UNIVERSITY OF GHANA
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ASSESSMENT OF LEVELS OF OCCUPATIONAL EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS IN DATA CENTRES IN GREATER ACCRA REGION-GHANA.

BY

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THIS THESIS/DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL) RADIATION PROTECTION DEGREE.

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DECLARATION

This thesis is the result of research undertaken by Kalognia Joshua in the Graduate School of Nuclear and Allied Sciences with exception of references to other people's work which has been duly acknowledged and was undertaken in accordance with guidance on supervision of thesis laid down by University of Ghana under the supervision of Dr. J. K. Amoako and Prof. J. J. Fletcher.

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ABSTRACT

Data centres use a lot of power, consumed by two main usages: power required to run the actual equipment and power required to cool the equipment. Usage of electricity results in the production of electric and magnetic fields (EMF). Even though electricity is useful in human lives, there have been reported cases of adverse health effects from EMF generated from its use. Because the use of electricity is ubiquitous and plays a vital role in society's economy, the possibility of harm from EMF to electric utility customers and workers deserves attention.The Electric and Magnetic fields for workers in data center in the Greater Accra Region have been assessed. The fundamental objective was to determine the levels of the electric and magnetic fields and to assess the extent of exposure of workers in the data centre to these fields. The results obtained for the electric field intensities in the data centre ranged from 6.03E-03 ± 7.54E-04 kVm^{-1} to 2.33E-04 ± 8.82E-05 kVm^{-1}.The results obtained for the resultant field strength in the data centre ranged from 3.12E-01± 8.77E-03 µT to 6.57E-02 ± 7.38E-03 µT. The results obtained for the magnetic flux density ranged from 3.9E-07 ± 8.77E-03 µT to 7.27E-08 ± 7.31E-03 µT. The results obtained for the induced current density ranged from 2.37E-06 ± 1.50E-02 mA/m^2 to 2.46E-07 ± 9.99E-03 mA/m^2.

Data obtained are below the basic restrictions for induced current density and reference levels for electric field and magnetic flux density set by the International Commission on Non-Ionizing Radiation Protection.

DEDICATION

This thesis is dedicated to God Almighty and to everyone who contributed towards the completion of this work.

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LIST OF ABBREVIATIONS

AC - Alternating Current

AGNIR – Advisory Group on Non-Ionising Radiation

B – Magnetic

DC- Direct Current

E – Electric

ELF - Extremely Low-Frequency

EM - Electromagnetic

EMF - Electric and Magnetic Fields

GAEC - Ghana Atomic Energy Commission

IARC - International Agency for Research on Cancer

ICNIRP - International Commission on Non-Ionizing Radiation Protection

ICRP - International Commission on Radiological Protection

LF – Low Frequency

MF - Magnetic Fields

NIEHS – National Institute of Environmental Health Sciences

NIR - Non-Ionizing Radiation

NRA - Nuclear Regulatory Authority

NRDC - Natural Resources Defence Council

NRPB - National Radiological Protection Board

RPI - Radiation Protection Institute

ULF - Ultra-Low Frequency

VLF - Very Low Frequency

WHO - World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

Energy that moves in a form of particles or waves can be termed as radiation (CDC, 2006).There are two types of radiation, which are ionising and non-ionising radiation. Non-ionising radiation (NIR) are electromagnetic radiations that do not cause ionisation (remove electrons from atoms) but may have enough energy to cause excitation of atoms and molecules.

NIR encompasses the long wavelength (> 10 nm), low photon energy (< 12.4 eV) portion of the electromagnetic spectrum from 1 Hz to 3 x 10^{15} Hz. NIR cannot be perceived by any human senses unless its intensity is so great that it is felt as heat. Narrow visible region is an exception. The ability to penetrate the human body, the sites of absorption and the subsequent health effects are very much frequency dependent (Kwan-Hoong, 2009).

The electromagnetic spectrum includes gamma rays, x-rays, ultraviolet rays, light rays, infrared rays, microwaves and radio waves. Electromagnetic radiation is transmitted through empty space (3 x 10^8 m/s). These electromagnetic radiations are distinguished from each other by their wavelengths and the amount of energy they transfer.

Data centres are facilities used to house computer systems and associated components such as storage and telecommunication systems. The equipment in the data centres are often in a form of servers mounted in 19 inch (0.4826 meters) rack cabinet. Data centres are used to run IT systems applications that handle the core business and operational data of an organization and also for off-site backups. Data centres use a lot of power, consumed by two main usages: power required to run the actual equipment and power required to cool the equipment. (Glanz, 2012).

Usage of electricity results in the production of electric and magnetic fields (EMF).There are two types of EMF, classified according to the frequency range: extremely low frequency (ELF) fields and very low frequency (VLF) fields. These frequency fields are non-ionising. ELF fields are defined by frequency range of 3-30 kHz. Electric and magnetic fields act independently of one another and are measured separately because of the quasi-static nature of the electromagnetic (EM) fields at these frequencies. Electric fields produced by voltage and measured in volts per meter (V/m) are present when an electric appliance is plugged in. The appliance does not need to be turned on for electric fields to be detected. Magnetic fields which are induced by alternating current (AC) and measured using derived quantity magnetic flux density (B) in Tesla (T) or Gauss (G) are present when the appliance is turned on.

EMF strength decrease as we move away from their source. EMF exposure is found in and around our homes and offices. (Habash, 2001).

Above the ELF range, electromagnetic fields propagate by means of tightly coupled electric and magnetic fields (radiation). In such cases, the magnitude of the electric field can be calculated exactly if the magnetic field is known and vice versa. However in the ELF range, the electric and magnetic fields are effectively uncoupled and can be evaluated separately as if they rose from independent sources.

At the low frequencies where it is customary to use the quasi-static approximation, the wavelength of electric and magnetic fields are very large (approximately 5000 km at 60 Hz) in relation to the size and distances of objects of interest (NRPB, 2001).

Electric and magnetic fields can occur together or separately. Therefore it is possible for humans to be exposed to just one of these fields or both.

For example when a power cord is plugged into a socket outlet, it creates an electric field along the cord. When the lamp is turned on, the flow of current through the cord creates a magnetic field, and the greater the current, the stronger the magnetic field. In the meantime the electric field is still present. In addition it is possible for humans to be exposed to various levels of EMF. Power transmission lines, for example generate strong electric and magnetic fields. However, distribution lines generate weak electric fields but can generate strong magnetic fields depending on the number and type of loads they supply.

Electric appliances, tools and power supplies in buildings are the main sources of EMF exposure that most people receive at work. People who work near transformers, electrical closets, circuit boxes or other high-current electrical equipment may have high-field exposures. In offices magnetic field levels are often similar to those at homes typically 5 $\times 10^{-8}$ – 4 × 10-7 Tesla (T). However these levels may increase dramatically near certain types of equipment.

The electricity we use is alternating current (AC), meaning electric charges oscillate at a particular frequency. Frequency of oscillation in Ghana is 50 Hz. The earth’s static fields are similar to the fields generated by direct current (DC) electricity. Because these fields are static rather than alternating, they do not induce currents in stationary objects as do fields associated with alternating current. Such static fields can induce currents in rotating and moving objects. Even though electricity is useful in human lives, there have been reported cases of adverse health effects from EMF generated from its use. (ICNIRP, 1998).

Most of the concern has focused on potential health effects of magnetic fields although electric and magnetic fields often occur together. The basis for this concern is that magnetic fields are difficult to shield and easily penetrate buildings and people, as opposed to electric fields which have very little ability to penetrate buildings or even human skin. Because the use of electricity is ubiquitous and plays a vital role in society's economy, the possibility of harm from EMF to electric utility customers and workers deserves attention.

1.2 Statement of the Problem

There are data centres in Ghana and we need to pay attention to them. These data centres contain servers and storage systems which emit ELF electric and magnetic fields because they use an excessive amount of electricity. In 2013 U.S data centres consumed an estimated 91 billion kilowatts-hour of electricity enough to power all the households in New York City (NRDC, 2013). Data centres consume 3% of all global electricity production and roughly ten times more per square meter than the average office (Kunateh, 2015). Researches have shown that these ELFs may cause cancer (IARC, 2002). Therefore there is a need to know the levels of ELF fields and exposures of workers in these data centres to these fields. This research will address this problem by making detailed examination of the nature of the ELF fields, quantify the levels in electric and magnetic field intensities and determine the current density induced inside the body. Comparison of these to accepted limits proposed by WHO and ICNIRP would be done.

1.3 Objectives

This study's primary objective is to determine the level of exposure of workers to Electromagnetic Fields in data centres. This would be achieved through the following tasks:

- Measurement of the intensities of electric and magnetic fields inside the data centre.
- Determine the Resultant Field Strength
- Determine the Induced Current Density inside the body.
- Determine the Magnetic Flux Density in the body.
- Comparison of the Electric and Magnetic field levels with internationally recommended standards such as ICNIRP and WHO.

1.4 Relevance and Justification

For years data centres have been noted to consume a high amount of electricity. Because there is a collection of communication systems, storage systems and other IT systems such as server power supplies, processors and uninterrupted power supplies and connective systems in data centres, workers are likely to be exposed to high levels of electric and magnetic fields, therefore we need to be concerned about their health. It is important to assess the level of exposure to these electric and magnetic fields because of the potential adverse health effects of these fields.

1.5 Scope and Limitations

This research is focused on the assessment of levels of extremely low frequencies in Data centres for Telecommunication operators in Accra. Data was taken at Tigo data centre. Based on the layout, measurement points were determined at various spots in the Data centre.

1.6 Organization of Thesis

This research work has been arranged as follows; in Chapter One, there are introductory notes on ELF electric and magnetic fields. Chapter two reviewed related literature to the thesis topic to justify this work. Chapter Three gives detailed explanation of the methods and equipment used in the data collection. In chapter Four, data obtained from the study is analysed and presented. It also discuss the significance of the results obtained and implications in relation to other published works. Chapter five draws conclusions regarding the significance of the study and made recommendations for further study based on the results of this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction.

In this literature review, the frequencies of magnetic and electric fields under study are between 5 Hz to 100 kHz. The range of these frequencies correspond to the following bands: Extremely low frequency (ELF) (3-30 Hz), Surface light fields (SLF) (30-300 Hz), Ultra low frequency (ULF) (300 Hz to 3 kHz), Very low frequency (VLF) (3-30 kHz) and Low frequency (LF) (30-300 kHz) according to the International Telecommunications Union. However in the scientific literature, the exposure assessment to fields from 5 Hz to 100 kHz is often referred to as ELF radiation exposure (WHO, 2007). Hence the term ELF has been used in this thesis to describe this frequency range.

