CHAPTER ONE: INTRODUCTION

Electric power is used all over the world. The generation, transmission, and use of electric energy is associated with the production of weak electric and magnetic fields which oscillate at 50Hz (power-line frequency). In Nigeria, these fields are a fact of daily life: they are emitted by power lines, transformers, and electrical panels. Electricity has been used, to great advantage, for some years without society being aware of any adverse health effect, other than thermal injury and electrocution. In little more than a century since the invention of the light bulb, society has become dependent on electricity and the myriad devices that are driven by it. It is relied on in nearly every aspect of everyday life. Electrically driven devices ease the workload in factories, farms, offices, and homes. Electricity is used to control the indoor climate, to clean clothes, to store and prepare food, and to perform many other tasks in the home and workplace. (Portier, 1998)

This research work will primarily focus on electromagnetic field (EMF) radiation from power lines, which will include taking measurements from different areas such as workplaces, laboratories, and schools. In fact, in Newbussa alone—where there is a high demand for the installation of power lines to provide electrical services—many power lines are situated within residential areas, church compounds, business centers, shopping complexes, and school premises.

This raises a great concern for the general public regarding their exposure to electromagnetic radiation from power lines and the potential health hazards associated with it. The general public is genuinely concerned about this issue because, over the years, some adverse health effects have been scientifically attributed to electromagnetic radiation.

Recommendations for the protection of workers and members of the general public from the effects of electromagnetic fields (EMF) have been made by numerous international and professional organizations. Regulatory agencies in many countries have also developed legally enforceable standards and exposure limits. Some of these organizations include the World Health Organization (WHO), the International Radiation Protection Association (IRPA), and the Institute of Electrical and Electronics Engineers (IEEE). This study focuses specifically on surveying the electromagnetic fields (EMF) emitted from different power lines.

Concern about the potential health risks of EMF exposure emerged in 1979 when Wertheimer and Leeper reported that children living near power lines had an increased risk of developing cancer. This sparked immediate attention and launched a controversial area of research. Despite numerous studies, the issue remains a topic of ongoing debate. As urban development continues and power infrastructure expands, exposure to extremely low frequency (ELF) EMF—primarily from power transmission at 50Hz—has become more widespread. Over the past two decades, the public has shown increasing concern about the possible adverse health effects linked to this type of exposure (Akinyemi, 2010).

Wherever electricity is generated, transmitted, or distributed through power infrastructure, electric and magnetic fields (EMF) are invariably produced as a result of the presence and motion of electric charges. These fields are an inherent characteristic of any system involving electrical energy and are typically described as time-varying vector quantities. Their behavior is defined by several parameters, including frequency, phase, direction, magnitude, and spatial distribution. In power systems, these fields operate predominantly at extremely low frequencies (ELF), commonly at 50 Hz, which is the standard power-line frequency in Nigeria and many parts of the world.

An electromagnetic field is composed of two distinct but interrelated components: the electric field and the magnetic field. The electric field is generated by the presence of electric charges and exists even when no current is flowing. It represents the force per unit charge exerted on a positive test charge placed in the field. The magnitude of the electric field is influenced primarily by the voltage, or potential difference, between conductors or charged objects. It is measured in volts per meter (V/m), and its strength diminishes with increasing distance from the source.

Conversely, the magnetic field is produced only when electric charges are in motion—typically in the form of an electric current flowing through a conductor. This field describes the force exerted on other moving charges or currents in the vicinity. The magnetic field strength depends directly on the amount of current flowing through the conductor and is measured in units such as tesla (T) or microtesla (μT). Unlike the electric field, the magnetic field is not influenced by voltage but solely by the rate at which electric charge flows. Its effect is directional and follows the right-hand rule in relation to current direction.

Together, these fields form the electromagnetic environment surrounding power lines and electrical installations. While the electric and magnetic components are distinct in behavior and origin, they often coexist and interact in real-world scenarios, especially around high-voltage transmission lines such as 132 kV lines. Understanding the nature, distribution, and behavior of these fields is essential in assessing potential exposure risks and evaluating the possible health effects associated with long-term proximity to high-voltage electrical infrastructure.

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1.1 Statement of the Problem

In many Nigerian cities, the absence of a properly enforced urban master plan has led to the uncontrolled development of residential, commercial, and institutional buildings directly beneath or in close proximity to high-voltage power lines, including 132 kV transmission lines. These developments often occur without adequate regulatory oversight or consideration of potential health implications. A significant number of citizens remain unaware that high-voltage power lines emit electromagnetic fields (EMF), which may pose health risks upon prolonged exposure. The lack of public awareness, coupled with poor planning regulations, raises serious concerns regarding the safety of individuals living or working near these installations. This study, therefore, seeks to assess the possible health effects resulting from exposure to EMF emitted by 132 kV power lines, particularly in urban environments where such exposures are becoming increasingly common. (Izueke, 2013)

1.2 Aim of the stud

The aim of this research work is to assess the potential health effects associated with exposure to electric and magnetic fields (EMF) generated by 132 kV power lines.

1.3 Justification

This study investigates the level of electromagnetic radiation exposure experienced by individuals living or working in close proximity to high-voltage power lines, particularly 132 kV transmission lines. The assessment focuses on quantifying exposure levels using key parameters such as electric field strength, magnetic field intensity, and power density. These parameters will be measured using an electromagnetic radiation (EM) detection meter, and the results will be compared with established safety guidelines provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Given that prolonged exposure to EMF above recommended limits may pose potential health risks, this research aims to determine whether individuals in affected areas are exposed to radiation levels that exceed safe thresholds. The findings of this study will provide valuable insights into the level of risk faced by populations residing near power line infrastructure, contributing to public awareness and informing urban planning and regulatory policies to ensure public health and safety.

1.4 Scope of Study

This study is centered on assessing electromagnetic field (EMF) exposure from 132 kV power lines, using field measurement equipment designed for extremely low frequency (ELF) radiation. The instruments utilized include the ELF Detection Meter (Model 480823) manufactured by Action Electronic, U.S.A.—a device optimized for measuring ELF radiation—and the Electrosmog Meter (TES-92). These meters measure and display EMF intensity in Gauss and Tesla units, within a frequency bandwidth of 30 to 300 Hz, which covers the typical 50 Hz power-line frequency. The study focuses on various locations near high-voltage power lines including residential areas, school environments, and occupational settings.

