MEDICAL APPLICATION OF ELECTROMAGNETIC WAVES

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ABSTRACT

Electromagnetic waves are produced by stream of photons travelling in waves. They come in a very wide range of wavelengths, which include radio wave, microwave, infrared (heat), visible light, ultraviolet, X-ray, and gamma-ray waves. They are used in medicine in one way or another. These waves travel through empty space as well as through air and other mediums. In this research, attempts are made to explore different ways in which electromagnetic waves can be useful in human medicine and also some of the hazards of Electromagnetic waves.

Keywords: Electromagnetic Waves, Human Medicine, Visible Light, Ultraviolet, X-Ray

1.0. INTRODUCTION

Radiation originating in a varying electromagnetic field, such as visible light, radio waves, x-rays, and gamma rays. It exists as a continuous spectrum of radiation, from that with the highest energy level and shortest wavelength (gamma rays) to that with the lowest energy and longest wavelength (long radio waves) [1]. The visible part of the electromagnetic spectrum has a wavelength between 400 and 700 nm. Ultraviolet and infrared radiations have wavelengths just below the short end and above the long end of the visible spectrum, respectively. X-rays have wavelengths from about 0.005 to 10 nm. All forms of electromagnetic radiation travel at the speed of light. Electromagnetic waves are stream of photons travelling in waves. The quantum theory is based on the fact that electromagnetic waves consist of discrete “packets” of electromagnetic radiation, called protons, which have neither mass nor charge and have energy inversely proportional to the wavelength of the wave. In order of increasing photon energy and decreasing wavelength, the electromagnetic spectrum is divided into radio waves, infrared light, visible light, ultraviolet light, and x-rays. The photon is the base particle for all forms of electromagnetic radiation. It is a bundle of energy of light always in motion. Electromagnetic waves (EMW) at low frequencies are referred to as electromagnetic fields (EMF) and those at very high frequencies are called electromagnetic radiation.

Electromagnetic waves generated by many natural and human-made sources can travel for long distances and play a very important role in daily life. In particular, the electromagnetic fields in the Radiofrequency (RF) zone are used in communications, radio and television broadcasting, cellular networks and indoor wireless systems [2]. Resulting from the technological innovations, the use of electromagnetic fields gradually increases.

2.0ELECTROMAGNETIC SPECTRUM

An electromagnetic field (EM) is generated when charged particles, such as electrons are accelerated. By nature these charged particles are surrounded by an electric field. Once these particles are in motion they produce a magnetic field. So, when these particles change of velocity (accelerate or slow down), an EM field is produced.

The electromagnetic spectrum is divided in frequencies. From an electrical point of view, the spectrum has been arbitrarily divided into three main bands or fields: Extremely Low Frequency (ELF) fields usually concern all frequencies up to 300 Hz. Intermediate Frequency (IF) fields concern all frequencies from 300 Hz to 10 MHz and Radiofrequency (RF) fields concern frequencies between 10 MHz and 300 GHz. The effects of electromagnetic fields on the human body depend not only on the concerned field intensity but on its frequency and energy as well.

The electric field (or E component of an EM field) exists whenever charge is present. Its strength is measured in volt per metre (V/m or dBmV/m) [3]. The V/m is primarily used to express the intensity of the EM field. Magnetic field (or B component of an EM field) arises from current flow. Its flux density is measured in tesla (T) in the International System (SI). On the earth' surface, the flux density of the magnetic field is always less than 1 G. At radio frequencies, electric and magnetic fields are closely interrelated and we measure their power densities in watt per square metre (W/m^2, usually expressed in mW/cm^2).

All forms of electromagnetic radiation reside on the electromagnetic spectrum which ranks radiation from lowest energy/largest wavelength to highest energy/shortest wavelength. The higher the energy, the stronger the radiation. Below is the electromagnetic spectrum at a glance.