ELFs are produced by both natural and man-made sources. The natural fields are very slowly varying or static. Electric field above the earth's surface in the air is typically 100 V/m but may increase 10-folds or more during strong electric storms. The geomagnetic field is typically 50 µT (König et al., 1981). Most of the man-made sources are at extremely low frequencies. The use of electricity at 50 or 60 Hz as a result of the generation, transmission and distribution results in widespread exposure of humans to ELF fields of the order of 10-100 V/m and 0.1-1 µT and occasionally to much stronger fields (National Research Council, 1997:Portier & Wolfe, 1998:NRPB, 2001). An integral part of modern civilization is electrical power. Interest and concern about potential hazards are understandable because ELF fields can interact with biological systems.

There is a long history for the study of the effects of electric and magnetic fields. Data were first gathered in the 1960s from studies of workers with occupational exposure to ELF fields pertaining to human health risks (IARC, 2002). First data were obtained in a series of studies of children and adults with residential exposure from appliances, electrical facilities and external and internal wiring and grounding systems addressing potential carcinogenic risks.

2.2 Physical characteristics of electromagnetic fields.

Electromagnetic fields propagate by means of tightly coupled electric and magnetic field (radiation) at frequencies above those of interest here. This means the magnitude of the magnetic field can be calculated if the electric field is known and vice versa. However electric and magnetic fields are effectively uncoupled and can be evaluated separately as if they rose from independent sources for ELF range. The wavelengths of electric and magnetic fields are very large (approximately 5000 km at 60 Hz) in relation to the size and distances of the objects of interest at low frequencies where it is customary to use the quasi-static approximation (National Radiological Protection Board, 2001). Electric and magnetic fields do not effectively radiate away from the source under these 'near-fields' conditions (less than one wavelength) nor do they occur together in an interrelated way.

2.3 Definitions, quantities and units.

2.3.1 Electric fields.

Electric fields are produced by electric charges, regardless of their state of motion.

An electric field **E** exist in a region of space if a charge experiences an electrical force F:

F=qE………………………………………………………………………….... 2.1

Where q is the unit positive charge.

The direction of the force or field conforms to the direction that a positive charge would move in the field. A single charge at a point produces an electric field in all directions in a pattern with infinite dimension and spherical symmetry. In practice, it is not possible to have a single isolated charge but instead of indefinitely long field lines, they will terminate on another charge (this could be a charge induced by the field itself in a conducting object or could be another charge already present in a conductor). Vector quantities are characterized by magnitude and direction which have been displayed in bold type. Also electric fields are characterised by displacement vector **D** or electric flux density, where **D**=ε**E** and ε characterises the material's permittivity. Sources of time-varying electric fields are electric utility facilities such as power lines, substations, building wiring and appliances. Electric fields from such sources emanate from unbalanced electric charges on energized conductors. The overall shape of the pattern of electric field experienced at any point depends on the distribution of charges and of objects in the vicinity. The voltage supplied by the power system is the source of unbalanced charge.

2.3.2 Induced Current Density

The current density induced in a circular shaped conductive object, by a uniform magnetic field derived from the Faraday's law of induction, is given by

$$\mathbf{J = \sigma .\pi .r. f .B} \qquad \text{...2.2}$$

Where

J = the current density (A/m^2);

σ = the conductivity of the medium taken as 0.2 S/m;

π = 3.14

r = the radius of the object (m);

f = the frequency of the magnetic field, 50 Hz in this case;

B = the magnetic flux density (μT).

Current density can be defined as the amount of current flowing through a given cross sectional area in a given time interval. The exposure limit field for uniform fields (in the frequency range 1 Hz to 1 kHz) is an induced current density in the central nervous system of 10 mA/m^2 and is in accordance with ICNIRP. The standard further notes that the uniform electric (unperturbed) and magnetic fields correspond to the exposure limit value calculations carried out by previous studies for detailed anatomical and reference male and female body models whose dimensions and mass correspond to those of the International Commission on Radiological Protection (ICRP, 2002) which is about 200 mm for the trunk and 100 mm for the head (Pretorius et al., 2009).

2.4 Magnetic flux density

A magnetic field can be represented as a vector and may be specified in one of two ways: as magnetic flux density B or as magnetic field strength H. B and H are expressed in teslas (T) and amperes per meter (A/m), respectively. In a vacuum and with good approximation in air, B and H are related by the expression

$$\mathbf{B = \mu H} \quad \text{..........} \quad \mathbf{2.3}$$

The constant of proportionality μ in equation 2.3 is termed the permeability of free space and has the numerical value $4\pi \times 10^{-7}$ expressed in henrys per meter (H/m) (ICNIRP, 2010).

2.4.1 Magnitude

Vector quantities like electric and magnetic fields are characterized by magnitude and direction. Electric fields are usually described across a unit distance in terms of potential difference. A 240 volt source that is connected to parallel plates separated by 1 m will produce a field of 240 volts per meter (kV/m, 100 volts per meter).

The magnetic flux density B often describes the magnitude of a magnetic field in terms of magnetic lines of force per unit area. The magnitude of electric and magnetic fields are usually expressed as root-mean-square (rms) values. Dividing the peak amplitude by the square root of two will give the rms values of single-frequency sinusoidally varying fields.

2.4.2 Frequency

Electric and magnetic fields are determined by the frequency characteristics of their sources. In Ghana, the currents and voltages of the electric power system oscillate at 50 times per second (Hz) which produces a sinusoidal rise and fall in the magnitude of the associated fields at the same frequency. Some electrical devices in the power system operate and produce fields at other frequencies. For 50 Hz system, fields can occur at multiples (harmonics) of the fundamental frequency: at 100, 150, 200 HZ, etc. and 120, 180, 240 Hz, etc., for a 60 Hz system. Electrified rail transport is sometimes powered at frequencies of 25 Hz in the USA (NRPB, 2001).

2.4.3 Polarization

Fields add vectorially: both the magnitude and direction of the field must be considered when combining fields from different sources. In static fields (direct current, DC), intensity and direction are constant over time.

A field vector produced by a single conductor changes its direction along a straight line (linearly polarised field). Also multiple sources in phase (current waves or synchronised voltage) produce linearly polarised fields. Fields from multiple conductors not in phase such as three-phase distribution or transmission lines are not necessarily linearly polarised. For these cases the field vector is not fixed in space therefore tracing out an ellipse by rotating during a cycle. The field is then polarised elliptically. The ratio of the minor to major field axis defines the degree of polarisation of the field or ellipticity. The ellipse forms a circle when the two axes of the ellipse are of equal magnitude and the field is described as a circularly polarised field; the field is linearly polarised when one axis is zero.

2.5 Physical interactions with biological materials

In order to understand the effects of electric and magnetic fields on humans and animals, their electrical properties, as well as their size and shape have to be considered with respect to the wavelength of the external field. For ELF, the size of all mammalian and other biological bodies is a very small fraction of the wavelength.

The permittivity and permeability usually are the electrical properties of the body that relates to its interaction with the electric and magnetic fields respectively. Human bodies have of numerous tissues whose electrical properties differ considerably.

The permittivity determines the interaction with the electric field and the dielectric constant defines the ability to store the field energy. The permittivity (ε) is usually written as ($\hat{\varepsilon}_r$, ε_0) where $\hat{\varepsilon}_r$ is the relative permittivity and ε_0 is the permittivity of the vacuum, 8.854×10^{-12} farad/m (WHO, 1984).

The permeability is the measure of the ability of a material to support the formation of a magnetic field within itself. It can be written as $\hat{\mu} = \hat{\mu}_r \mu_0$

Conductivity, σ is used to characterise conductive materials, i.e. those having free electric charges (examples are electrons and ions). Free charges in motion can interact with both electric and magnetic fields.

Most of the biological tissues have a permeability equal to that of free space (vacuum, air) (Foster & Schwan, 1989, 1996). Humans and many animal species are known to have minuscule amounts of biogenic magnetite ($Fe_3 0_4$) in their brains and other tissues (permeability $\mu_r \geq 1$) (Kirschvink et al., 1992).

A large extent of water and electrolyte contents determine the permittivity of biological tissues. Hence tissues which have higher water contents such as blood, kidneys and liver have higher dielectric constants and conductivities than tissues such as fat and lungs. Both the conductivity and permittivity vary with frequency and exhibit relaxation phenomena. Counterion polarisation is the physical phenomenon responsible for the dispersion at low frequencies (Foster & Schwan, 1989, 1996).

Biological bodies such as humans and animals at ELF can be considered as conductive dielectrics and induced fields in tissues can solely be determined on the basis of their conductivity. Table 2 lists the most recently published conductivity measurements (Gandhi et al., 2001) to provide an idea of the range of conductivity values for biological tissues.

Table 2.1: Conductivity of various tissues assumed for power-frequency electric and magnetic fields.

Tissue	σ (S/m)	Tissue	σ (S/m)
Bladder	0.2	Heart	0.5
Blood	0.7	Kidney	0.09
Bone	0.08	Liver	0.04
Bone	0.02	Lungs	0.07
Brain	0.06	Muscle	0.24
Cerebrospinal fluid	2.0	Skin	0.04
Eye sclera	0.5	Spinal cord	0.07
Fat	0.02	Testes	0.42

Source: From Gandhi et al., (2001)

2.6 Sources of alternating fields

2.6.1 Electric fields

2.6.1.1 Naturally occurring fields

Naturally occurring ELF EMF is associated with atmospheric processes like thunderstorms, lightning and ionospheric currents. The natural electric field encountered above the earth surface of the Earth varies greatly with location and time. The charge separation (the primary cause of the field) that occurs between the Earth and the ionosphere acts as a perfect conductor separated by air of negligible conductivity (König et al., 1981). The field near the surface in fair weather has a typical strength of about 130 v/m (Dolezalek, 1979). The strength generally depends on local temperature, height, humidity profile and the presence of ions in the atmosphere. In the presence of fog and rain, deviations of up to 200% from fair-weather levels have been recorded (WHO, 2007). Daily changes are attributed to meteorological phenomena, such as thunderstorms, which affect the rate of charge transfer between the upper atmosphere and the ground.

Atmospheric inversion layer phenomena produce electric fields at the lower end of the ELF range (König et al., 1981). The field strengths and range of frequencies vary widely with season, geographical location and time of day. The atmospheric fields related to lightning discharges have spectral components below 1 Hz but the largest amplitude components have frequencies between 1 and 30 kHz. The intensity is less than 0.5 V/m for time-varying fields related to atmospherics such as lightning between 5 Hz and 1 kHz and amplitudes generally decrease with increasing frequency. At the power frequencies the natural electric fields strength is about 10^{-4} V/m (EC, 1996). Table 2 shows the characteristics of the Earths electric field in the ELF range.