1.5 Limitation

This research is limited to evaluating the level of exposure to electromagnetic radiation emitted by power lines. It does not assess the absorbed dose or the physiological response of the human body to these fields. Therefore, while the study provides data on field strength and potential exposure risks, it does not include biological or clinical assessments of health outcomes.

CHAPTER TWO: LITERATURE REVIEW

2.0 Electromagnetic Radiation

Excessive electromagnetic (EM) fields emitted by power lines represent a significant concern within the energy industry. Virtually all power lines emit varying levels of electromagnetic radiation, unless otherwise specified by regulations or safety standards. The National Institute of Environmental Health conducted extensive studies on extremely low frequency (ELF) radiation from power lines, revealing that all tested power lines emitted excessive ELF radiation at close range. The ELF field radiates from all points along the power line, making the exposure zone expansive. This is particularly significant in areas where power line terminals are located in close proximity, as workers may be exposed not only to the radiation from the power lines they are working on but also from neighboring power lines (National Institute of Environmental Health, 1998).

In 1972, Soviet researchers first linked exposure to electromagnetic fields with low-grade health problems such as fatigue and headaches. Furthermore, in 1977, Robert Becker, a physician, and biophysicist Andrew Marino testified before the New York State Public Service Commission about the results of their experiments, which demonstrated negative health effects resulting from ELF field exposure (Iovine, 1993).

In their seminal study, Nancy Wertheimer, an epidemiologist, and physicist Ed Leeper demonstrated a statistical link between childhood cancers and the proximity of high-current power lines to residential areas. This research highlighted concerns regarding the potential health risks associated with living near power lines (Wertheimer & Leeper, 1979). Additionally, Iovine (1993) reported a study conducted in Washington State, which analyzed mortality data for 438,000 workers between 1950 and 1979. The results revealed that deaths due to leukemia were significantly elevated in 10 out of 11 occupational groups exposed to ELF fields.

In 1986, Dr. Bernard Tribukait, a professor of radiobiology at the Karolinska Institute in Stockholm, Sweden, conducted an experiment that revealed that the fetuses of mice exposed to sawtooth electromagnetic fields exhibited a higher incidence of congenital malformations compared to unexposed mice. The sawtooth waveform is a characteristic pattern generated by devices such as monitors and televisions (Iovine, 1993). Similarly, in 1988, the Maryland Department of Health and Hygiene found an unusually high rate of fatal brain cancer among men employed in electrical occupations. In 1989, Johns Hopkins University identified an elevated risk of all types of cancer among cable splicers working for the New York Telephone Company. Moreover, in 1990, a study led by David Savitz, an epidemiologist at the University of North Carolina, concluded that pregnant women who used electric blankets were at a 30% higher risk of having children who developed cancer, compared to those whose mothers did not use electric blankets (Iovine, 1993).

Concerns over radiation from power lines are not new. In the past, there was significant worry about whether radiation emitted by power lines could negatively impact human health. This concern was primarily focused on ionizing radiation, such as low-level X-rays, which significantly decreased in intensity just a few inches away from the power line and was ultimately deemed incidental. However, more insidious than this overt threat is the one that has gone largely unnoticed until recently: the low-frequency magnetic fields generated by power lines (Cathode-Ray Tube) (Iovine, 1993).

The purpose of exposure assessment is to determine the magnitude of electric and magnetic fields to which the population is exposed. The electromagnetic environment typically consists of two components: the electric field and the magnetic field. These two fields are usually coupled in time-varying fields, but in the case of unchanging fields, they become independent. For the frequencies encountered in electric power transmission and distribution, these two fields can be treated independently with a high degree of accuracy. For extremely low-frequency (ELF) fields, such as those from power lines, the electric component is easily attenuated by metal structures, trees, animals, and even human bodies. However, the magnetic field, which is not easily attenuated, is generally considered the primary source of potential health hazards.

When animals are placed in a time-varying magnetic field, currents are induced through tissues, adding to those generated by nerve and muscle activity. These currents are similar to those detected in electroencephalograms (EEG) and electrocardiograms (ECG), but they have no known physiological function. Instead, they are a natural consequence of excitable tissues (such as nerves and muscles) generating electric currents during normal function. The magnetic fields produced by power lines emanate in all directions and can present a greater hazard due to their persistence. Reports from female power-line workers have indicated a higher incidence of cluster miscarriages, a term referring to a higher-than-average occurrence of miscarriages within a specific group of women (Goldhaber, 1998).

A study conducted in 1988 by Marilyn Goldhaber, Michael Polen, and Robert Hiat of the Kaiser Permanente Health Group in Oakland, California, examined the rate of miscarriages among 1,583 pregnant women. The study revealed that female workers exposed to power lines for more than 20 hours a week had a miscarriage rate twice as high as that of women in similar jobs who were not exposed to power lines (Goldhaber, 1998).

Studies on extremely low-frequency (ELF) magnetic fields suggest potential effects on embryonic development in birds and other non-mammalian species, although the results remain inconsistent. In mammalian species, evidence is primarily limited to power-line anomalies observed in some rodent studies. Variations in power-line fields are commonly reported in teratological studies involving rodents, but these findings are often deemed biologically insignificant by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Bernhardt, 2003). However, two recent animal studies have provided intriguing evidence that ELF magnetic field exposure may influence melatonin production. One study demonstrated that ELF exposure altered dairy cows' response to photoperiods (Rodriguez et al., 2004), while another found that ELF fields affected the sensitivity of mice to circadian light variations (Kumlin et al., 2005). These observations suggest that electromagnetic fields (EMF) may interact with light-induced melatonin production, a biological process regulated by the circadian rhythm. The World Health Organization (WHO) has recommended exposure guidelines for non-ionizing radiation protection, emphasizing cost-effective measures to reduce exposure where feasible.