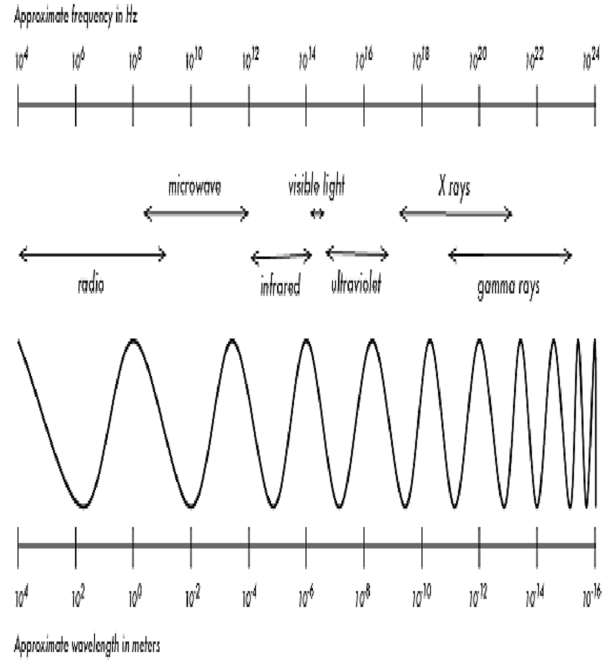

Figure 1: Electromagnetic spectrum at a glance

1. Radio waves:

Radio waves have the longest wavelength in the EM spectrum (up to football field long). They are invisible to our eyes.

2. Microwaves:

It is an electromagnetic wave with a wavelength in the range of 0.001-0.3m shorter than that of a normal radio wave but longer than those of infrared radiation. It is an EM wave of extremely high frequency of 1GH or more.

3. Infrared:

Is the part of the invisible spectrum that is contiguous to the red end of the visible spectrum and that comprises of EM radiation of wavelength from 300mm to 1nm. It lies between the visible and invisible portion of the EM spectrum.

4. Visible:
It is the range of wavelength of electromagnetic radiation that is normally visible from 380 to 760mm. It is the only part of the EM spectrum we can see. We see the different wavelength in this band of the spectrum as the colours of the rainbow. The sun for example is a natural source of visible waves.

5. Ultraviolet:
A spectrum of ultraviolet radiation is characterized by short wavelength and high quantum energies as compared to visible light. Its wavelength lies between 400nm to 10nm. Human cannot see ultraviolet rays, but some insects can. Our atmosphere's ozone layer blocks most of the UV rays [4].

6. X-rays:
X-radiation is a form of electromagnetic radiation that has a wavelength n the range of 0.01 to 10 nanometers corresponding to frequencies in the range of 30 petahertz to 30 exahertz and energies in the range of 100ev to 100kev [5]. We are most familiar with their use in a doctor's office, but x-rays also naturally occur in space.

7. Gamma rays:
Gamma ray is a penetrating electromagnetic radiation arising from radioactive decay of atomic nuclei. The wavelength is generally in the range of 1×10^{-10} to 2×10^{-13} meters. It is an EM radiation with the shortest wavelength but has the most energy of the entire spectrum. Nuclear explosions and radioactive atoms generate these rays.

3.0 **MEDICAL APPLICATION OF ELECTROMAGNETIC WAVES**

Electromagnetic wave can be applied in human being to aid the treatment of the following:

1. In the treatment of tumors:
RF is mainly used to treat tumors in lungs, kidney and bone. A needle-like RFA probe is placed inside the tumor, RF waves passing through the probe increase the temperature within tumor tissue resulting in its destruction. RFA may be combined with locally delivered chemotherapy treatment, and it is of particular value in reducing the size of inoperable tumors.

2. In physiotherapy:
Shortwave diathermy is used in physiotherapy treatment. The RF fields are used to speed up the healing of tissues by providing deep heat to a large area of the body positioned under conductance plates. Diathermy also allows superficial structures to be heated selectively by means of various surface heating techniques. It is also used to relieve pain and muscle spasm, resolve inflammation, reduce swelling, increase joint range and decrease joint stiffness.

3. Medical Imaging:
Radiography is an image obtained by placing a part of the patient in front of an X-ray detector and then illuminating it with a short X-ray pulse. Bones contain much calcium, which due to its relatively high atomic number absorbs X-rays efficiently. This reduces the amount of X-rays reaching the detector in the bones, making them clearly visible on the radiograph. The lungs and trapped gas also show up clearly because of lower absorption compared to tissue, while differences between tissue types are harder to see.