Table 2.2: Characteristics of the Earths electric field in the ELF range.

Frequency range (Hz)	Electric field strength (V/m)	Comment
0.001-5	$0.2\text{-}10^{3}$	Short duration pulses of magnetohydrodynamic origin
7.5-8.4 and 26-27	$0.15\text{-}0.6 \times 10^{-6}$	Quasi-sinusoidal pulses of underdetermined origin
5-1000	$10^{-4}\text{-}0.5$	Related to atmospheric changes (atmospherics)

The Earth-atmosphere system approximates electromagnetically to a three conductive layer radial shell, denoted as the Earth-ionosphere cavity, in which electromagnetic radiation is trapped. Schumann resonances at frequencies 5-50 Hz are created globally in this cavity broadband electromagnetic impulses like those from lightning flashes (Bliokh et al., 1980: Schumann, 1952: Sentman, 1987). Electric fields of up to a few tenths of a millivolt per meter can be ascribed to the Schumann resonance (König et al., 1981).

2.6.1.2 Artificial fields

2.6.1.2.1 Electric power industry

The Electric field environment within towers of transmission lines has been characterized and rated between 230 and 765 kV by Bracken and colleagues. Electric fields may be between 10 to 30 kV/m during operations such as climbing the towers. These fields would not be typically oriented parallel to the body (Bracken et al., 2005: Bracken et al, 2004).

2.6.1.2.2 Overhead power lines

Electric field at a point near a power line depends on its distance, voltage of the line, radius of the conductor and how close together are the various charged conductors making up the line. With all factors being equal, thicker conductors at ground level result in larger electric fields.

Electric fields are affected by conducting objects. The highest electric field strength from overhead lines is typically around 10 kV/m at ground level (AGNIR, 2001b: NIEHS, 1995).

2.6.1.2.3 Underground cables and substations

Buried cable produces no electric field above the ground due to the screening effect of the ground itself and the inclusion of a metal sheath on the underground cable which screens the electric field.

Substations also produce insignificant electric fields outside their perimeter. Higher-voltage substations have security fences surrounding them which screens the electric field since its metallic.

2.6.1.2.4 House wiring and appliances

Electric field produced by any source outside the home will be attenuated considerable by the home structure. All common materials for building are sufficiently conducting to screen fields. The ratio of the field outside to the field inside typically ranges from 10 to 100 or more (AGNIR, 2001b)

There are sources of electric and magnetic fields within homes. House wiring can produce electric fields which are strongest close to the wiring but which can be significant over the volume of the house. The electric field produced by wiring partly depends on how it is installed. The fields produced by wiring installed within walls is attenuated by an amount depending on the building materials and wiring installed in metal trunking or conduit produces very small external fields (AGNIR, 2001b).

Another main source of electric fields within home is mains appliances. Mains appliances when connected to the mains (in contrast to magnetic fields produced only when current is being drawn) produces power-frequency electric fields even when not operating and are left plugged in. The size of the electric field depends on the wiring of appliance and also how much of the wiring is enclosed by the metal which will screen the electric field. With distance the electric field falls rapidly from the appliances just like magnetic fields does. There is no background for fields from sources outside the home for electric fields except those homes that are very close to high electric field source. Therefore the electric field from the appliance is still appreciable even though rather small at greater distances from the appliance than for the case of magnetic fields.

Since fields within the volume of a room are rarely uniform or smoothly varying the electric fields are easily perturbed by conducting objects. Many objects especially metal objects perturb the field and can create local areas of high electric field strengths.

2.6.2 Magnetic fields

2.6.2.1 Naturally occurring fields

Ranging from a few milliseconds up to 10^{12} seconds the earth's magnetic field changes continually. The main feature of the geomagnetic field is its close resemblance to a dipole field (which is explained by electrical currents that flow in the core) aligned approximately with the earth's spin axis. At the magnetic pole, the vertical component of the field reaches a maximum of about 70 µT and approaches zero at the magnetic equator. Conversely the horizontal component has a maximum just over 30 µT at the magnetic equator and is close to zero at the poles. Changes of the dipole field with periods of the order of 100 years or so constitute the secular variation and are explained by eddy currents located near the core boundary (Bullard, 1948).

ELF variations arise mainly from the effects of solar activity in the ionosphere and atmospheric effects such as lightning discharges which cause resonance oscillations in the Earth-ionosphere cavity. Changes over 11 year and 27 day periods in ELF signals and circadian variations reflect the solar influences (EC, 1996). Atmospherics or the electromagnetic fields that arise from lightning discharges have very broad frequency range with spectral components from below 1 Hz up to a few megahertz. The peak intensity from lightning discharges occurs typically at 100-200 Hz in ELF range for peak intensities. The Schumann resonance are a source of ELF magnetic fields of the order of 10^{-2}nT at frequencies up to a few tens of hertz (König et al., 1981). The measurement of signals with frequencies below 100 kHz is extremely difficult due to interferences from man-made signals. The natural magnetic field at 50 or 60 Hz is typical of the order of 10^{-6} μT (Polk, 1974).

2.6.2.2 Artificial fields

Artificial sources which are the dominant sources of ELF magnetic field (MF) are associated with generation, distribution and usage of electricity at frequency of 50 Hz or 60 Hz. Electrical wiring, powerlines and electrical appliances such as television, hair-dryers, computers, fridges, electric blankets, etc. all produce ELF MF.

2.6.2.3 Electrical appliances

Depending on how appliances are manufactured and designed, EMF will vary greatly. Surveys have been conducted to measure fields from common appliances such as hair dryers, Television sets, stereo headsets and sewing machines. Compared to ambient levels, exposure levels were small (Kaune et al., 2000). The mean magnetic field measurements from appliances tend to be high for microwave ovens, coffee grinders, hair dryers and electric shavers and low in beds. In occupational settings, magnetic fields measurements were highest from electrical appliances (Mezei et al., 2001).

2.7 Epidemiology

The study of long term effect of exposure is called epidemiology. These studies investigate the occurrence and distribution of diseases in real life situations and in human populations. Epidemiologists then establish statistical associations between the occurrence of disease in a population and exposure to an infectious or non-infectious agent (NIEHS-NIH, 2002). Scientists evaluate all relevant evidence from cellular studies, animal studies and epidemiological studies when deciding about the potential health hazard because epidemiological studies are difficult to control and to detect effects and factors, such as bias, misclassification, confounding, and statistical variation that can affect the outcome of the research (IARC, 2002).

There have now been over 150 studies investigating aspects of cancer in relation to residential or occupational exposure, studying almost every major population group in the world since the first epidemiological study in 1979 linking elevated residential magnetic fields to childhood leukemia (Michaelis et al., 1997). In 2002 the International Agency for Research on Cancer (IARC) classified ELF magnetic fields as a 'possible carcinogen' (category 2B) on the basis of epidemiological evidence of an association between time-weighted average (TWA) 50/60 Hz magnetic fields above 0.4 μT and childhood leukemia. Epidemiological studies of ELF exposures and cancer show a weak association between ELF field exposure and nervous system cancer and leukemia (U.S. Congress, Office of Technology Assessment, 1989). Residence in homes near external power lines is associated with an approximate 1.5-fold excess risk of childhood leukemia. Elevated risks of various cancers have been reported in occupationally exposed persons, especially leukemia, nervous system tumors and breast cancer; but the lack of uniformity of the results has been a major concern (Repacholi et al., 1999).

2.8 Biological and Health Effects

For more than three decades biological and health effects of EMF exposure has been going on at an accelerating pace. Results have been mixed and their interpretation has been controversial due to little consensus on biological effects and virtually none on health effects that might arise from fields at the levels found in occupational or general community environments.

Based on the following correspondence between current density and biological effects organizations have recommended exposure limits for ELF-EMF: (Bernhardt et al., 1986)

- 1-10 mA/m^2; minor biological effects have been reported;
- 10-100 mA/m^2; well established effects occur, including effects on the visual and nervous systems;
- 100-1000 mA/m^2; stimulation of excitable tissue occurs, causing possible health hazards;
- 1000 mA/m^2 and above; extrasystoles and ventricular fibrillation can occur.

How the effect of field forces on charged entities, creating currents, and how the relations between fields and induced currents are quantified through the conductivity of the medium, for example, tissue are described below:

Calcium Efflux: Effects on doubly ionized, radioactive calcium occurring in windows of field frequency and power in vitro experiments have been examined. A chemical exposure analogy would be as if a little benzene were harmful but a greater amount were not, and a still greater amount were again harmful.

A reasonable increase in the exchange of calcium-45 with a physiologic bath was observed for sectioned chick brain exposed to a 147-MHz carrier wave amplitude modulated at 16 Hz in the first of these studies (Bawin et al., 1975). Exposure to just a 16-Hz E field had the opposite effect, decreasing efflux and other modulation frequencies did not produce as large an effect. Later work suggested that the effect depended on the relative orientation and strength of the earth's magnetic field, and that it occurred in "windows" of field frequency and intensity and even temperature of the experimental preparation (Blackman et al., 1991).

Phosphenes: This is the sensation of flickering light within the eye. It appears to be produced by stimulation of retinal tissue and by any number of agents (e.g., mechanical shock, pressure, chemical substances and sudden fright). It is termed electrophosphenes and magnetophosphenes, if the agent inducing phosphenes is ELF fields depending on the field that causes them. Phosphenes occur when the induced current density is of the order of 10 mA/m^2 or more. Studies have demonstrated that the sensitivity to phosphenes is greatest around 20 Hz. In general, B-field intensities must be on the order of 10 mT for the production of magnetophosphenes.

Genetic Effects. No reliable effects of genetic toxicology studies have been found, but there are scattered positive findings (McCann et al., 1993).

Effect on Melatonin: Animal studies have demonstrated effects on melatonin from E fields, (18,19 B fields,(Kato et al., 1993) and no effects.(Lee et al., 1995). E-field exposure decreased serum melatonin but not pineal melatonin levels;(Grota et al., 1994) if exposure was during the mid- or late-dark phase, pulsed static B fields affected melatonin, but not when exposure was during the day time or early dark phase;(Yaga et al., 1993) short-term B-field exposure affected pineal and nocturnal serum melatonin, while long-term exposure affected just nocturnal serum melatonin;(Selmaoui et al., 1995) serum melatonin was not affected by daytime E- and B-field exposure with a slow onset, but it was reduced by variable exposure with a rapid onset/offset (Rogers et al., 1995). Conclusion was made by the National Institute of Environmental Health Sciences (NIEHS) Working Group that there is weak evidence that exposure to E and B fields alters melatonin in rodents but not in sheep or baboons (NIEHS Working Group Report., 1998).