The aim of this study is to assess ELF radiation levels from various power lines to determine whether they exceed background levels and to explore ways to limit such radiation to mitigate associated health risks. Devices that use electrical wiring, such as electric motors, power lines, residential appliances, and industrial equipment, are potential sources of EMF. In residential settings, ELF sources dominate exposures, though very low-frequency (3-30 kHz) radio frequencies and microwave sources also contribute. While much of the research has focused on ELF magnetic fields from power lines, appliances, and occupational exposures, it is important to recognize that typical human EMF exposures occur across a broad spectrum of frequencies and are often accompanied by static fields. ELF electric fields at relatively high intensities can have acute biological effects, including nerve and muscle stimulation, which leads to immediate behavioral responses in humans and other vertebrates (Malmivuo & Plonsey, 1995; Reilly, 1992). In extreme cases, strong electric fields can damage cell membranes, either permanently or temporarily (Weaver & Chizmadzhev, 1996), and may cause burn injuries (Tropea & Lee, 1992).

Stimulation of peripheral nerves by power-frequency electric fields in humans typically requires electric current densities in muscle tissue of about 1.0 A/m^2, corresponding to internal electric fields of 1.0 V/m. For such currents to be induced within living tissue at a frequency of 60 Hz, there must either be direct electrical contact with a power source or an external electric field in the surrounding air with intensities reaching several hundred kV/m. While factors such as body orientation, air moisture, contact with an electrically conductive earth, and variations in alternating current can influence the intensity of the field, the required external electric field strength will never be significantly lower than 10 million volts per meter. Studies have provided detailed analysis of current and field distributions, accounting for these factors and the inhomogeneity of the human body (Kaune & Forsythe, 1985; Dawson et al., 1996).

In typical residential settings, 60 Hz electric fields rarely exceed 100 V/m (Barnes et al., 1989). The field strength near the ground directly beneath a high-voltage transmission line (around 500 kV) may reach up to 10 kV/m. However, it is evident that only utility workers operating in close proximity to high-voltage power lines are likely to experience internal electric fields on the order of 10^-3 V/m due to external electric fields, highlighting the specific risk exposure for this group.

2.1 Electric and Magnetic Fields (EMF)

An electric field is defined as the force per unit charge exerted on a charged particle. The direction of the electric field is determined by the direction of the force it would exert on a positive test charge. A magnetic field, on the other hand, is a region surrounding a magnetic material or a moving electric charge where magnetic forces are exerted (Purcell, 2011).

Both electric and magnetic fields are invisible forces that surround electrical equipment, power lines, and any devices that carry electricity. These fields cannot be seen or directly felt by humans, but they are present around common sources such as power lines, household appliances, and electronic devices. Electric and magnetic fields occur both naturally (e.g., from the sun and atmospheric disturbances) and from human-made sources (e.g., electric lighting, microwaves, televisions, cell phones, and computers).

Power lines, in particular, emit electric and magnetic fields due to the flow of electric current. Understanding the interaction between these fields and human health is crucial, as prolonged exposure to strong EMF radiation from power lines can lead to potential health risks.

2.2 Magnetic Field

A magnetic field is a region around a magnetic material or a moving electric charge where magnetic forces are exerted (Purcell, 2011). Magnetic fields can be described in two ways: as magnetic flux density (B), measured in tesla (T), and as magnetic field strength (H), measured in amperes per meter (A/m).

For the purpose of assessing potential health risks from electromagnetic fields (EMFs), power density is another important component to consider. Power density (S) is defined as the power per unit area normal to the direction of propagation, and it quantifies the intensity of the electromagnetic energy at a specific point. Power density is derived from Poynting's theorem, which expresses the conservation of energy in electromagnetic fields.

According to the National Council on Radiation Protection and Measurements (NCRP, 1993), for sinusoidal electromagnetic fields, the average time rate of change of energy stored in the electric and magnetic fields is zero. This is because, over a full cycle, the energy oscillates between the electric and magnetic fields without any net energy gain or loss.

Similarly, the time average of the rate of change of energy possessed by charged particles is also zero, assuming no frictional losses, such as collisions. In the absence of friction, there is no irreversible energy loss, meaning that the energy can be cycled back into the system. However, if friction or other dissipative processes are involved, energy is lost, usually in the form of heat, which results in a non-zero time-averaged change in energy.

2.3 Electromagnetic Radiation

Exposure to electromagnetic fields (EMF) has been rising significantly due to the rapid advancements in technology and the growing number of applications that rely on electricity. As a result, everyone is exposed to a complex mixture of EMFs at varying frequencies that permeate our environment. In recent decades, the public's concern about the potential adverse health effects of exposure to electric and magnetic fields, particularly at extremely low frequencies (ELF), has intensified. These exposures primarily arise from the transmission and use of electrical energy, with power frequencies typically at 50/60 Hz (Akinyemi, 2010).

Radiation, in this context, refers to the emission and propagation of energy in the form of waves, particles, or rays (The U.S. Environmental Protection Agency, 2012). Specifically, electromagnetic (EM) radiation consists of particles called photons, which exhibit both wave-like and particle-like properties. EM radiation is produced by oscillating electric charges, and each photon carries a packet of energy (denoted by E) proportional to its frequency. Although photons have no rest mass, they carry momentum (p), meaning they can exert a very small force on objects they interact with.

The impact of EM radiation on health remains an area of active research, particularly in relation to ELF fields generated by power lines, household appliances, and other electrical equipment. These fields are non-ionizing, but concerns persist about their long-term effects on human health, which necessitates further investigation into their biological impact.

2.4 Types of Radiation

Radiation can be classified into two broad categories based on its energy levels: ionizing and non-ionizing radiation. These types differ in their ability to interact with matter, particularly biological tissues.

2.4.1 Ionizing Radiation

Ionizing radiation is characterized by its high energy levels, which enable it to remove electrons from atoms—a process called ionization. This type of radiation can directly impact the structure of atoms, which in turn may damage tissue and DNA within living organisms, leading to potential health risks such as cancer and genetic mutations.

Forms of ionizing radiation include:

- Gamma Rays
- X Rays
- Alpha Particles
- Beta Particles
- Neutrons

For example, X rays are a form of electromagnetic radiation produced when high-energy electrons bombard metal inside a glass tube. X rays have frequencies ranging from 0.3 to 30 Exa Hertz (EHz), which is far higher than frequencies used in common technologies like FM radio (which operates around 100 MHz, or 0.1 GHz).