4. Fluoroscope
This is an imaging technique commonly used by physicians to obtain real-time moving images of the internal structure of a

patient through the use of fluoroscope. A fluoroscope consists of an X-ray source and fluorescent screen between which a patient is placed. Examples include cardiac catheterization and barium swallow.

5. Radiation Therapy

Radiation therapy is the treatment using penetrating x-rays, gamma-rays, or particles such as protons or neutrons on the affected region of the body to destroy the cancer cells. To produce the high energy radiation, particle accelerators such as Cobalt-60 radiation therapy unit or clinac 2100 accelerator are used. Radiation therapy is a modern treatment technique where the results are faster with fewer side effects than other more traditional forms of treatment. Depending upon the position of the radiation source, different types of treatments are used.

6. External beam radiotherapy

External beam radiotherapy is one of the kinds of radiation therapy used for destroying cancer cells. In this therapy the external beam is directed towards the affected part of the patient's body. This beam comprising of high energy particles destroys the cancer cells. The energy of X-rays and Gamma rays produced by these beams are expressed in terms of KV or MV, in this case the voltage is the maximum electric potential used by the LINAC to produce the photon beam. External beam radiotherapy is also called as teletherapy.

7. Proton therapy

Proton therapy is an advanced facility used for the treatment of cancer. A positively charged particle in the atomic nuclei is called a proton and these are used in proton beam therapy. Proton beam therapy uses a machine called cyclotron which is used to energize protons. Protons are extracted from the cyclotron and directed with magnetic fields to the tumor. How deeply the radiation penetrates is calculated based on the tumor's location. Protons lose only a small amount of energy when they enter the body. Their remaining energy is released when they reach the tumor, delivering the most effective dose of radiation. Proton beams have no exit dose unlike conventional radiation therapy.

8. X-Rays

X-rays are a type of radiation used for medical diagnosis. X-rays are like any electromagnetic radiation, consisting of energetic particles called photons. X-rays pass through the skin but are resistant to bones; this property of x-rays helps in finding any fractures in the patient's body. X-rays are produced in a X-ray machine which has a X-ray tube where the electron gun shoots electrons which hit the target material (tungsten is most widely used as a target element)with a very high velocity. X-rays result from the atomic processes which occur when the target is being hit. The first atomic process is called Bremsstrahlung, a process where the change in velocity of electrons hitting the tungsten produces X-rays. These electrons slow down after swinging around the nucleus of a tungsten atom and lose energy by radiating x-rays. The second atomic process is K-shell emission; here an electron shot from the electron gun hitting the tungsten atom has enough energy to kick the electron from the k-shell (lowest energy state) of the atom. The electron from the outer shell will fall into the K-shell, and this falling electron gives rise to x-rays which are photons of a specific energy. X-rays are not only used in medicine but also in industry, at airports to check customers and baggage, and by art historians to see if a picture has been painted on top of an older one.

9. Gamma Rays

Gamma rays are electromagnetic radiation like X-rays, but they have higher energy. Gamma rays are energetic photons or a light wave in the same electromagnetic family as light and x-rays, but much more energetic and so, potentially harmful. These waves are generated by radioactive atoms and by nuclear explosions. Gamma rays can be produced in labs through the process of nuclear collision and also through the artificial radioactivity that accompanies these interactions. The high-energy nuclei needed for the collisions are accelerated by devices such as the cyclotron and synchrotron. By using these accelerators Gamma rays are produced using Bremsstrahlung process. Gamma-rays can kill living cells, a fact which medicine uses to its advantage, using gamma-rays to kill cancerous cells.

4.0. EMR EFFECTS ON THE HUMAN BODY BY FREQUENCY

Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behaviour have created more and more artificial sources. Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work, from the generation and transmission of electricity, domestic appliances and industrial equipment, to telecommunications and broadcasting. Tiny electrical currents exist in the human body due to the chemical reactions that occur as part of the normal bodily functions, even in the absence of external electric fields. For example, nerves relay signals by transmitting electric impulses. Most biochemical reactions from digestion to brain activities go along with the rearrangement of charged particles. Even the heart is electrically active - an activity that your doctor can trace with the help of an electrocardiogram.