Reproduction and Development: There have been scattered positive findings for exposure to test animals, but no consistent, reproducible observations (Huuskonen et al., 1998). For example, female miniature swine were exposed to 60-Hz E fields of 35 kV/m for 20 hr/day in a multigenerational study. There were conflicting results in breeding (Sikov et al., 1987) Because of the ambiguities in the swine study, a study using a similar protocol was performed with rats (E field= 0, 10, 65, and 130 kV/m).(Rommereim et al., 1988) There were no significant increases in litters with malformations among the exposed animals.

2.9 Exposure Guidelines

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an international scientific body which is recognised by the World Health Organization (WHO) for its expertise in this area. The ICNIRP guidelines are based on a careful examination of the research data on the health effects of exposure to ELF fields. The guidelines also includes margins for safety. They were first proposed in 1990. After consideration of some research, they were reconfirmed in 1993 and 1998. ICNIRP has continued to review new research published since 1998, but has not seen any need to amend their guidelines (ICNIRP, 1998). Conclusion was made that the only effects clearly evident in the research data were those caused by currents induced in the body by ELF electric and magnetic fields. In very strong fields, these induced currents can interfere with the body's nervous system and so should be limited to levels where no effects can occur. For electric fields, ICNIRP also wished to limit the possibility of experiencing small shocks in strong electric fields. While acknowledging the results of studies which found a weak association between ELF magnetic field exposures and the risk of childhood leukemia, ICNIRP considered that the results were lacking support from other sources to form the basis for exposure guidelines. The ICNIRP guidelines set a basic restriction on the density of electric current induced in the body by ELF fields. As induced current density is difficult to measure in the body, the guidelines also prescribe reference levels in terms of the more easily measured field strengths. Compliance with the reference levels ensures compliance with the basic restrictions (ICNIRP, 1998). Exceeding the reference level does not necessarily mean the basic restriction has been exceeded.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter describes the materials and method used for this thesis work.

3.2 Measuring Instruments

The instrument used to measure the electric and magnetic fields is the ME 3851A Digital Electrostress Analyzer with F1B2H31 (frequency filter module: 16 Hz Band Pass/50 Hz High Pass/ 2 kHz High Pass) made in Germany by Gigahertz solutions. It is frequency selective. It has a selective range of 5 Hz to 100 kHz, 16 Hz, 50 Hz to 100 kHz and 2 kHz to 100 kHz. It has a range selection of 200 nT/Vm: (fine) 0 to 199.9 nT, 0 to 199.9 V/m and 2000 nT/Vm: (coarse) 0 to 1999 nT, 0 to 1999 V/m. Range of meter for electric is 0.1 V/m to 1999 V/m and range of meter for magnetic is 0.1 nT to 1999 nT.

It has a battery charging outlet with an extension cord of the suppled adapter: 12-24 VDC, with (+) at the internal conductor and (-) at the external conductor. It is only used during battery charging.

It has a screen for displaying the type of field in use and also a speaker icon for turning on speaker.

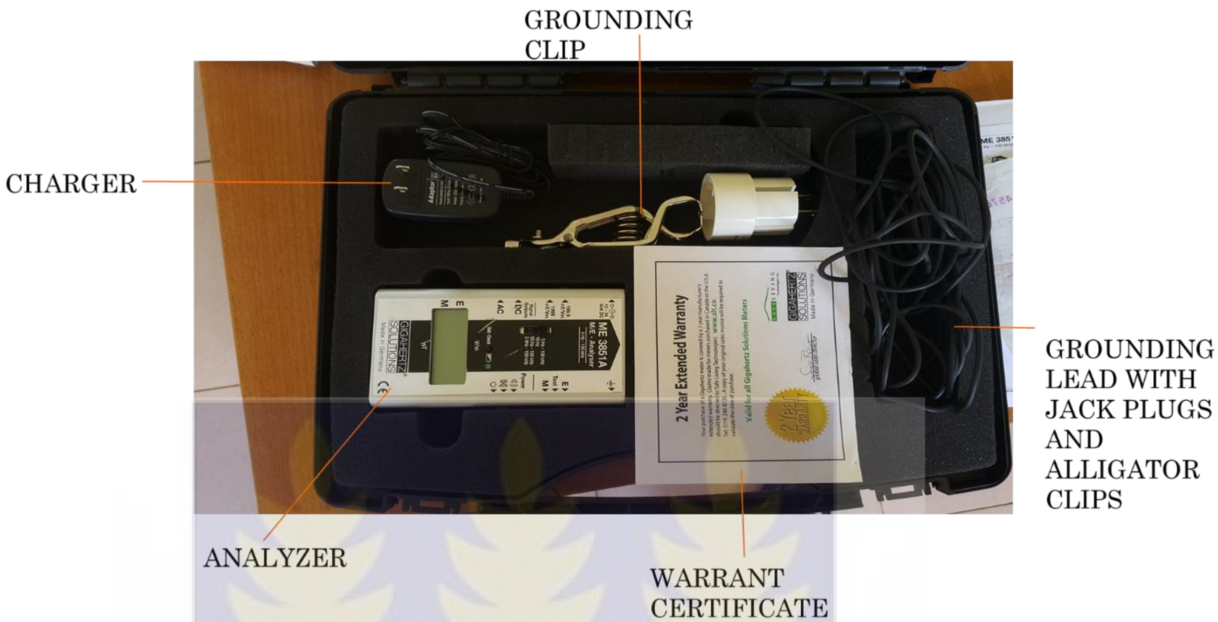


Plate 3.1: ME 3851A Digital Electrostress Analyzer in its kit.

3.2.1 Measuring AC Electric fields

In order to obtain reliable and reproducible results the field meter was connected to a ground potential through the supplied grounding lead or grounding clip.

The jack plug of the grounding lead was inserted into the dedicated socket (ground icon) with the grounding lead running alongside the case to the back.

The AC or DC socket was touched with the finger in order to bring my body to the ground potential.

3.2.2 Positioning of the Field meter

The field meter has been calibrated for measurements taken in close proximity to the body. Field sources located behind the field meter are shielded through the body in order to avoid misleading concentrations of field lines onto the electric field sensor. Stretch-out arm measurements were avoided.

3.2.3 AC Electric Field Testing

The field meter is turned on and the switch "Field Type" is set to "E" foe AC electric field

The frequency filter was set to "5 Hz to 100 kHz"

The grounding lead must run to the back of the case and the person performing the survey as well as anybody around must be located behind the field meter.

The field meter was held close to the body. Further away will give a false or higher reading.

3.2.4 AC Magnetic Field Testing

The field meter was turned on and the switch "Field Type" was set to "M" for AC magnetic field.

The frequency filter was set to "5 Hz to 100 kHz"

For reliable measurements of AC magnetic fields, neither the field meter nor the person performing the measurements was grounded.

The field meter was held as shown in the pictures below: point to the front (Plate 3.2 (a)), to the ceiling (Plate 3.2 (b)) and to the side so that it is perpendicular to the front axis (Plate 3.2 (c)).

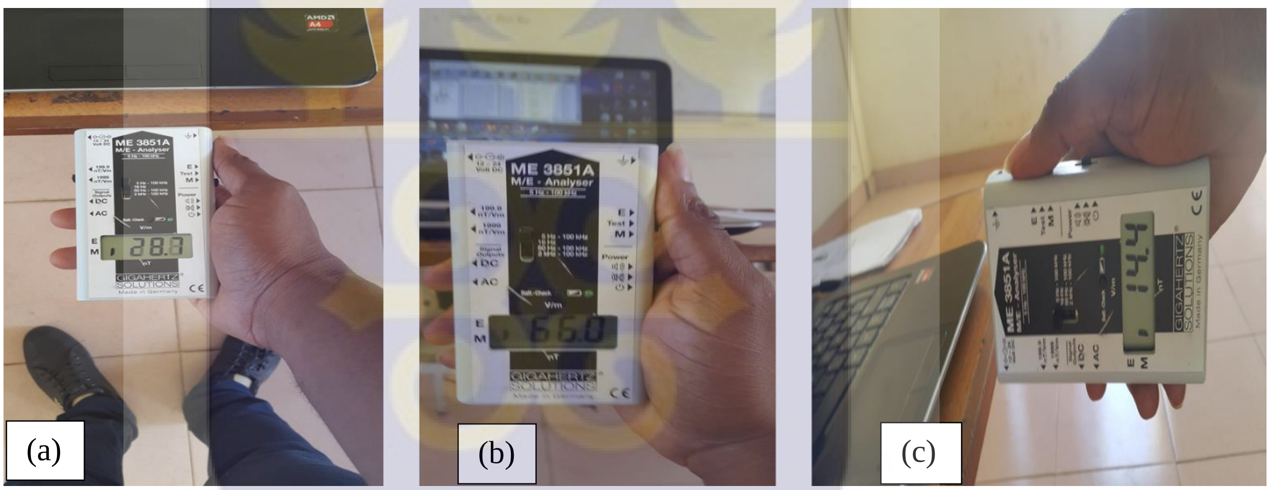
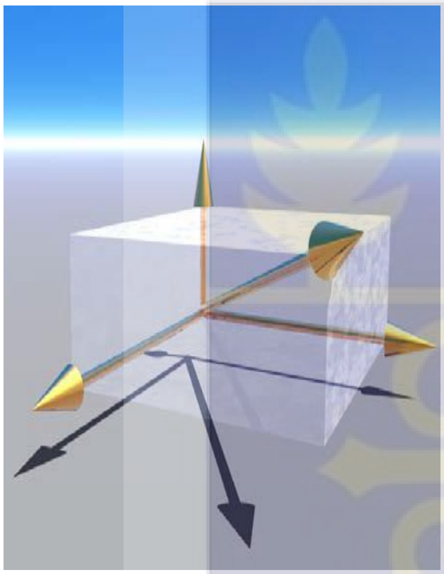


Plate 3.2 : (a) point to the front, (b) to the ceiling and (c) to the side so that it is perpendicular to the front axis.

The resultant, total magnetic field strength (the sum of the single field strengths, 3-D measurement) can be accurately calculated according to the following equation:

RESULTANT FIELD STRENGTH = Square Root ($X^2 + Y^2 + Z^2$)………………...3.1

The direction of the resultant field, which is also called the "substitute field" has been illustrated in Plate 3.3. Photos for Plate 3.2 showing the single measurements of the three dimension as well as Plate 3.4 were taken in the classroom during a typical test session. Inserting the values displayed in the above equation, the result would come very close to the value which is displayed in Plate 3.4. There the field meter is held perpendicular to the resultant field.