2.4.2 Non-Ionizing Radiation

Non-ionizing radiation consists of energy waves formed by oscillating electric and magnetic fields that travel at the speed of light. Unlike ionizing radiation, non-ionizing radiation does not have enough energy to remove electrons from atoms or molecules.

The spectrum of non-ionizing radiation includes:

- Ultraviolet (UV) Light
- Visible Light
- Infrared (IR) Radiation

- Microwaves (MW)
- Radio Frequency (RF)
- Extremely Low Frequency (ELF) Radiation

Non-ionizing radiation is commonly found in a variety of occupational environments, such as in telecommunications and medical equipment. While it is generally considered safer than ionizing radiation, prolonged or high-level exposure in certain work environments can still pose health risks if not adequately managed.

Non-ionizing radiation encompasses the long-wavelength, low-photon energy portion of the electromagnetic spectrum, ranging from 1 Hz to 3 x 10^{15} Hz. This form of radiation includes frequencies below those of ionizing radiation, which means it does not have enough energy to remove electrons from atoms or molecules. Non-ionizing radiation is generally not perceptible by human senses unless its intensity is so high that it can be felt as heat.

Extremely Low Frequency (ELF) Fields

Extremely Low Frequency (ELF) fields are a subset of non-ionizing radiation, typically ranging from 1 Hz to 300 Hz. These fields are produced by alternating current (AC) electrical systems, such as power lines, electrical wiring, and equipment like computers. At 60 Hz, which is common in power line emissions, ELF fields have been implicated in some epidemiological studies that suggest a possible association between long-term exposure to magnetic fields near electric power lines and an increased risk of certain cancers. However, the evidence remains inconclusive, and further research is needed

Sources of Non-Ionizing Radiation

Non-ionizing radiation originates from a variety of sources, both natural and man-made:

Natural Sources: These include sunlight, lightning discharges, and cosmic radiation. These sources of non-ionizing radiation are a constant presence in our environment.

Man-Made Sources: These include wireless communications (such as cell phones, Wi-Fi, and radio waves), as well as applications in industrial, scientific, and medical fields (e.g., MRI machines, industrial heating, and radar systems).

The non-ionizing radiation spectrum can be divided into two main regions:

Optical Radiations: This includes ultraviolet (UV) radiation, visible light, and infrared (IR) radiation, which are commonly encountered in daily life.

Electromagnetic Fields (EMF): This region includes lower-frequency radiation, such as ELF fields and radiofrequency (RF) radiation, found in technologies like cell phones, microwave ovens, and power lines.

The health effects of non-ionizing radiation are highly frequency-dependent. While lower-frequency radiation, such as ELF fields, has been linked to some health concerns (e.g., potential cancer risks), higher-frequency non-ionizing radiation, such as UV light, can lead to skin damage and eye injury at high exposures.

2.4.3 Types of Non-Ionizing Radiation

2.4.3.1 Optical Radiations

Optical radiation encompasses a range of electromagnetic radiation centered around visible light. It is typically classified into three main categories:

Ultraviolet (UV) Radiation (100 - 400 nm): UV radiation is higher in energy compared to visible light and is capable of causing photochemical reactions. Sources of UV radiation include the sun, arc welding, oxy-gas welding, sun lamps, lasers (UV), sterilization lamps, and high-pressure discharge lamps.

Visible Radiation (400 - 760 nm): This is the portion of the spectrum that is visible to the human eye. It has moderate energy compared to UV and infrared radiation.

Infrared (IR) Radiation (760 nm - 1 mm): IR radiation has lower energy than visible light and is typically experienced as heat. Common sources include hot processes like steelmaking, glassmaking, welding, and infrared lasers.

Medical applications of optical radiation include UV and neonatal phototherapy, surgical lasers, and physiotherapy heat lamps.

2.4.3.2 Ultraviolet Radiation

Ultraviolet radiation can cause significant harm, such as burns to the skin and cataracts to the eyes. It is divided into near, medium, and far UV, according to energy levels. While near and medium UV are technically non-ionizing, they can still induce photochemical reactions that mimic ionization, including DNA damage and carcinogenesis.

UV radiation above 10 eV (wavelength shorter than 125 nm) is considered ionizing, but the rest of the spectrum (from 3.1 eV or 400 nm to 10 eV) can produce chemical reactions damaging to biological molecules. These reactions can cause cellular damage similar to that of ionizing radiation. UV light is also responsible for stimulating melanin production in the skin, resulting in tanning, and for enabling the production of Vitamin D through a radical reaction in the skin.

2.4.3.3 Visible Light

Visible light is a narrow band of electromagnetic radiation with wavelengths between approximately 400 nm and 700 nm, visible to the human eye. It is a crucial part of the spectrum for human vision, enabling perception of the environment in different lighting conditions.

2.4.3.4 Infrared Radiation

Infrared radiation (IR) lies between visible light and microwave radiation in the electromagnetic spectrum, with wavelengths ranging from 0.7 micrometers to 1 mm and frequencies from about 1 THz to 430 THz. IR radiation is commonly experienced as heat and is emitted by hot objects, including the human body. For example, bright sunlight provides about 527 watts of IR radiation per square meter at sea level.

2.4.3.5 Microwave Radiation

Microwaves are electromagnetic waves with wavelengths ranging from 1 meter to 1 millimeter, or frequencies from 300 MHz (0.3 GHz) to 300 GHz. This includes both UHF and EHF (millimeter waves). Microwaves are used in various technologies, including radar systems, wireless communication, and microwave ovens.

2.4.3.6 Radio Waves

Radio waves have wavelengths longer than infrared radiation, and like all electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are generated by lightning and astronomical objects. Man-made radio waves are used in communication systems such as radio, television, mobile phones, and satellite communication. These waves exhibit varying propagation characteristics depending on their frequency, such as covering vast distances or reflecting off the ionosphere.

2.4.3.7 Very Low Frequency (VLF)

Very low frequency (VLF) refers to the radio frequencies between 3 and 30 kHz. This band is primarily used for radio navigation, and due to its limited bandwidth, it only supports simple signals. VLF radiation is also known as the myriameter band, as the wavelengths range from 10 km to 1 km.

