- Microwave ovens
- Electric heaters

The electric field strength produced by some of the home appliances at a user distance is normally well below the guidance limit set by ICNIRP.

Typical Electric field strength measured near a house hold appliances at a user distance.(4)

Table 4.Electric field strength measured near a house hold appliances **[6]**

Electric appliances	Electric field strength(V/m)
Iron	120
Stereo receiver	180
Refrigerator	120
Mixer	100
Toaster	80
Hair drier	80
TV	60
Coffee machine	60
Vacuum cleaner	50
electric oven	8
Light bulb	5

All of the home appliances use the frequency of 50 Hz whereas the guidance limit guidelines for the value of electric fields strength is 5000 V/m**.**

Typical magnetic fields strength of various household devices in different distance are shown below. Whereas the guidance set by ICNIRP is 100(μT) [6]

Table 5. Magnetics field measured in terms of distance **[6]**

Electric appliances	3 cm distance (μT)	30 cm distance (μT)	1 m distance (μT)
Hair drier	6-2000	0.01-7	0.01-0.03
Electric shaver	15-1500	0.08-9	0.01-0.03
Vacuum cleaner	200-800	2-20	0.13-2
Fluorescent light	40-400	0.5-2	0.02-0.25
Microwave oven	73-200	4-8	0.25-0.6
Portable radio	16-56	1	< 0.01
Electric oven	1-50	0.15-0.5	0.01-0.04
Washing machine	0.8-50	0.15-3	0.01-0.15
Iron	8-30	0.12-0.3	0.01-0.03
Dishwasher	3.5-20	0.6-3	0.07-0.3
Computer	0.5-30	<0.01	
Refrigerator	0.5-1.7	0.01-0.25	<0.01
Color TV	2.5-50	0.04-2	0.01-0.15

5.2 Electromagnetic fields and optical radiation in hospitals

Patients in the hospital and the staff working there are also at risk of exposure to electromagnetic fields. This exposure can be higher than the limits for the general population or for the workers. This kind of exposure can be associated with risk factor which might

suggest using alternative methods. The range of frequency used in hospital for diagnostic and therapeutic purpose is between 0 to 300 gigahertz. There are various types of equipment used in hospitals that produce electric and magnetic fields. One of the most important diagnostic applications of EMF is magnetic resonance imagining (MRI) which uses static magnetic low frequency and radiofrequency EMF.

The possible and probable health effect of strong magnetic field and low frequency are nausea and nerve simulation whereas strong radio frequency and optical radiation can cause heat related damages.

5.3 Electromagnetic fields near power transmission lines

Power lines normally carry very high voltage current from one place to another. When current flows through the wire two fields are created as electric and magnetic fields. These are two essential components of electromagnetic fields. The electric fields proportional to the voltage on the line. On the ground, the electric field is at maximum where the wire dips in the middle when the line is close to the ground. The electric field is influenced by the presence of object. Even the objects like tree or building which is poor conductor influence the electric field. Therefore, the presence of electric fields becomes weak inside the buildings close to the lines.

Magnetic radiation from power line varies to the electrical consumption. So, the presence of magnetic fields varies upon the time, day and season. The consumption of electricity is normally higher in winter season as compared to other seasons.[7]