While the most acute exposures to harmful levels of electromagnetic radiation are immediately realized as burns, the health effects due to chronic or occupational exposure may not manifest for months or years

a. Radio frequency

High power extremely low frequency RF with electric field levels in the low Kv/m range are known to induce perceivable currents within the human body that create an annoying tingling sensation. These currents will typically flow to ground where the body is well insulated.

b. Microwave hazards

Microwave exposure at low power levels below the specific absorption rate set by government regulatory bodies are considered harmless-non-ionizing radiation and have no effect on human body. However, levels above the specific absorption rate (SAR) set by the government regulatory bodies are considered harmful. The standards for safe exposure levels to RF and microwave radiation are set to SAR level of 4W/Kg, the threshold before hazardous biological effects occur due to energy absorption in the body. A safety factor often was then incorporated to arrive at the final recommended protection guidelines of a SAR exposure threshold of 0.4W/Kg or RF and microwave radiation.

Exposure to high power microwave RF is known to create effects ranging from a burning sensation on the skin and microwave auditory effect to extreme pain at the mid-range, to physical microwave burns and blistering on skin and internals at high power levels.

c. Infrared Hazards

Infrared wave lengths longer than 750nm can produce changes in the lens of the eye glass blower's. Cataract is an example of a head injury that damages the anterior lens capsule among unprotected glass and iron workers. Cataract-like changes can occur in the workers who observe glowing messes of glass or iron without protective eye-wear for many hours a day. Another important factor is the distance between the worker and the source of radiation. In the case of arc welding, infrared radiation decreases rapidly as a function of distance, so that a distance more than 3 feet away from where welding take place, it does not pose an ocular hazard any more, but ultraviolet radiation still does. This is why welders wear tinted glasses and surrounding worker only has to wear clear ones that filter UV.

d. Visible light hazards

Moderate and high power laser are potentially hazardous because they can born the retina of the eye or even the skin. To control the risk of injury, various specifications for example ANSI ZI36 in the US, and IEC 60825 internationally define "classes" of lasers depending on their power and wavelength. These regulations also preferable required safety measures, such as labeling lasers with specific warning, and wearing laser safety goggles during operation.

As with its infrared and ultraviolet dangers, welding creates an intense brightness in the visible light spectrum, which may cause temporary flash blindness. Some sources state that there is no minimum safe distance for exposure to this radiation emission without adequate eye protection.

e. Ultraviolet hazards

Short term exposure to strong ultraviolet sunlight causes sunburns within hours of exposure. Ultraviolet light, specifically UV-B has been shown to cause cataracts and there is some evidence that sunglasses worn at an early age can slow its development in later life. Most UV light from the sun is filtered out by the atmosphere and consequently airline pilots often have high rates of cataracts because of the increase level of UV radiation in the upper atmosphere. It is hypothesized that depletion of the ozone layer and a consequent increase in level of UV light on the ground may increase future rates of cataracts. Note that the lens filters UV light, so once that is removed via surgery, one may be able to see UV Light. Prolonged exposure to ultraviolet radiations from the sun can lead to melanoma and other skin malignancies. Clear evidence establishes ultraviolet radiation, especially the non ionizing medium wave UVB , as the cause of most non melanoma skin cancer, which are the most common forms of non in the world, UV rays can also cause wrinkles, liver spots, moles and freckles in addition to sun light, other sources include tanning beds, and bright desk sun light, Damage is cumulative over one's life time, so that permanent effect man not be evidence for some time after exposure ultraviolet radiation of wave lengths shorter than 300 { actinic rays can damage the cornral epithelium. This is most commonly the result of exposure to the sun at high attitude, and in areas where shorter wave lengths are readily reflected from bright surfaces, such as snow, water and sand. UV generated by a welding are can similarly cause damage to the cornea known as “are eye” or welding flash burn of photokeratitis.