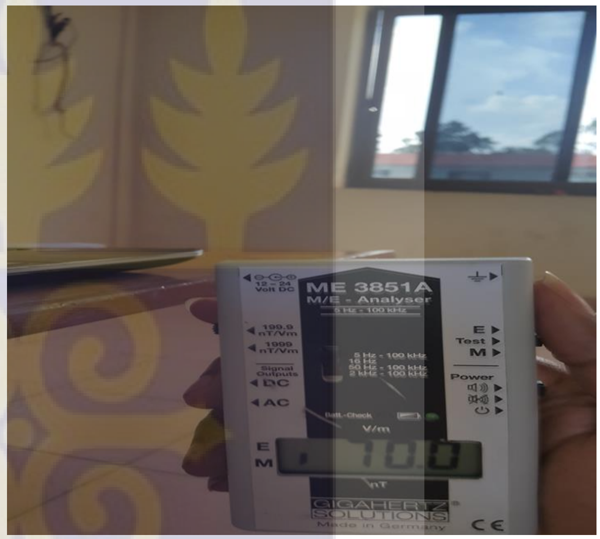


Plate 3.3: Illustration of substitute field. **Plate 3.4: Resultant field measurement.**

Tape measure was used to measure the various heights and distances.

3.3 Description of Site and Measurement Procedures.

Measurement was taken at Tigo data centre in Ghana. It is located at Barnes Road, adjacent Data Bank, opposite National Service Secretariat building in Accra. The area of the data center room was 67.633 m^2 .The room contains about four hundred (400) servers: four (4) rack rows and seven (7) racks on each row and five (5) air conditioning units.

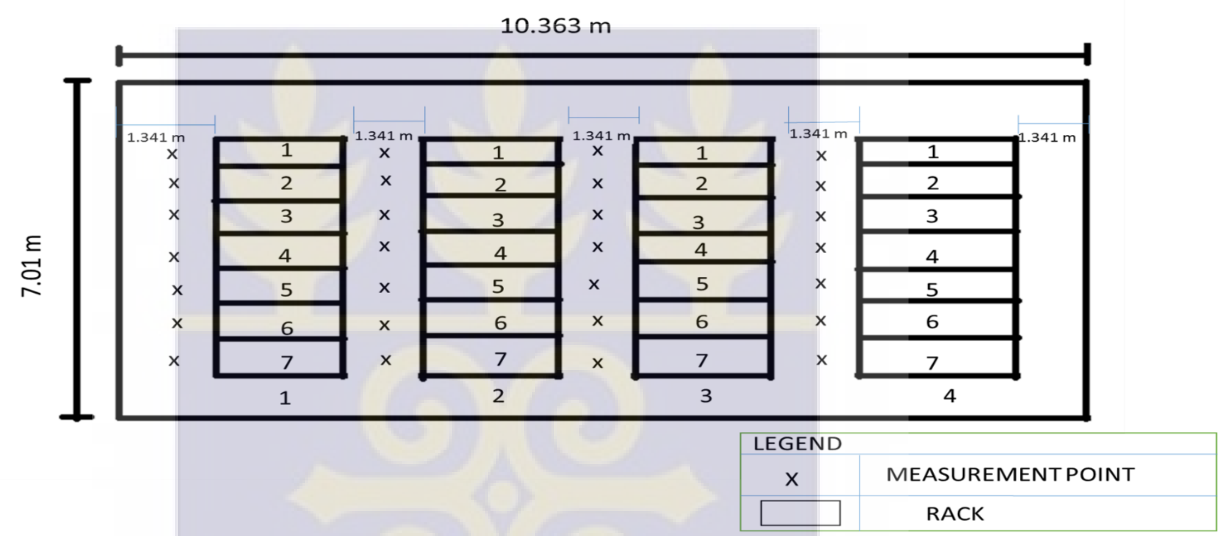


Figure 3.1 : Sketch of Data Centre.

Measurement of electric and magnetic fields were taken in front of each rack. For the electric field the instrument was grounded before reading was recorded. This was done in different heights of 0.6m, 1.0m, 1.5m, 1.6m and 1.7m and a distance of 0.671 m from every rack. Since the distance between one rack and the wall or one rack and a rack in front of it was 1.341 m, 0.671m was the best distance one can stand when working on a server in a rack. The same procedure was done for the magnetic field measurements but the equipment was not grounded. Magnetic field measurement in the x, y and z axis were taken in front of each rack.

Figure 3.2: Demonstration of heights and distance in front of racks.

3.4 Data analysis

3.4.1 Calculation of Induced Current Densities due to ELF MFs

An approach to calculate the induced current density for workers in Data Centres as described in equation 2.2 was used in this study. The induced current densities in the head, trunk and lower extremities were calculated. The induced current densities for head and trunk were compared to the ICNIRP Basic Restriction of 10 mA/m^2 to determine whether it was exceeded. The dimensions and mass of the head, trunk and lower extremities corresponds to detailed anatomical and reference male and female body models to those of the International Commission on Radiological Protection (ICRP, 2002), which is about 0.2 m for lower extremities, 0.2 m for the trunk and 0.1 m for the head.

3.4.2 Calculation of Magnetic flux densities due to ELF MFs

An approach to calculate the magnetic flux density for workers in Data Centres as described in equation 2.3 was used in this study. The resultant field strength for each rack at different heights was derived from the magnetic field intensities using equation 3.1. This was then used to find the magnetic flux density by multiplying the resultant field strength by the permeability of free space μ.

3.5 Uncertainty Analysis

To calculate the uncertainty of the electric and magnetic field measurements, the various sources of uncertainty in the measurements were identified. The size of the uncertainty from each source was estimated and finally the individual uncertainties were combined to give the overall uncertainty at any point. The standard uncertainty and u(E) and u(B) was first found by first calculating the estimated standard deviation S, which is given by the expression

$$S = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}} \quad \text{...3.2}$$

where

$$\bar{X} = \sum_{i}^{n} \frac{X_i}{n}$$

Because the distribution was a normal one, u(E) and u(B)was calculated using the formula

$$\mathbf{U} = \frac{s}{\sqrt{n}} \quad \text{.......} \quad \mathbf{3.3}$$

Where n is the number of measurements, which is equal to 3.

The instrument can read electric and magnetic fields to 0.1 nT and 1 nT which means that the instrument can give an error of ±0.1 and ±1.

This was taken as uniformly distributed uncertainty

To find the standard uncertainty, $u(E)_s$ and $u(B)_s = \frac{a}{\sqrt{3}}$

where a is the half width of the error = 0.05 and 0.5

Therefore the standard uncertainty for the ME 3851A Digital Electrostress Analyzer are

$$u(E)_s = \frac{0.05}{\sqrt{3}}$$

$$=0.028868$$

and

$$u(B)_{s1} = \frac{0.05}{\sqrt{3}}$$

$$=0.028868$$

$$u(B)_{s2} = \frac{0.5}{\sqrt{3}}$$

=0.28868

For the combined standard uncertainty, it was found by using the equations 3.4 and 3.5

Combined standard uncertainty for electric fields, $U(E)_c$ = $\sqrt{(\boldsymbol{U})^2 + (\boldsymbol{U}(\boldsymbol{E})_s)^2}$**…3.4**

Combined standard uncertainty for magnetic fields, $U(B)_c$= $\sqrt{(\boldsymbol{U})^2 + (\boldsymbol{U}(\boldsymbol{B})_{s12})^2}$**.3.5**

The expanded uncertainty, U at a 95 % confidence level was found by multiplying the combined standard uncertainty by a coverage factor, k = 2.

Symbolically, U = k × combined standard uncertainty

= 2 × combined standard uncertainty

This reported uncertainty is based on a standard uncertainty multiplied by a coverage factor k =2, providing a level of confidence of approximately 95% (Bell, 2001).

The mean electric field and the magnetic field levels were written as $\bar{x} \pm$ U in the units of kV/m^2 and μT.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results of the ELF electric field and magnetic field measurements taken at Tigo data centre in Accra. The electric and magnetic fields in the data centre where measured according to the rows (first to fourth row) and racks (first to seventh rack).

4.2 Assessment of Electric field levels in the data centre.

4.2.1 Electric field levels for first row

The electric field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table B1 to B28 in appendix B shows the values for the electric field measured in Vm^{-1}. Table 4.1 shows the values for the mean electric field values in kVm^{-1} for each rack on the first row.

Table 4.1: Values for the mean electric field values in kVm^{-1} for each rack on the first row.

Height(m)	E1(kV/m)	E2(kV/m)	E3(kV/m)	E4(kV/m)	E5(kV/m)	E6(kV/m)	E7(kV/m)
0.6	4.23E-03	3.30E-03	2.33E-03	7.33E-04	5.00E-04	8.00E-04	2.67E-04
1	4.40E-03	3.23E-03	1.40E-03	1.10E-03	8.67E-04	8.67E-04	5.00E-04
1.5	2.70E-03	3.30E-03	1.80E-03	1.53E-03	2.00E-03	6.00E-04	2.33E-04
1.6	4.20E-03	3.93E-03	1.27E-03	2.77E-03	2.00E-03	8.67E-04	3.67E-04
1.7	6.03E-03	3.93E-03	6.67E-04	2.70E-03	2.13E-03	9.33E-04	8.00E-04

Note: E1(kV/m), E2(kV/m), E3(kV/m), E4(kV/m), E5(kV/m), E6(kV/m) and E7(kV/m) are Electric fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The electric field ranged from 2.33E-04 ± 8.82E-05 kVm^{-1} to 6.03E-03 ± 7.54E-04 kVm^{-1}.

4.2.2 Electric field levels for second row

The electric field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.2 shows the values for the mean electric field values in kVm^{-1} for each rack on the second row.

Table 4.2: Values for the mean electric field values in kVm^{-1} for each rack on the second row.

Height(m)	E1(kV/m)	E2(kV/m)	E3(kV/m)	E4(kV/m)	E5(kV/m)	E6(kV/m)	E7(kV/m)
0.6	1.33E-04	1.67E-04	5.33E-04	7.67E-04	4.00E-04	8.67E-04	2.00E-04
1	2.00E-04	1.33E-04	6.33E-04	2.33E-04	9.67E-04	1.00E-03	2.33E-04
1.5	2.00E-04	1.00E-04	8.67E-04	3.33E-04	1.50E-03	8.00E-04	2.00E-04
1.6	3.67E-04	1.33E-04	1.33E-03	1.00E-03	2.03E-03	1.13E-03	1.00E-04
1.7	2.00E-04	1.67E-04	1.27E-03	1.97E-03	1.93E-03	1.20E-03	1.67E-04

Note: E1(kV/m), E2(kV/m), E3(kV/m), E4(kV/m), E5(kV/m), E6(kV/m) and E7(kV/m) are Electric fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The electric field ranged from 1.00E-04 ± 5.77E-05 kVm^{-1} to 2.03E-03 ± 3.38E-04 kVm^{-1}.