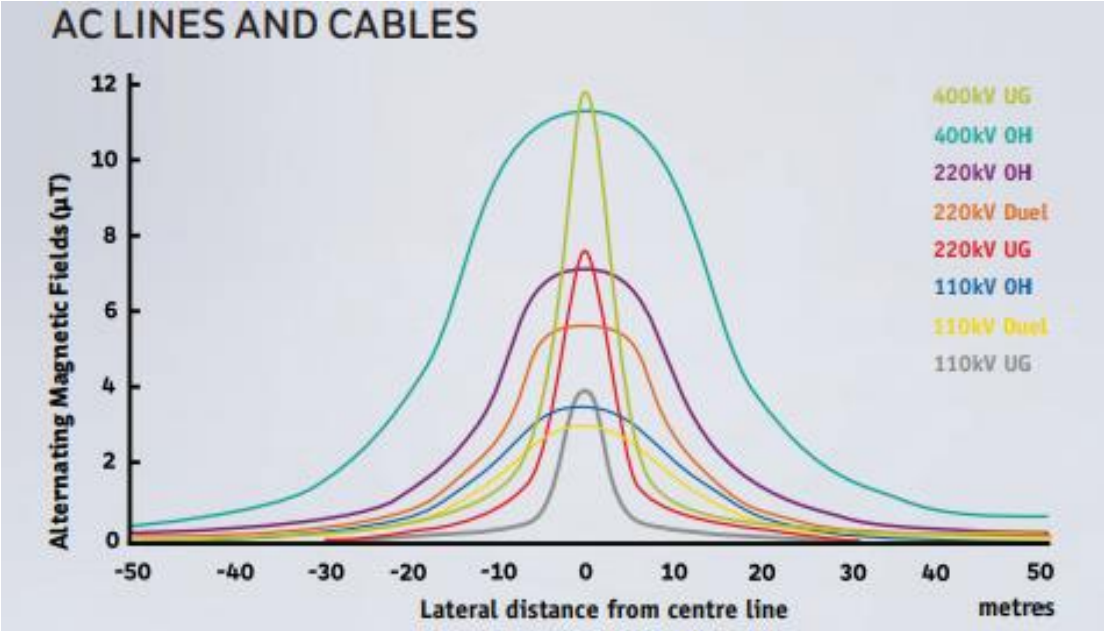

Figure 7. Presence of magnetic fields from overhead AC Power lines **[7]**

The figure 11 shows the level of magnetic fields from overhead lines as shown in fig the field strength decreases with the decrease in distance. These are all below the guidance limit set by ICNIRP for general public.

Direct interaction between low and high frequency electric and magnetic field and living tissue takes place in induced electric quantities (current and voltage).The current induced in a living tissue is defined by its density J (expressed in ampere per meter squareA/m^2) which corresponds to the current passes through a unit surface perpendicular to the direction of the current. None the less to set exposure limit value internal electric field is used (mV/m) which is considered as the relevant biophysical parameter to define the relation of the nerves.

The figure below shows that the man exposed to electric and magnetic fields below the high voltage power line the induction mechanism shows that the vertical electric field and horizontal magnetic fields. Figure 8 shows that the electric and magnetic field passing through a human body in the first scenario (E- field) in this case a current passes through a body is taken by ground but the magnetic field forms a closed loop in a body.