f. Effects on pregnancy outcome

Many different sources and exposures to electromagnetic fields in the living and working environment, including computer screens, water beds and electric blankets, radiofrequency welding machines, diathermy equipment and radar, have been evaluated by the WHO and other organizations. The overall weight of evidence shows that exposure to fields at typical environmental levels does not increase the risk of any adverse outcome such as spontaneous abortions, malformations, low birth weight, and congenital diseases. There have been occasional reports of associations between health problems and presumed exposure to electromagnetic fields, such as reports of prematurity and low birth weight in children of workers in the electronics industry, but these have not been regarded by the scientific community as being necessarily caused by the field exposures (as opposed to factors such as exposure to solvents).

g. Electromagnetic hypersensitivity and depression

Some individuals report "hypersensitivity" to electric or magnetic fields. They ask whether aches and pains, headaches, depression, lethargy, sleeping disorders, and even convulsions and epileptic seizures could be associated with electromagnetic field exposure. There is little scientific evidence to support the idea of electromagnetic hypersensitivity. Recent Scandinavian studies found that individuals do not show consistent reactions under properly controlled conditions of electromagnetic field exposure. Nor is there any accepted biological mechanism to explain hypersensitivity. Research on this subject is difficult because many other subjective responses may be involved, apart from direct effects of fields themselves. More studies are continuing on the subject.

Table 1 below shows electromagnetic wave comparison table

Table 1. LIGHT COMPARISON TABLE

Name	**Wavelength**	**Frequency(Hz)**	**Proton Energy**
Gamma ray	Less than 0.01nm	More than 30EHz	124Kev-300Gev
X-ray	0.01nm-10nm	30EHz-30PHz	124ev-124Kev
Ultra violet	10nm-380nm	30PHz-790THz	3.3ev-124ev
Visible	380nm-700nm	790THz-430THz	1.7ev-33ev
Infrared	700nm-1mm	430THz-300GHz	1.24mev-1.7ev
Microwave	1mm-1meter	300GHz-300MHz	1.24mev-1.24mev
Radio	1mm-100,000 Km	300GHz-3Hz	12.4fe-1.24mev

5.0. PRECAUTIONARY APPROACHES

With more and more research data available, it has become increasingly unlikely that exposure to electromagnetic fields constitutes a serious health hazard, nevertheless, some uncertainty remains [6]. The original scientific discussion about the interpretation of controversial results has shifted to become a societal as well as political issue. The public debate over electromagnetic fields focuses on the potential detriments of electromagnetic fields but often ignores the benefits associated with electromagnetic field technology. International guidelines and national safety standards for electromagnetic fields are developed on the basis of the current scientific knowledge to ensure that the fields humans encounter are not harmful to health. To compensate uncertainties in knowledge (due, for example, to experimental errors, extrapolation from animals to humans, or statistical uncertainty), large safety factors are incorporated into the exposure limits. The guidelines are regularly reviewed and updated if necessary [7]. It has been suggested that taking additional precautions to cope with remaining uncertainties may be a useful policy to adopt while science improves knowledge on health consequences. However, the type and extent of the cautionary policy chosen critically depends on the strength of evidence for a health risk and the scale and nature of the potential consequences. The cautionary response should be proportional to the potential risk.

Several policies promoting caution have been developed to address concerns about public, occupational and environmental health and safety issues connected with chemical and physical agents. Strict adherence to existing national or international safety standards: such standards, based on current knowledge, are developed to protect everyone in the population with a large safety factor. Simple protective measures: barriers around strong electromagnetic field sources help preclude unauthorized access to areas where exposure limits may be exceeded. Open communication during the planning stages can help create public understanding and greater acceptance of a new facility, also an effective system of health information and communication among scientists, governments, industry and the public can help raise general awareness of programmes dealing with exposure to electromagnetic fields and reduce any mistrust and fears.

6.0. CONCLUSION

Electromagnetic waves have been proven to be a vital tool in diagnosing and treatment of various sicknesses in human body. It can be used in the treatment of tumors, physiotherapy, medical Imaging, Radiation Therapy, External beam radiotherapy etc. Some of the hazards of Electromagnetic waves include that of the microwave, visible light hazards, Ultraviolet hazards etc.

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