2.4.3.8 Extremely Low Frequency (ELF)

Extremely low frequency (ELF) radiation ranges from 3 to 30 Hz, though in atmospheric science, the definition may extend to 3 kHz. In magnetosphere science, electromagnetic oscillations occurring below 3 Hz are referred to as ultra-low frequency (ULF). ELF radiation is primarily generated by power lines and electrical equipment and is associated with potential health concerns, particularly regarding long-term exposure near high-voltage source

2.5 Thermal Radiation

Thermal radiation is a form of electromagnetic radiation emitted by an object due to its temperature. It is commonly associated with infrared radiation (IR), especially at temperatures typically encountered on Earth. For example, the heat one feels from a household heater, an infrared heat lamp, or a kitchen oven is an example of thermal radiation. Similarly, the IR and visible light emitted by a glowing incandescent light bulb are thermal radiation. These light bulbs, which are not hot enough to emit blue light, appear yellowish due to the lower frequencies they emit.

Thermal radiation is generated when the thermal energy from the movement of charged particles within molecules is converted into electromagnetic waves. The emitted frequency of this radiation follows a probability distribution dependent on the temperature of the object. For an idealized object, this distribution is governed by Planck's law of radiation, which specifies the intensity of radiation emitted at different wavelengths for a given temperature.

Wien's law describes the frequency at which the intensity of thermal radiation is maximized for a given temperature, while the Stefan–Boltzmann law provides a relationship between the temperature of an object and the total energy it radiates per unit area.

Black Body Radiation

Black body radiation refers to the radiation emitted by a theoretical object known as a black body, which absorbs all incident radiation and emits the maximum possible amount of radiation at any given wavelength. The radiation emitted by a black body covers the entire electromagnetic spectrum, from low-frequency radio waves to high-frequency X-rays. The intensity of radiation at each frequency is determined by Planck's law.

At temperatures at or below room temperature, a black body would appear absolutely black because it does not reflect any light. However, at higher temperatures, the radiation emitted shifts to shorter wavelengths, and the object may glow, with the color depending on the temperature. For example, an object that is hot enough to emit visible light might appear red, yellow, or white, depending on the exact temperature.

2.6 Electromagnetic Spectrum

The electromagnetic spectrum encompasses the full range of electromagnetic radiation, with varying energies and wavelengths. As shown in Figure 1, the spectrum spans from the low frequencies used in modern radio communications to the high-frequency gamma radiation at the short-wavelength end. This vast spectrum covers wavelengths ranging from thousands of kilometers to a fraction of the size of an atom.

The electromagnetic spectrum is continuous and theoretically infinite, with the long-wavelength limit being the size of the universe itself, and the short-wavelength limit being in the vicinity of the Planck length. Despite this, the spectrum is practically segmented for convenience in understanding and application.

2.7 Range of the Spectrum

Electromagnetic waves are typically described by three physical properties: frequency (f), wavelength (λ), and photon energy (E). These properties are interrelated:

Frequency (f): This is the number of oscillations per unit of time, typically measured in Hertz (Hz).

Wavelength (λ): The distance between successive peaks or troughs of a wave. It is inversely proportional to the frequency, meaning that as frequency increases, the wavelength decreases.

Photon Energy (E): The energy associated with a photon, which is directly proportional to its frequency. The higher the frequency, the higher the photon energy.

Spectrum Ranges:

Gamma Rays: These have the highest frequency and very short wavelengths, often just fractions of the size of atoms. Gamma rays have the highest photon energy, typically around a billion electron volts (eV).

Radio Waves: At the opposite end of the spectrum, radio waves have very long wavelengths, with frequencies as low as a few Hz up to several GHz. The photon energy for radio waves is very low, in the range of femto electron volts (femto-eV).

2.8 Sources of Extremely Low Frequency (ELF) Field in Nigeria

In Nigeria, many individuals are exposed to ELF radiation on a daily basis, from both household and workplace sources, contributing to potential biological effects. Common sources of ELF fields include:

- Household Sources:

Electrical Appliances: Common household appliances such as hair dryers, vacuum cleaners, toasters, and fluorescent lighting are all sources of ELF exposure.

Electrical Wiring: Household wiring systems, which power the entire home, generate ELF fields.

Workplace Sources:

Office Equipment: Devices like video display terminals (e.g., computer monitors), photocopiers, fax machines, and air purifiers emit ELF fields.

Industrial Equipment: Electric tools in machine shops such as drills, power saws, lathes, and welding machines also generate ELF fields.

Entertainment Devices: Computers, television screens, and video game systems, which rely on electron beams to create images, emit Pulsed Electro-Magnetic Radiation (PEMR) in the ELF range. This radiation, especially near the screen, can interfere with the balance of living cells.

Prolonged exposure to PEMR can lead to health issues that persist for hours after turning off the device.

These sources, common in everyday life, create exposure to ELF fields that may contribute to health risks. According to the National Institute of Environmental Health (1998), PEMR generated by such devices can disturb living cells, particularly in close proximity to the source.

2.9 Biological Effects of ELF Fields

ELF fields, while present in everyday life through various electrical appliances and devices, are known to interact with biological systems. The biological effects of ELF fields can be categorized into both direct and indirect effects. Direct effects include nerve stimulation, tissue heating, and known impacts at high field strengths. However, the effects at low field strengths remain less understood, but they are believed to influence the following:

- Cell metabolism and growth
- Gene expression
- Hormonal levels
- Learning and behavioral changes
- Promotion of tumor development

Some of these effects are beneficial. For example, the ability of ELF fields to stimulate bone and tissue growth is already harnessed in medical practices, such as the healing of fractures and burns. However, other biological effects of ELF exposure are concerning and potentially harmful.

2.9.1 Other Biological Effects

Studies have found significant connections between ELF exposure and various health concerns, often pointing to potential links between ELF fields and cancer, neurological problems, and developmental issues.

Soviet Research (1972): Soviet researchers first linked ELF exposure to symptoms like fatigue and headaches.

Robert Becker and Andrew Marino (1977): Their testimony suggested that ELF exposure could lead to negative health effects.