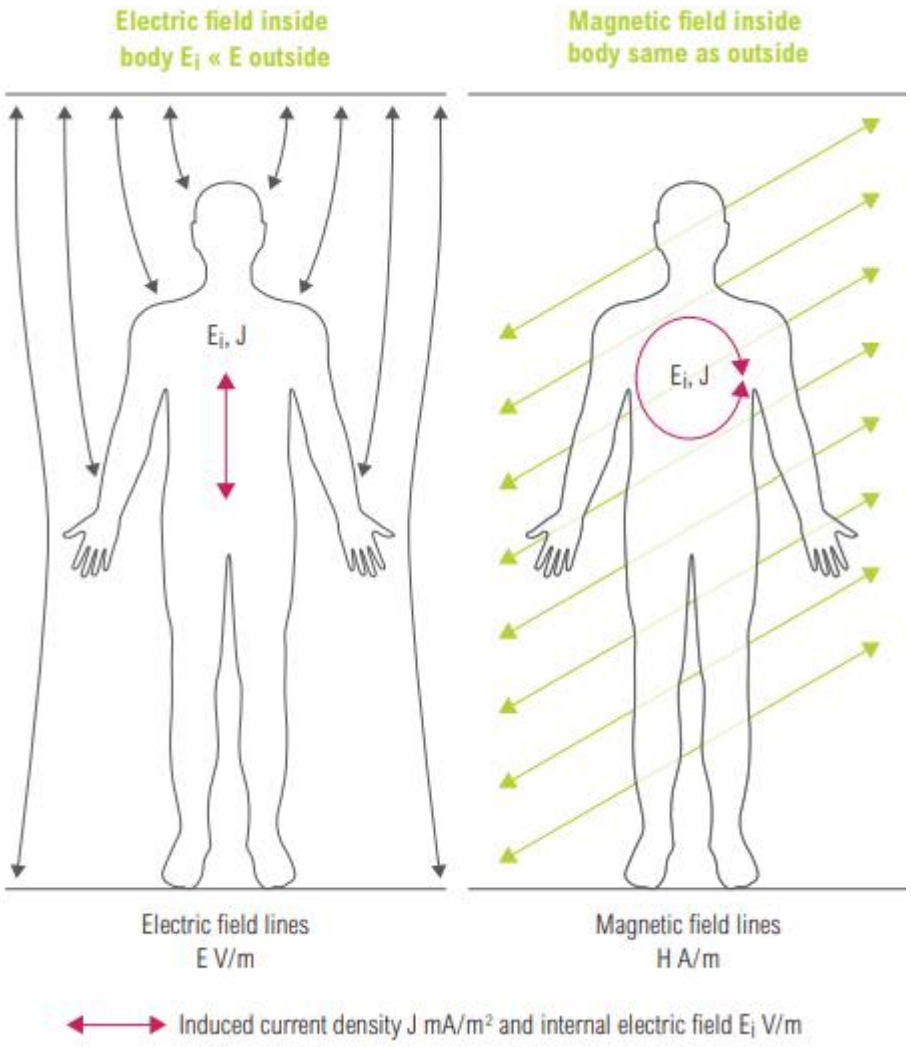

Figure 8. Vertical electric field and to a horizontal magnetic field exposed on human **[8]**

The debate between researcher and many epidemiologists have been going on since many years but the study does not find any concrete evidence to prove childhood leukemia. Till date, no heath agency or any epidemiology studies have not found that the exposure of EMF from power lines or any other electrical sources cause a long-term effect on humans.

6 Electromagnetic fields and human health

6.1 SAR (Specific Absorption Rate)

The specific absorption rate (SAR) is an expression of the energy absorption rate of electromagnetic fields by a human body when exposed to radio frequency. It is defined as the power absorbed per mass of tissue and its unit is watt per kilogram (W/kg).[1]

Figure 15 shows the absorption of the electromagnetic fields depending on the frequency. The absorption of the energy of a human body is differentiated as a function of frequency.

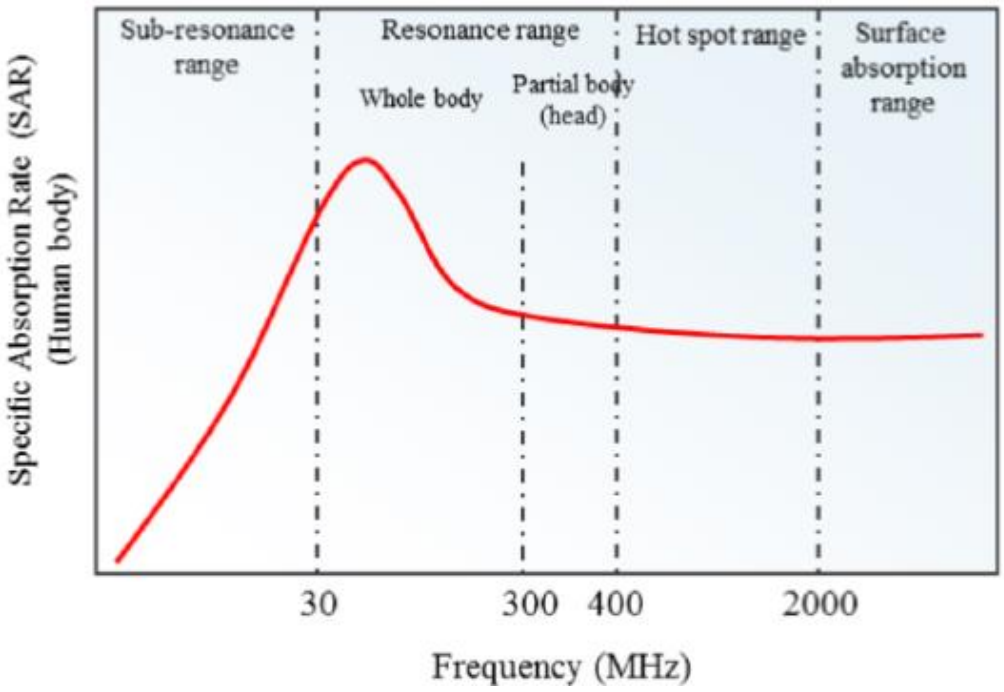

Figure 9. The rate of absorption of electromagnetic fields as function of frequency.**[1]**

When the frequency is below 100 kHz, the absorption rate is negligible to the extent that the temperature increase is not measurable. However, from above 100 kHz, the human body is more conductive. The magnetic ad electric field is created through the electric and magnetic coupling according to the types of emf sources.