4.2.3 Electric field levels for third row

The electric field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.3 shows the values for the mean electric fields in kVm^{-1} for each rack on the third row.

Table 4.3: Values for the mean electric field values in kVm^{-1} for each rack on the third row.

Height(m)	E1(kV/m)	E2(kV/m)	E3(kV/m)	E4(kV/m)	E5(kV/m)	E6(kV/m)	E7(kV/m)
0.6	7.33E-04	8.00E-04	2.67E-04	7.33E-04	1.13E-03	1.13E-03	3.83E-03
1	7.00E-04	6.67E-04	6.67E-04	1.10E-03	6.67E-04	1.27E-03	3.57E-03
1.5	8.00E-04	1.07E-03	8.00E-04	1.17E-03	1.07E-03	7.67E-04	3.43E-03
1.6	7.67E-04	8.67E-04	1.07E-03	8.67E-04	1.27E-03	1.13E-03	3.60E-03
1.7	6.67E-04	1.13E-03	8.67E-04	1.20E-03	1.00E-03	1.17E-03	3.87E-03

Note: E1(kV/m), E2(kV/m), E3(kV/m), E4(kV/m), E5(kV/m), E6(kV/m) and E7(kV/m) are Electric fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The electric field ranged from 2.67E-04 ± 1.45E-04 kVm^{-1} to 3.87E-03 ± 1.86E-04 kVm^{-1}.

4.2.4 Electric field levels for fourth row

The electric field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.4 shows the values for the mean electric fields in kVm^{-1} for each rack on the fourth row.

Table 4.4: Values for the mean electric field values in kVm^{-1} for each rack on the fourth row.

Height(m)	E1(kV/m)	E2(kV/m)	E3(kV/m)	E4(kV/m)	E5(kV/m)	E6(kV/m)	E7(kV/m)
0.6	3.50E-03	2.60E-03	2.93E-03	5.33E-04	1.00E-03	7.00E-04	4.00E-04
1	2.63E-03	2.67E-03	2.50E-03	1.43E-03	2.10E-03	8.00E-04	3.67E-04
1.5	3.00E-03	3.13E-03	2.20E-03	2.70E-03	1.73E-03	1.27E-03	4.67E-04
1.6	3.30E-03	3.23E-03	2.47E-03	3.83E-03	9.33E-04	8.67E-04	5.33E-04
1.7	4.87E-03	3.53E-03	2.93E-03	5.73E-03	1.80E-03	1.07E-03	6.00E-04

Note: E1(kV/m), E2(kV/m), E3(kV/m), E4(kV/m), E5(kV/m), E6(kV/m) and E7(kV/m) are Electric fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The electric field ranged from 3.67E-04 ± 2.47E-04kVm^{-1} to 5.73E-03 ± 1.92E-03 kVm^{-1}.

4.3 Assessment of Magnetic flux density using magnetic field levels in the data centre.

4.3.1 Magnetic field levels, Magnetic flux density and Induced current density for first row.

The magnetic field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.5 shows the resultant magnetic field values for the first row in µT.

Table 4.5: Resultant magnetic field values for the first row in µT.

Height(m)	H1(µT)	H2(µT)	H3(µT)	H4(µT)	H5(µT)	H6(µT)	H7(µT)
0.6	7.79E-02	6.36E-02	5.81E-02	6.83E-02	6.59E-02	6.70E-02	6.89E-02
1	7.05E-02	6.93E-02	6.52E-02	6.59E-02	7.12E-02	6.42E-02	6.23E-02
1.5	6.42E-02	7.34E-02	6.79E-02	6.27E-02	6.76E-02	6.56E-02	6.27E-02
1.6	6.97E-02	7.02E-02	6.78E-02	7.00E-02	7.45E-02	6.26E-02	6.58E-02
1.7	7.25E-02	6.80E-02	7.56E-02	8.15E-02	7.64E-02	6.84E-02	7.22E-02

Note: H1(μT), H2(μT), H3(μT), H4(μT), H5(μT), H6(μT) and H7(μT) are resultant magnetic fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The resultant magnetic field ranged from 8.15E-02 ± 1.00E-02 μT to 5.81E-02 ± 7.31E-03μT.

Figure 4.1 shows the comparison of the magnetic flux density of each rack on the first row with different heights taken.

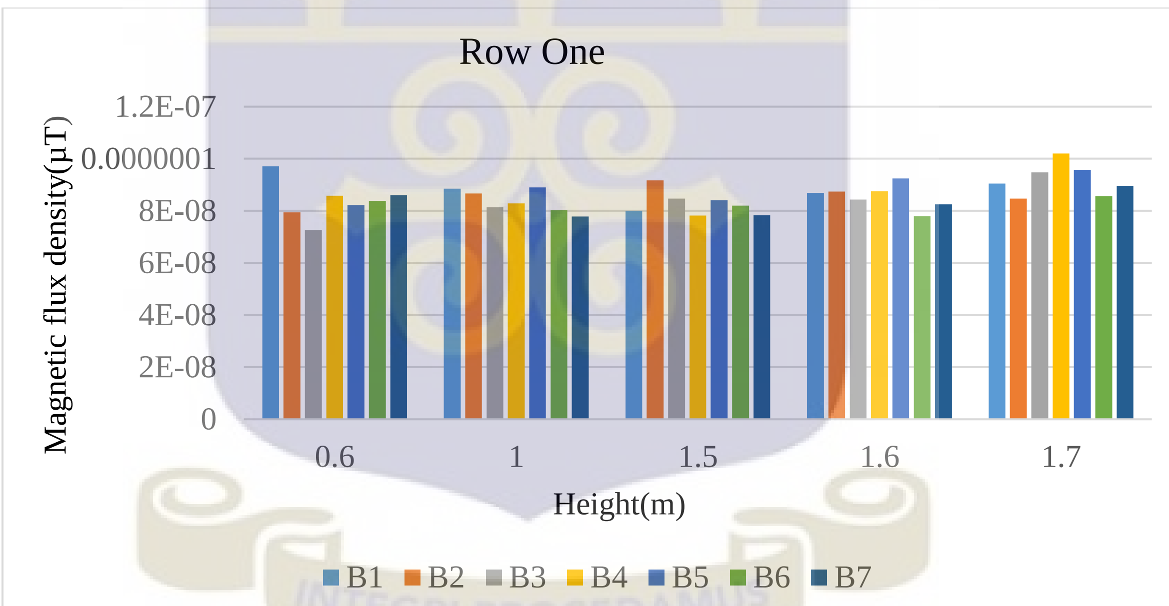


Figure 4.1: Magnetic flux densities for the racks at different heights for first row.

Note: B1, B2, B3, B4, B5, B6 and B7 are magnetic flux densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.1 the maximum magnetic flux density is at fourth rack at 1.7 meters height which is 1.02E-07 ± 1.00E-02 µT and the minimum magnetic flux is at rack three at 0.6 meters which is 7.27E-08 ± 7.31E-03 µT.

Figure 4.2 shows the comparison of the current density of each rack on the first row with different heights taken.

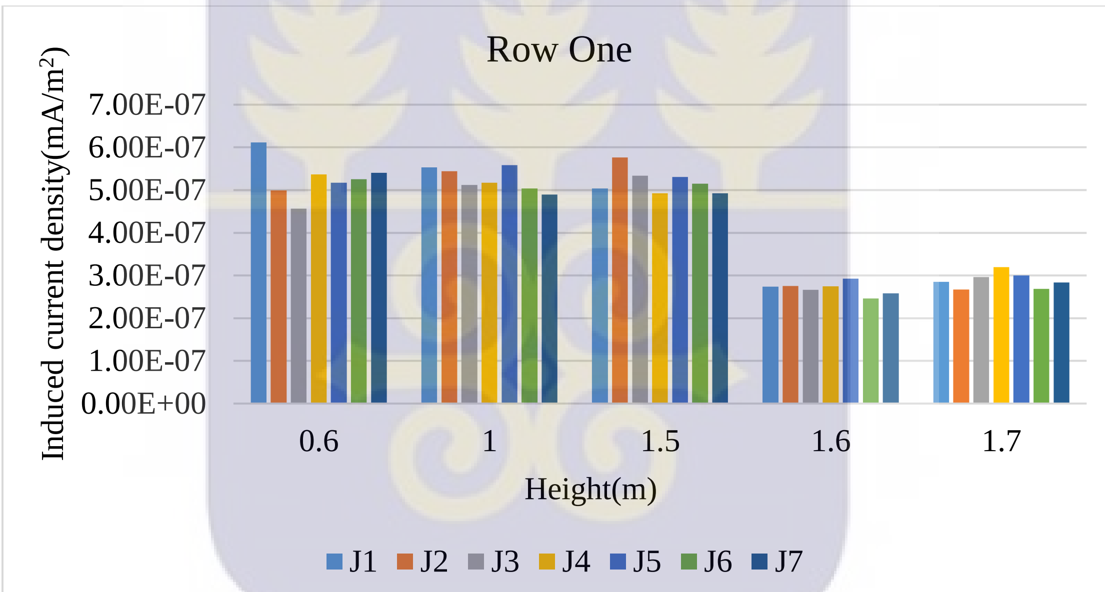


Figure 4.2: Induced Current densities for the racks at different heights for first row.

Note: J1, J2, J3, J4, J5, J6 and J7 are induced current densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.2, the maximum current density is at the first rack at 0.6 meters height which is 6.11E-07 ± 9.17E-03 mA/m^2 and the minimum current density is at sixth rack at 1.6 meters which is 2.46E-07 ± 9.99E-03 mA/m^2.

4.3.2 Magnetic field levels and Magnetic flux density for second row.

The magnetic field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.6 shows the resultant magnetic field values for the second row in µT.

Table 4.6: Resultant magnetic field values for the second row in µT.

Height(m)	H1(µT)	H2(µT)	H3(µT)	H4(µT)	H5(µT)	H6(µT)	H7(µT)
0.6	2.24E-01	1.27E-01	9.79E-02	9.07E-02	8.44E-02	7.82E-02	7.94E-02
1	2.88E-01	1.29E-01	9.42E-02	8.64E-02	7.65E-02	7.72E-02	8.65E-02
1.5	3.02E-01	1.26E-01	1.01E-01	9.12E-02	7.89E-02	7.87E-02	6.57E-02
1.6	3.10E-01	1.30E-01	1.05E-01	8.23E-02	8.08E-02	7.53E-02	7.28E-02
1.7	3.12E-01	1.35E-01	1.02E-01	8.54E-02	7.70E-02	7.46E-02	7.20E-02

Note: H1(µT), H2(µT), H3(µT), H4(µT), H5(µT), H6(µT) and H7(µT) are resultant magnetic fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The resultant magnetic field ranged from 6.57E-02 ± 7.38E-03µT to 3.12E-01 ± 8.77E-03 µT.