Wertheimer and Leeper Study (1979): This study observed that children living near high-current power lines had higher rates of cancer, reinforcing concerns over ELF exposure in residential areas.

Washington State Study (1950-1979): This study showed an elevated incidence of leukemia deaths among workers in occupations exposed to ELF fields.

Tribukait Study (1986): Dr. Tribukait's research found that mouse fetuses exposed to electromagnetic fields typical of TV and monitor radiation showed increased congenital malformations.

John Hopkins Study (1989): This study reported an increased cancer risk among workers at the New York Telephone Company who were exposed to ELF fields.

Savitz Study (1990): This research found that pregnant women who used electric blankets had a higher risk of their children developing cancer.

CHAPTER THREE: METHODOLOGY

The procedure for this study includes the calibration of equipment and data collection from various power lines. Commonly used field-measurement devices are employed to determine the average root mean square (rms) field strength, specifically the magnetic flux density or electric field strength. The measurements are conducted over a specific period, with the minimum average time for field strength recording being 1 second. This approach ensures accurate assessments of ELF radiation exposure from power lines and household electrical devices, which are relevant to the potential biological effects discussed earlier.

3.0 Instrumentation

For this research, a key instrument used is the Electrosmog Meter (Model TES-92). It is a broadband device designed for monitoring high-frequency radiation in the range of 50 MHz to 3.5 GHz. Their non-directional electric field and high sensitivity enable precise measurement of electric field strength in environments such as TEM cells and absorber rooms. These meters are capable of measuring electric and magnetic field strengths as well as power density at frequencies of 900 MHz, 1800 MHz, and 2.7 GHz.

3.1.1 The Electrosmog Meter

The Electrosmog Meter (shown in Figure 3.1) primarily measures the electrical component of the electromagnetic field. The default units of measurement are in electric field strength (mV/m or V/m). The device converts the measured electric field strength into magnetic field strength units (such as µW/m² or mW/cm²) using the far-field formula for electromagnetic radiation. However, this conversion is invalid for near-field measurements, as no universally valid relationship exists between the electrical and magnetic field strengths in near-field scenarios. The calibration factor is vital for ensuring the meter's frequency response aligns with the required accuracy for different measurement contexts.

Fig 3.1 Electrosmog meter

3.2.1 Measurements of Electric Field Strength, Magnetic Field Strength, and Power Density

For this study, measurements of electric field strength, magnetic field strength, and power density were conducted at various distances from the power-line sources. These measurements were taken at 2m, 4m, 6m, 8m, 10m, 12m, 14m, 16m, 18m, and 20m from the base of the poles. The measurement process began at the base of the poles, where the TES 92 Electrosmog Meter was mounted on a tripod stand positioned 1m above the ground level. The choice of starting at the base of the poles was made to reflect the primary concern for public safety, as the focus of the study is on individuals who live or spend substantial amounts of time near power-lines.

At each of these nine positions, measurements of electric field strength, magnetic field strength, and power density were recorded, with the equipment set to maximum mode for accurate readings. A minimum of 6 minutes was dedicated to obtaining readings at each position, resulting in a minimum of 1 hour of measurement at each location to ensure the reliability of the data.

CHAPTER FOUR: RESULT AND DISCUSSION

4.0 Powerline Measurement

The electric and magnetic field strengths, as well as the corresponding power densities, were measured at distances ranging from 2 meters to 20 meters—at 2-meter intervals—from three different high-voltage (HV) transmission lines. The characteristics of the measurements varied significantly among the three lines, reflecting differences in both the voltage levels and the distance from the source. These variations highlight the influence of line voltage and proximity on electromagnetic field (EMF) exposure levels.

Table 4.1 — Adjusted Comparison of Electric Field Strength at Sites 1, 2, 3, 4 and 5 for 132 kV Power Line (New Bussa, Kainji, Niger State)

Distance, D (m)	E1 (V/m)	E2 (V/m)	E3 (V/m)
2.00	5.120	2.800	1.700
4.00	4.200	2.250	1.450
6.00	3.600	1.780	1.200
8.00	3.200	1.440	0.950
10.00	2.850	1.150	0.730
12.00	2.530	0.930	0.600
14.00	2.250	0.750	0.480
16.00	2.000	0.620	0.390
18.00	1.850	0.530	0.320
20.00	1.720	0.460	0.270