The absorption of electromagnetic fields is more effective when the electric incident is parallel to the body. Figure 13 shows the power absorbed by a body during exposure to an electric field 1V/m.[1]

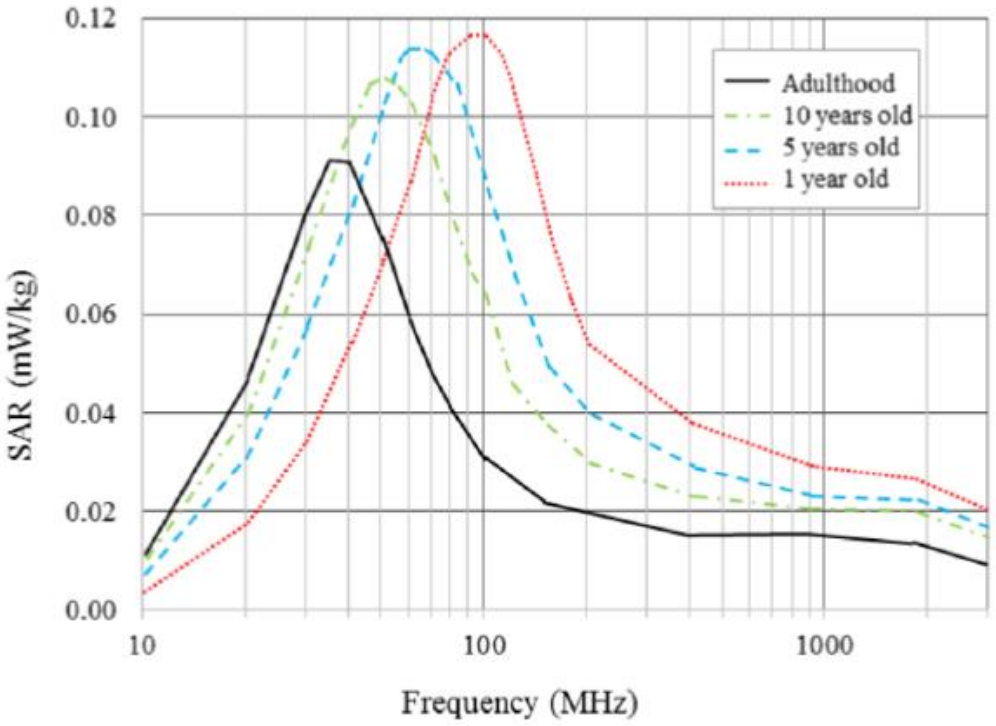

Figure 10. Specific absorption rate (SAR) of a human body with respect to frequency when the electric field is 1 V/m.**[1]**

Figure 10 illustrate that the absorption rate of a child is higher than a grown-up human. A child is likely to be more exposed to electromagnetic fields in comparison to an adult.

6.2 Biophysical mechanism

When electromagnetic fields penetrate the tissue of human body, the energy transforms into heat. The effect cause by this type of fields is called thermal effect. The process of mechanism that may lead to effect on health and well-being can be seen below.[1]