Figure 4.3 shows the comparison of the magnetic flux density of each rack on the second row with different heights taken.

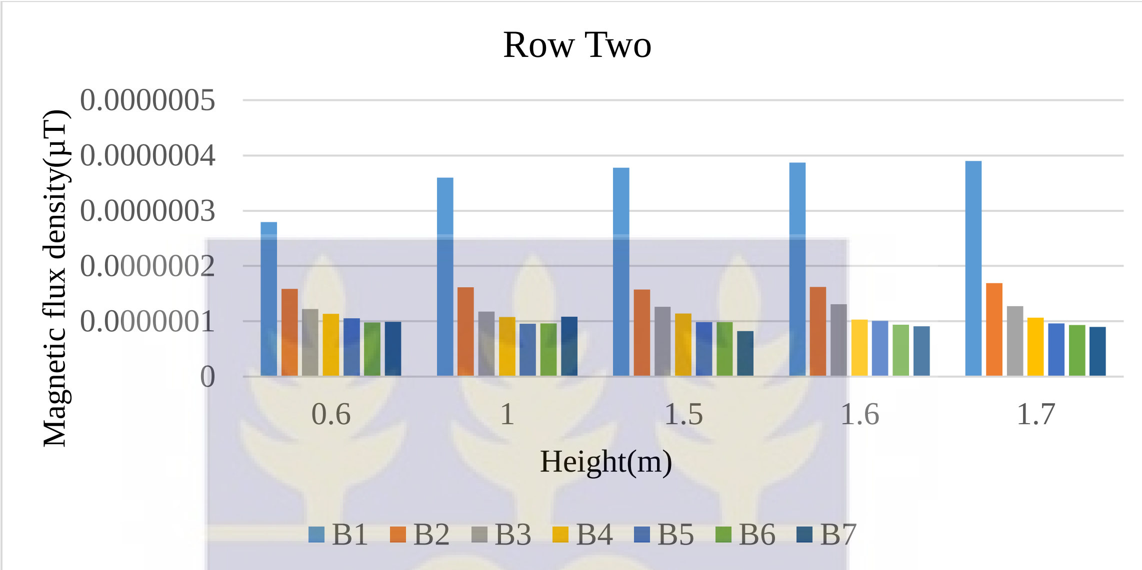


Figure 4.3: Magnetic flux densities for the racks at different heights for second row.

Note: B1, B2, B3, B4, B5, B6 and B7 are magnetic flux densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.3, the maximum magnetic flux density is at the first rack at 1.7 meters height which is 3.9E-07 ± 8.77E-03 µT and the minimum magnetic flux is at seventh rack at 1.5 meters which is 8.21E-08 ± 7.38E-03 µT. From Table 4.6, the high increase in the magnetic field level in the first rack was as a result of the rack being close to a fire panel and an electrical distribution board. These emanate magnetic fields which add up to the magnetic fields being produced by the servers in the racks. The higher the magnetic field, the higher the magnetic flux density.

Figure 4.4 shows the comparison of the current density of each rack on the second row with different heights taken

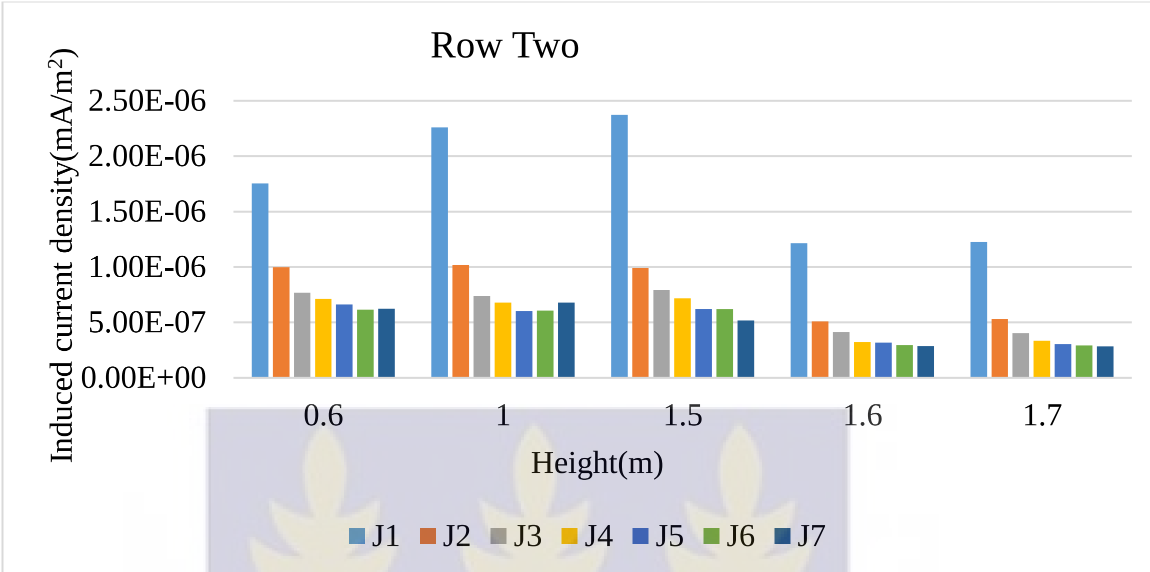


Figure 4.4: Induced Current densities for the racks at different heights for second row.

Note: J1, J2, J3, J4, J5, J6 and J7 are induced current densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.4, the maximum current density is at the first rack at 1.5 meters height which is 2.37E-06 ± 1.50E-02 mA/m^2 and the minimum current density is at seventh rack at 1.7 meters which is 2.83E-07 ± 6.47E-03 mA/m^2.

4.3.3 Magnetic field levels and Magnetic flux density for third row.

The magnetic field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.7 shows the resultant magnetic field values for the third row in µT.

Table 4.7: Resultant magnetic field values for the third row in µT.

Height(m)	H1(µT)	H2(µT)	H3(µT)	H4(µT)	H5(µT)	H6(µT)	H7(µT)
0.6	1.84E-01	1.21E-01	1.00E-01	9.01E-02	8.07E-02	8.27E-02	7.86E-02
1	1.93E-01	1.16E-01	9.83E-02	9.04E-02	7.54E-02	8.40E-02	7.80E-02
1.5	2.32E-01	1.09E-01	9.28E-02	9.14E-02	8.02E-02	7.91E-02	7.82E-02
1.6	2.63E-01	1.03E-01	9.46E-02	9.75E-02	8.14E-02	7.63E-02	7.98E-02
1.7	2.98E-01	9.57E-02	9.15E-02	1.01E-01	7.58E-02	7.26E-02	7.20E-02

Note: H1(µT), H2(µT), H3(µT), H4(µT), H5(µT), H6(µT) and H7(µT) are resultant magnetic fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The resultant magnetic field ranged from 7.20E-02 ± 6.99E-03 µT to 2.98E-01 ± 1.61E-02 µT.

Figure 4.5 shows the comparison of the magnetic flux density of each rack on the third row with different heights taken.

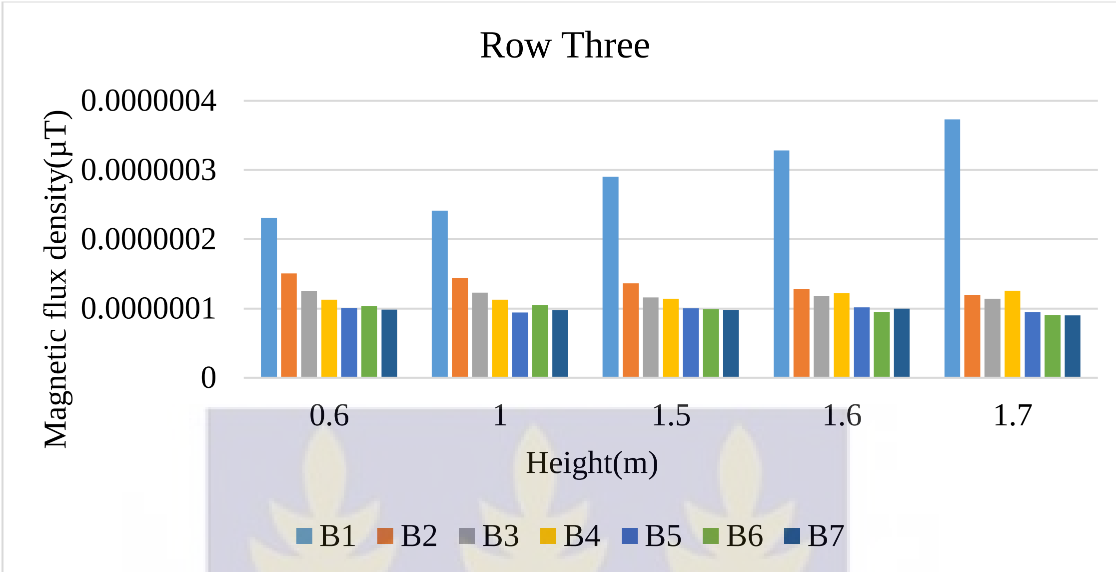


Figure 4.5: Magnetic flux densities for the racks at different heights for third row.

Note: B1, B2, B3, B4, B5, B6 and B7 are magnetic flux densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.5, the maximum magnetic flux density is at the first rack at 1.7 meters height which is 3.73E-07 ± 1.61E-02 µT and the minimum magnetic flux density is at seventh rack at 1.7 meters which is 8.99E-08 ± 6.99E-03 µT. Also the increase in the magnetic field for the first rack was as a result of the rack being close to the fire panel and electrical distribution board.