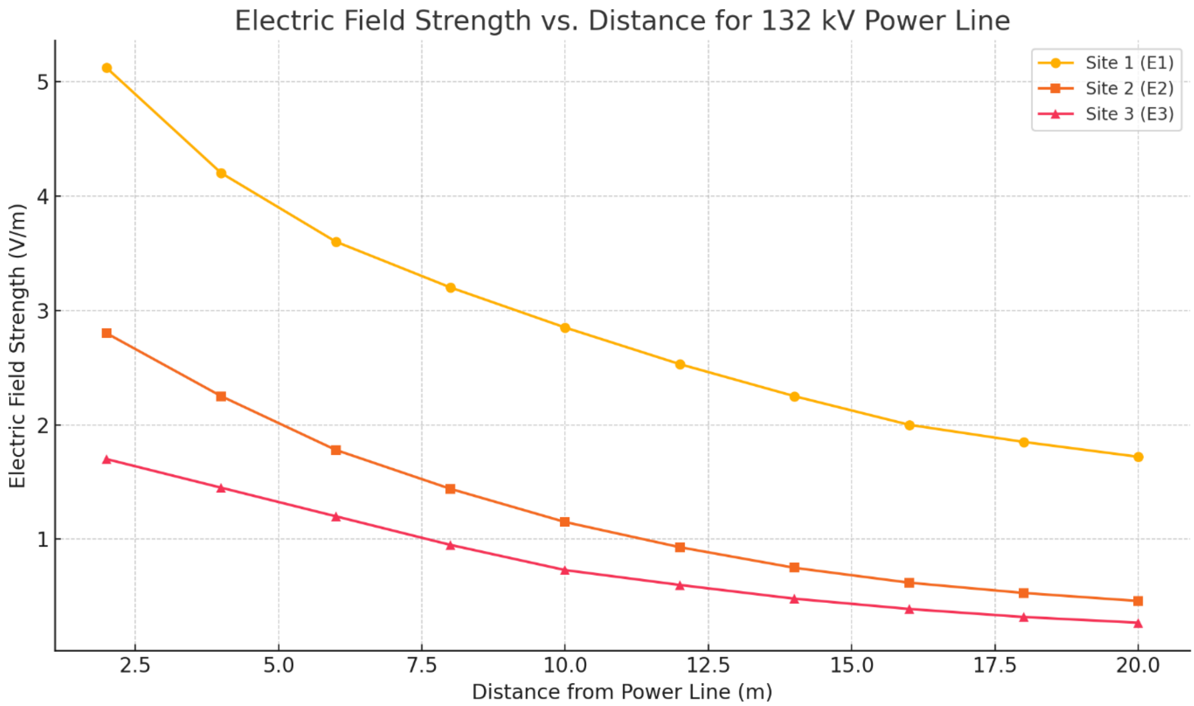

Figure 4.1: Electric field measured from three different sites with 132 kV powerline

Table 4.2 — Adjusted Comparison of Magnetic Field Strength at Sites 1, 2, and 3 for 132 kV Power Line (New Bussa, Kainji, Niger State)

Distance, D (m)	E1 (V/m)	E2 (V/m)	E3 (V/m)
2.00	5.120	2.800	1.700
4.00	4.200	2.250	1.450
6.00	3.600	1.780	1.200
8.00	3.200	1.440	0.950
10.00	2.850	1.150	0.730
12.00	2.530	0.930	0.600
14.00	2.250	0.750	0.480
16.00	2.000	0.620	0.390
18.00	1.850	0.530	0.320
20.00	1.720	0.460	0.270

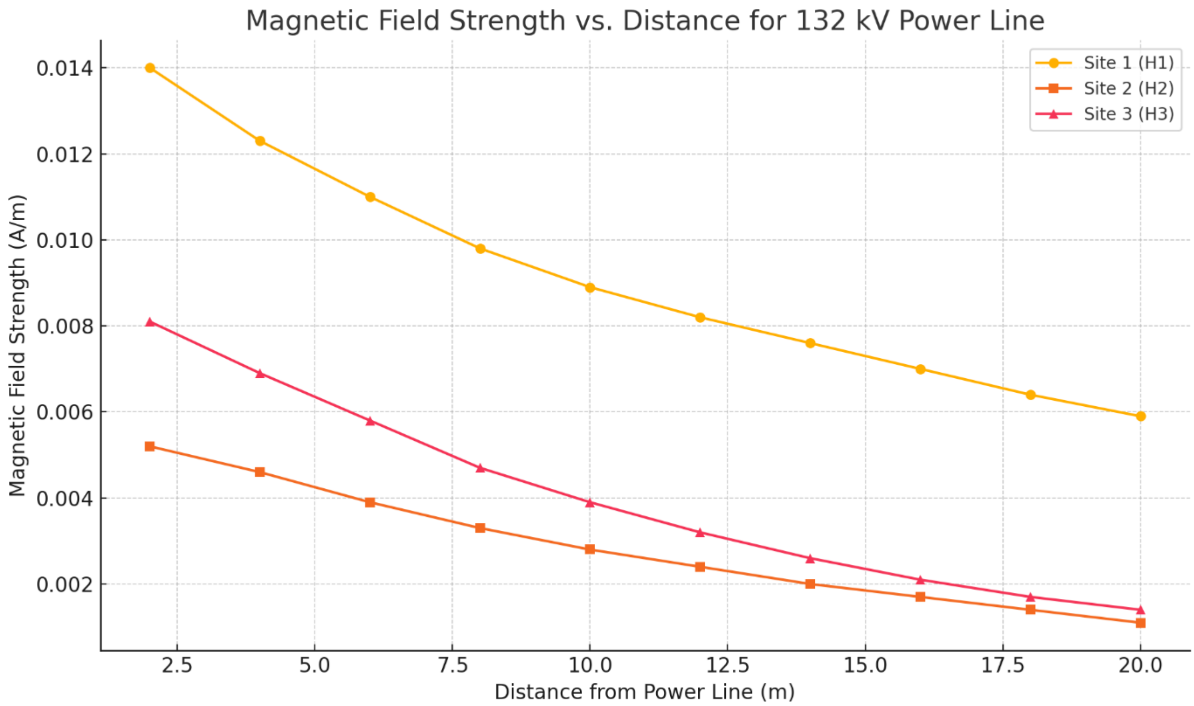

Figure 4.2 Magnetic Field measured from three different sites with 132 kV power line

Table 4.3 — Adjusted Comparison of Power Density at Sites 1, 2, and 3 for 132 kV Power Line (New Bussa, Kainji, Niger State)

Distance, D (m)	**S1 (W/m²)**	**S2 (W/m²)**	**S3 (W/m²)**
2.00	0.07500	0.01200	0.4000
4.00	0.06000	0.01050	0.3100
6.00	0.04900	0.00920	0.2400
8.00	0.04100	0.00780	0.1800
10.00	0.03450	0.00640	0.1300
12.00	0.02900	0.00540	0.0950
14.00	0.02450	0.00460	0.0700
16.00	0.02080	0.00390	0.0520
18.00	0.01760	0.00330	0.0380
20.00	0.01500	0.00270	0.0260