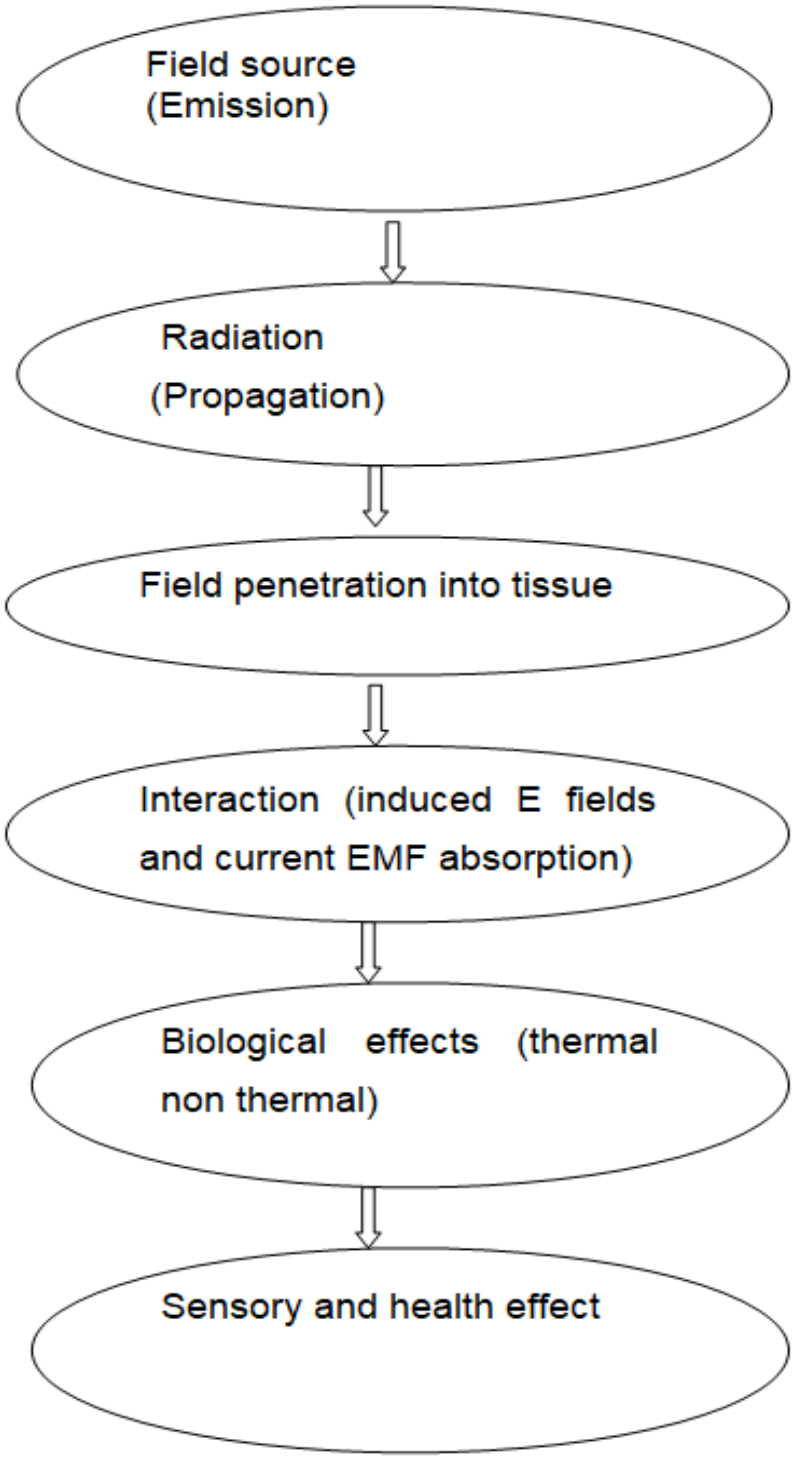

Figure 11. Process of mechanism that may lead to effect on health due to exposure of EMF

Electromagnetic fields can directly affect an exposed body causing biological effects. This kind of effect may be thermal at high frequency because of the absorption of the field or non-thermal at low frequency because of the presence of induced electric fields and current inside of a human body. The biological effect is a physical, biochemical or behavioral change in organism in response to stimulus. If they are in limit of a homeostasis, within the limit that allows the organism to retain the internal balance, the changes are reversible.

6.3 Biological effect

The direct biological effect of electromagnetic fields is divided into two parts: sensory effect and health effect. Sensory effect can cause transient sensory perceptions and minor changes in brain function in the exposed person. The indirect effect is caused by the presence of object in electromagnetic fields. Burns produced by a contact, current disturbances of an active medical devices, spark discharge and attraction of ferromagnetic elements are examples of this kind of effect.[1]

The main effects caused by electromagnetic fields can be shown in figure below

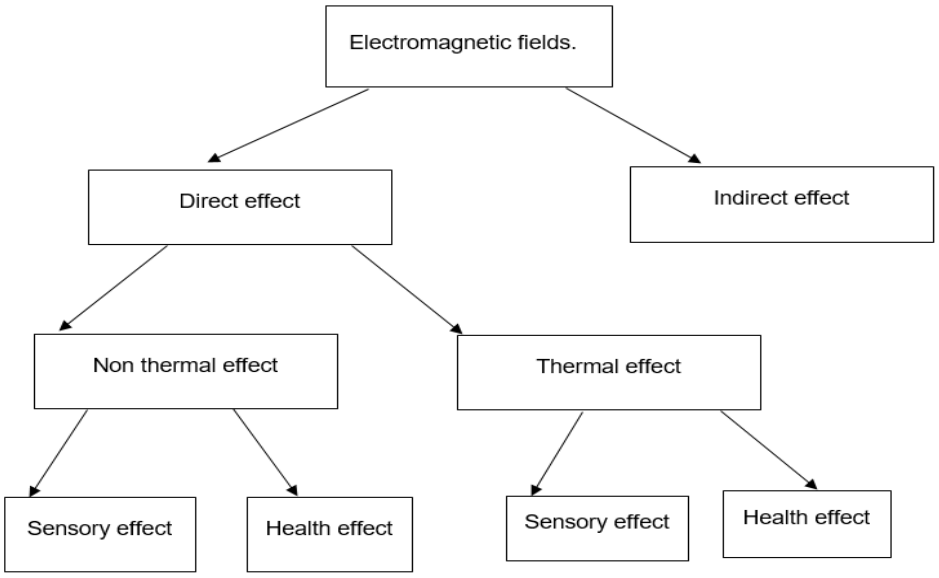

Figure 12. Effect caused by electromagnetic fields **[1]**

Direct effect is the effect in a human body caused directly by its presence of electromagnetic fields. Some common problems because of direct effect of electromagnetic fields are, [6]

- Effect on sense organs
- Vertigo and nausea from static magnetic fields
- Heating of a body parts because of high frequency fields

Indirect effect is the effect cause by the presence of object in electromagnetic fields such as,

- Human body interference with medical devices such as cardiac pacemaker
- electric shocks or burns from a contact current
- Interference with medical equipment.

The impact of electromagnetic fields in human health can be very dangerous depending upon the sources of EMF and its frequency range. The effect of electromagnetic fields depends normally in its frequency in intensity. In some situation, the other factors such as shape of the waveforms may be also important. Some of these fields can have impact on our sensory organs nerve system and muscle while others cause heating. The effect caused by the hearting is called thermal effect.

The figure below describes the different effect of EMF on human body with comparing to increasing frequency.[9]

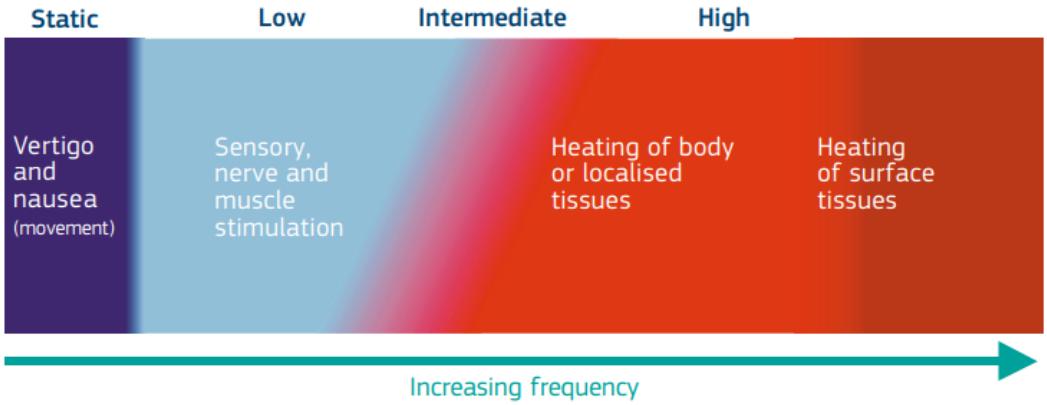

Figure 13. Effect of frequency in various frequency ranges.**[9]**

6.3.1 Effect of electromagnetic field on brain development

The process of development of the neurological system is highly complex and long process, and similarly progress of brain is a part of process as well has more complex molecular mechanism and hormonal changes independently of this process. Human brain development is a continuous process starting from third gestational week. The stage of development of brain easily affected by physical and environmental factors. [10]. It was reported that long term exposure to emf might cause Alzheimer´s disease. Epidemiological studies as well as experimental studies on effect of mobile phone or electromagnetic fields have found that emf may also have beneficial effect and might be used for treatment for some CNS (central nervous system) disorder. Contrarily the use of mobile phones heavily can cause headache and vertigo. [10]