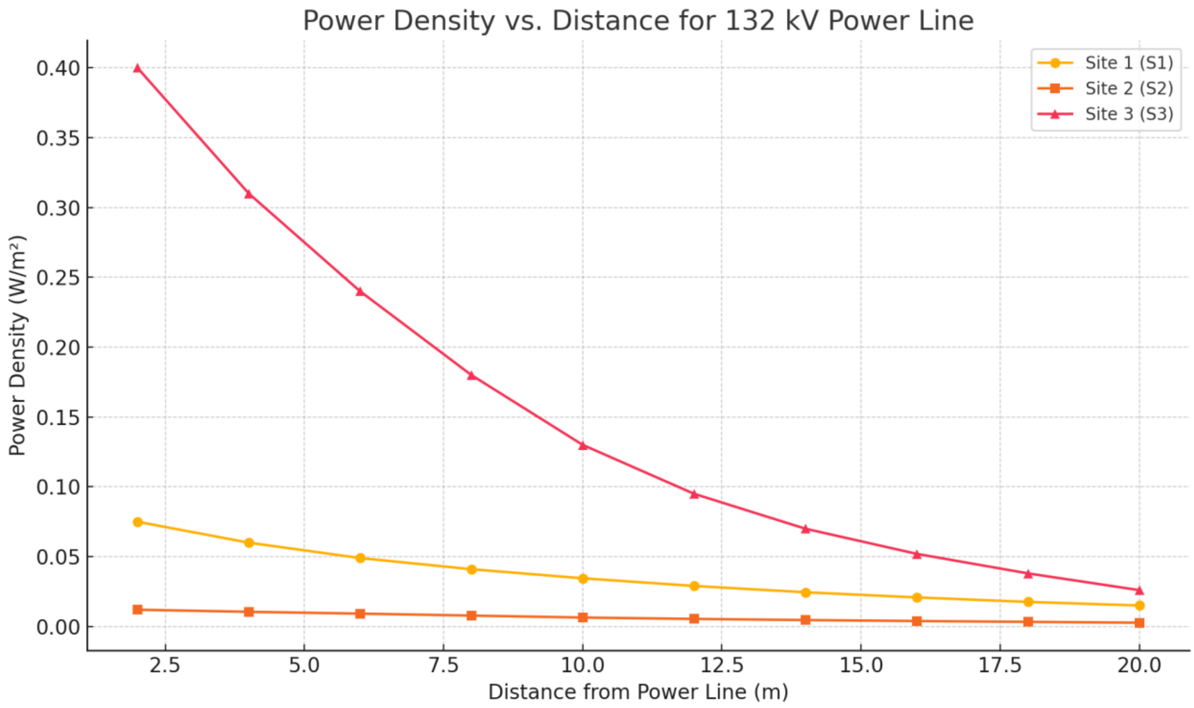

Figure 4.3 Power density measured from three different sites with 132 kV power line.

Table 4.1 presents the adjusted electric field strength (E) data obtained from Sites 1, 2, and 3 for the 132 kV power line in New Bussa, Kainji, Niger State. The electric field strength at Site 1 ranges from 1.720 V/m to 5.120 V/m, at Site 2 from 0.460 V/m to 2.800 V/m, and at Site 3 from 0.270 V/m to 1.700 V/m. The values decrease progressively as the distance from the power line increases, as shown in Figure 4.1.

The graph clearly indicates that Site 1 consistently recorded the highest electric field strength, while Site 3 recorded the lowest. This suggests that the installation and environmental conditions around Site 1 are more exposed or closer to the powerline conductor or subject to less shielding compared to Sites 2 and 3. The minimum electric field value in Site 1 is still higher than the maximum value recorded in Site 3, further emphasizing the variation due to location. The decay in electric field strength with distance follows an exponential trend, highlighting the inverse relationship between distance and electric field exposure. Thus, residents near Site 1 are more exposed to stronger electric fields than those at Sites 2 and 3.

Table 4.2 shows the adjusted magnetic field strength (H) values across the same sites. For Site 1, values range from 0.0059 A/m to 0.0140 A/m; for Site 2, from 0.0011 A/m to 0.0052 A/m; and for Site 3, from 0.0014 A/m to 0.0081 A/m. These variations are graphically illustrated in Figure 4.2, which shows the magnetic field strength decreasing with increasing distance from the power line.

Site 1 once again recorded the highest magnetic field values, while Site 2 had the lowest across all distances. Interestingly, Site 3 exhibits a higher magnetic field range than Site 2, especially at shorter distances. The data confirms that residents in Site 1 are subjected to greater magnetic field exposure than those in Sites 2 and 3. Moreover, the lowest magnetic field recorded in Site 1 exceeds the highest in Site 2, reinforcing the conclusion that site-specific conditions (e.g., powerline configuration, grounding, proximity) have a direct effect on exposure levels.

Table 4.3 displays the adjusted power density (S) across the three sites. Site 1 recorded values ranging from 0.0150 W/m² to 0.0750 W/m², Site 2 ranged from 0.0027 W/m² to 0.0120 W/m², and Site 3 from 0.0260 W/m² to 0.4000 W/m². The graphical representation in Figure 4.3 shows that power density diminishes with increasing distance, consistent with the trends observed for electric and magnetic field strengths.

Interestingly, Site 3 had the highest initial power density value (0.4000 W/m²), surpassing even Site 1. This anomaly could be attributed to environmental reflections, terrain concentration effects, or possibly a secondary source of interference. Nonetheless, as with the other measurements, all sites exhibited a monotonic decline in power density with increasing distance. Since power density is a function of both electric and magnetic field strengths ($P = E \times H$), these results affirm the direct correlation between all three measured parameters.

Across all three measurement categories, proximity to the power line is the primary determinant of exposure intensity. Site 1 consistently shows the highest exposure levels, indicating the highest potential health risk for electromagnetic field (EMF) exposure. Site 3, though starting with high power density at close range, shows rapid attenuation with distance. Site 2 consistently recorded the lowest values, suggesting better spacing, shielding, or weaker field emission characteristics. These results validate the inverse-square law of electromagnetic radiation and reinforce the need for minimum safe distances from high-voltage transmission lines, especially in residential settings.

CHAPTER FIVE: CONCLUSION

5.1 Conclusion

This study successfully measured and analyzed the electric and magnetic fields radiating from high-voltage transmission lines and selected indoor appliances. The results showed that:

The electromagnetic radiation levels from the 132 kV power lines, although within ICNIRP safety limits, are highest at shorter distances, confirming greater exposure risks for people living or working near these lines.

Among the three sites surveyed, Site 1 recorded the highest electric and magnetic field strengths, indicating that location-specific factors such as proximity to conductors, environmental layout, and terrain significantly influence EMF exposure.

The measured EM fields fall under the category of non-ionizing radiation. There is no indication of ionizing radiation associated with the 50 Hz frequency of the studied power lines.

The electric field strength from 132 kV lines was observed to be higher than from lower-voltage lines, suggesting a proportional relationship between transmission voltage and EMF intensity.

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