Among young children whose skull thickness is very thin, so the absorption rate of EMF is higher in children and adolescents with compared to the adults. The radiation penetration of the skull of 5 years old is 75% where as young is 50% and adult is 25%.[10]. Figure 14 shows that the penetration of EMF of a child is deeper. Children absorbs more energy than adults from the same cellular phone moreover the stage of development of child immune system is in always in a progress. [10]

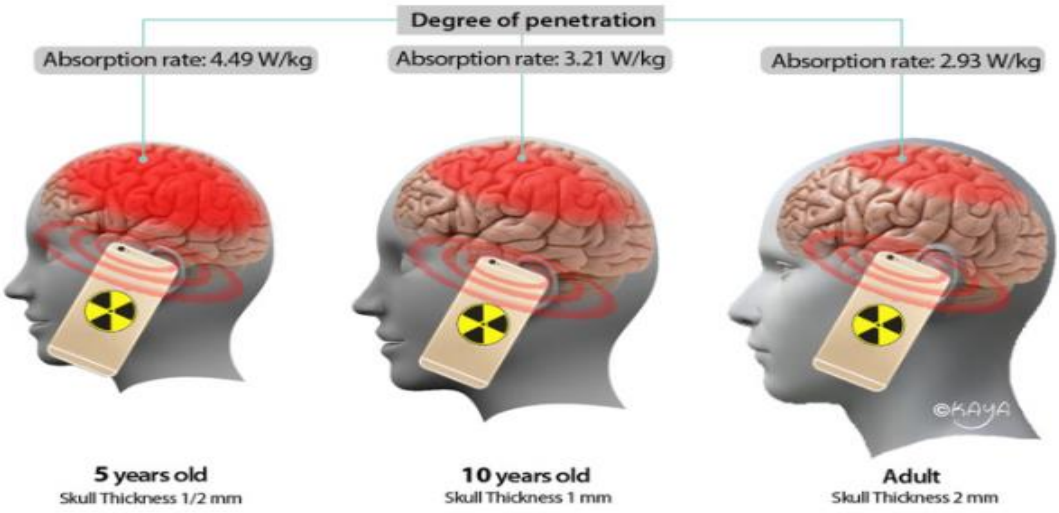

Figure 14.EMF absorption rate of a brain in different ages.**[10]**

7 Structure of EMF directive 2013/35 EU

In the year in 2013 European commission adapted the directive which covers the least possible health and safety requirements regarding the exposure of the workers to the risk of electromagnetic fields. This directive covers the frequency from 0 GHz to 300 GHz and it applies to all the occupational sector. This directive defines the exposure limit value and action level equivalent to respectively the basic restriction and reference level of ICNIRP guidelines. Workplaces where can be the high presence of electromagnetic fields due to the equipment operating at high current and voltage where workers and employee have to follow some protective measure as guide by EU directive. The most fundamental requirement for the works and employee given by EU Directive are: [9]

- Employers are obligated to access the extent of exposure from EMF.
- The exposure limit value (ELV) are established for electromagnetic fields and should not be exceeded or special precaution measure have to be taken in account when if that have to exceeded.
- Employers most provide adequate instruction and training to the workers.

8 Measured data of electric and magnetic fields of household's appliances.

The following data was obtained using two devices EM Eye CTM (Electromagnetic and RF signal meter) 045 and LIYMY LM70001 (electromagnetic radiation tester) in normal home where the measurement was obtained from various household devices. Data was observed from proximity to the devices and in 3 feet range from the appliances. The value was in decreasing order when measurement was carried out from decreasing distance of 3 feet. When the data was obtained from microwave and oven, the level of electric and magnetic field was higher. The threshold limit set by ICNIRP (INTRNATIONAL COMMISION OF NON-IONIZING RADIATIOJ) was well above the limit of the measurement taken. Measurement set up for the measurement of electric and magnetic fields can be shown in fig 15 the measurement was taken from normal user distance from the sources.

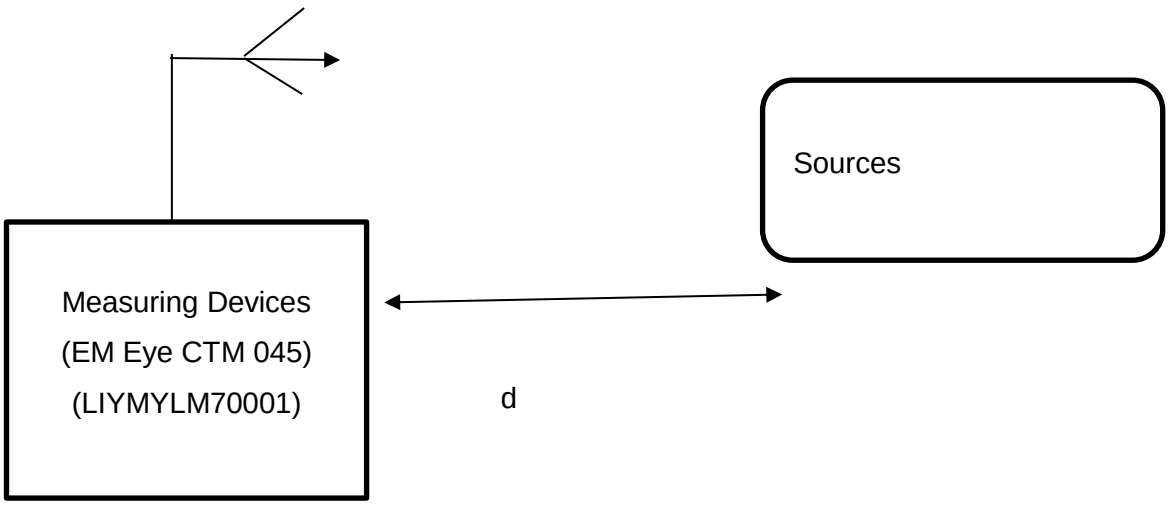

Figure 15. Measurement set up for the measurement of electric and magnetic fields

In above figure d is the distance of 3 feet from the source from where the measurement electric and magnetic was taken.

Table 6. The table below shows that the various households appliances having different magnetic and electric field.

Home Appliances	Frequency	Electric Field	Magnetic Field
Laptop	0.18 Ghz	70 V/m	0.17μT
Wi-Fi router	0.5 Ghz	60V/m	0.14μT
Cellular phone	0.6 Ghz	2V/m	0.15μT
Television	0.2 Ghz	3V/m	0.08μT
Microwave oven	0.4 Ghz	120V/m	4.5μT
Electric kettle		20V/m	1.05μT
Rice cooker		2V/m	0.2μT

9 Conclusion

This study focuses to analyze the exposure of electromagnetic fields and its effects on human. The major part of this thesis is the result of the study of various articles and reports from different publication and organization. The direct and indirect effect caused by EMF is discussed in this report.

To accomplish this thesis many reports by verified authority and report of some individual and organization was studied in detail. Their result and finding of those repost were analyzed and compared together. The measurement of electric and magnetic field was taken from two devices EM Eye CTM (Electromagnetic and RF signal meter) 045 and LIYMY LM70001 (electromagnetic radiation tester) and was compared with the international threshold limit. The measurement was taken from general household appliances was found out that the result obtained was the well below the guidance limit of ICNIRP.

The effect of electromagnetic field depends on the frequency. The long term exposure of higher frequencies electromagnetic field might have some effects such as increase body temperature and damage of tissue on the other hand the long term exposure of low frequency can cause anxiety headache.

As a result, the general exposure of emf does not have any serious effect on humans but the exposure for long period of time can have some effects on health. Several adverse health effects have been studied for the possible effect of Extremely Low Frequency (ELF)can have effect like childhood leukemia depression and cancer and development disorder in humans. The overall conclusion is biased and still this is in a debate whether the exposer of emf is harmful for health.

This study analyzed both direct and indirect effect of exposure of emf and its regulation. This report can be used for different purpose this report has mentioned the limits threshold level and its effect in different frequencies. This thesis might help for the people to understand the level of electric and magnetic fields exposure from different sources.

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