Figure 4.6 shows the comparison of the current density of each rack on the third row with different heights taken

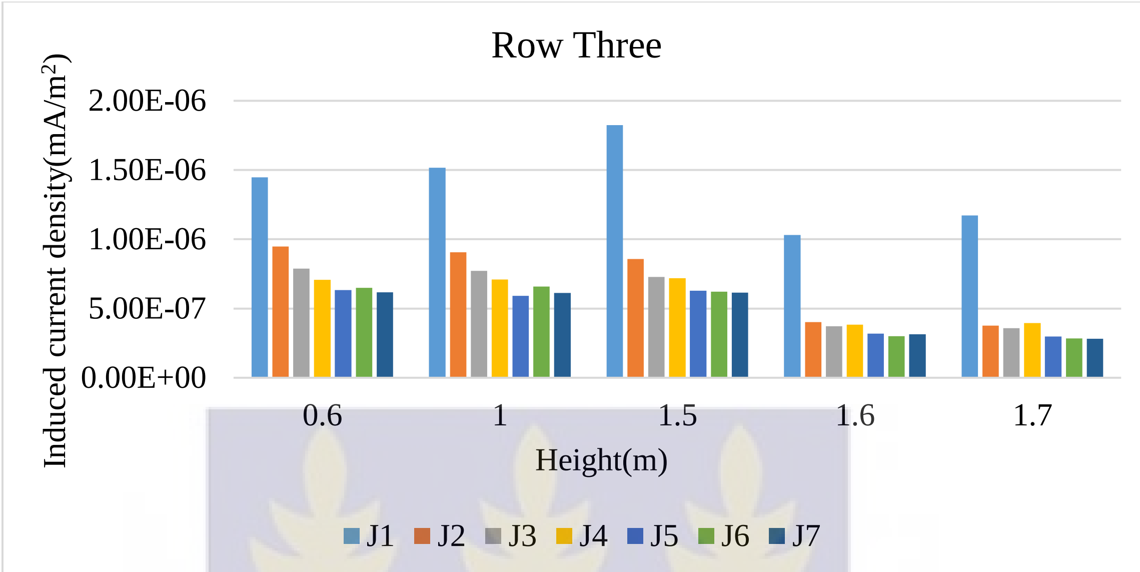


Figure 4.6: Induced Current densities for the racks at different heights for third row.

Note: J1, J2, J3, J4, J5, J6 and J7 are induced current densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.6, the maximum current density is at the first rack at 1.5 meters height which is 1.82E-06 ± 6.47E-03 mA/m^2 and the minimum current density is at seventh rack at 1.7 meters which is 2.82E-07 ± 6.99E-03 mA/m^2.

4.3.4 Magnetic field levels and Magnetic flux density for fourth row.

The magnetic field levels at a distance of 0.671 meters and 0.6, 1.0, 1.5, 1.6 and 1.7 meters of height was measured in front of each rack. Table 4.8 shows the resultant magnetic field values for the fourth row in µT.

Table 4.8: Resultant magnetic field values for the fourth row in µT.

Height(m)	H1(µT)	H2(µT)	H3(µT)	H4(µT)	H5(µT)	H6(µT)	H7(µT)
0.6	6.64E-02	7.02E-02	6.59E-02	7.55E-02	7.13E-02	7.37E-02	8.44E-02
1	6.82E-02	6.74E-02	6.53E-02	7.51E-02	7.30E-02	7.31E-02	7.62E-02
1.5	6.95E-02	7.23E-02	7.01E-02	7.94E-02	7.32E-02	7.49E-02	6.78E-02
1.6	6.57E-02	6.72E-02	7.22E-02	7.64E-02	7.40E-02	8.24E-02	7.75E-02
1.7	7.44E-02	6.88E-02	7.25E-02	8.24E-02	7.97E-02	8.05E-02	7.41E-02

Note: H1(µT), H2(µT), H3(µT), H4(µT), H5(µT), H6(µT) and H7(µT) are resultant magnetic fields for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

The resultant magnetic field ranged from 8.44E-02 ± 5.36E-03 µT to 6.53E-02 ± 4.32E-03 µT. Figure 4.7 shows the comparison of the magnetic flux density of each rack on the fourth row with different heights taken.

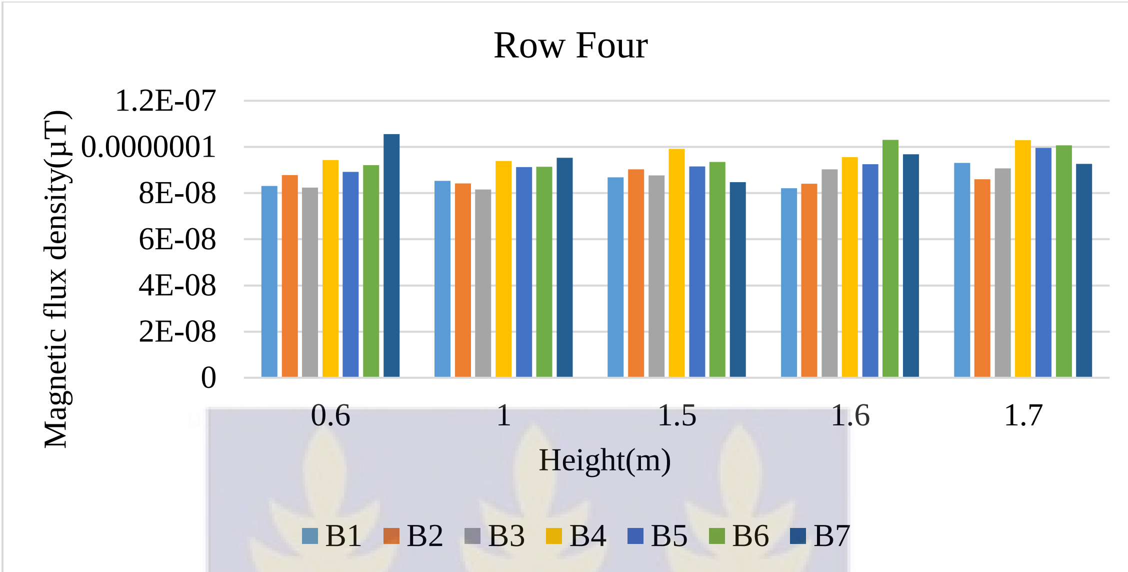


Figure 4.7: Magnetic flux densities for the racks at different heights for fourth row.

Note: B1, B2, B3, B4, B5, B6 and B7 are magnetic flux densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.7, the maximum magnetic flux density is at the seventh rack at 0.6 meters height which is 1.06E-07 ± 5.36E-03 µT and the minimum magnetic flux density is at third rack at 1.0 meters which is 8.16E-08 ± 4.32E-03 µT.

Figure 4.8 shows the comparison of the current density of each rack on the fourth row with different heights taken

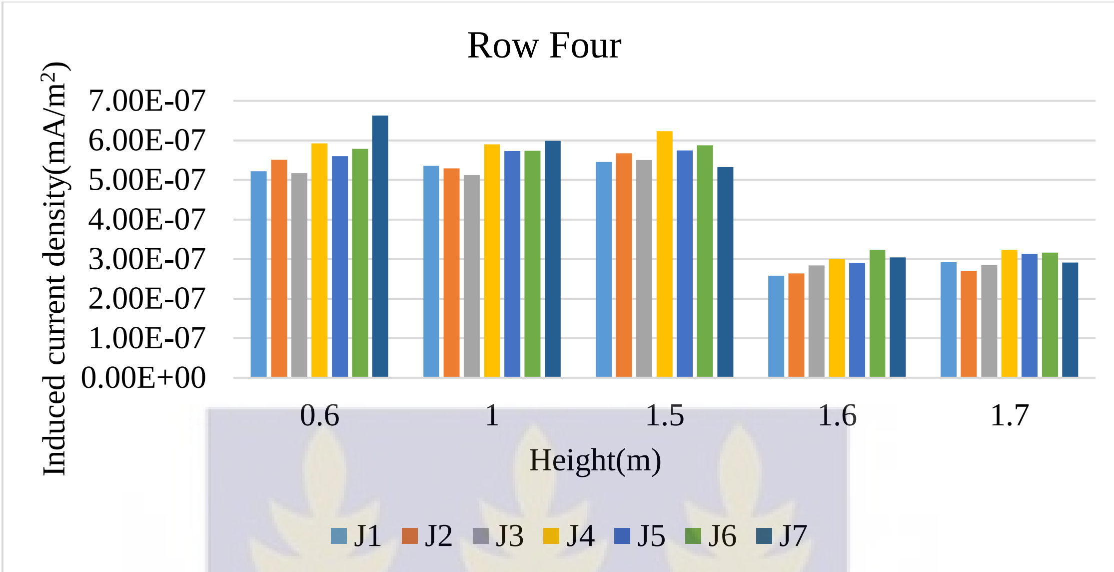


Figure 4.8: Induced Current densities for the racks at different heights for fourth row.

Note: J1, J2, J3, J4, J5, J6 and J7 are induced current densities for first rack, second rack, third rack, fourth rack, fifth rack, sixth rack and seventh rack respectively.

From figure 4.8, the maximum current density is at the seventh rack at 0.6 meters height which is 6.63E-07 ± 5.36E-03 mA/m^2 and the minimum current density is at first rack at 1.6 meters which is 2.58E-07 ± 4.56E-03 mA/m^2.

4.4 Comparison of Results with Standards

4.4.1 Results Compared to International Standards

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines are the most accepted guidelines for non-ionizing radiation. They are endorsed by the World Health Organization (WHO), for the International Union for

Telecommunication (ITU) and for more than 30 countries all over the world including administrations of health, telecommunications, environment and others.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set-up guidelines for limiting exposure to time varying electric and magnetic fields (1 Hz-100 kHz) published in: health physics 99(6):818-836; 2010. Table 4.1 shows the summary of the ICNIRP (1998) Exposure Guidelines.

Table 4.9: Basic restrictions and guidelines for occupational exposure to 50 Hz ELF electric and magnetic fields.

EXPOSURE CHARACTERISTICS	BASIC RESTRICTIONS INDUCED CURRENT DENSITY (mA/m^2)	REFERENCE LEVEL	
		ELECTRIC FIELD STRENGTH (kV/m)	MAGNETIC FLUX DENSITY (μT)
OCCUPATIONAL	10	10	500

SOURCE: ICNIRP GUIDELINES (1998)

The maximum electric field measured was 6.03E-03 ± 7.54E-04 kVm^{-1}. The maximum magnetic flux density expected was 3.9E-07 ± 8.77E-03 μT. The maximum induced current densities expected in the head was 1.75E-06 ± 8.77E-03 mA/m^2 for row two (first rack 1.7 meters height) and trunk of the workers was 1.75E-06 ± 7.54E-04 mA/m^2.for row two (first rack 1.5 meters height). These are therefore well within the ICNIRP Reference Level and Basic Restriction.

4.4.2 Comparison of Results to other Occupationally Exposed Workers

Some works have been done in Ghana related to ELF electric and magnetic fields.

Assessment of the levels of magnetic field in electricity transmission substations and nearby public access points in the Greater Accra region of Ghana was done (Akomaning-Adofo, 2010). The maximum magnetic flux densities for occupationally exposed workers were as follows: Volta, 18.98 µT ± 0.15 µT, New Tema 19.77 µT ± 0.12 µT, Achimota 19.78 µT ± 0.17 µT and Mallam 19.54 µT ± 0.19 µT. The internally induced current density varies from 149.35 to 447.49 µA / m^2.

The level of Electromagnetic Field exposure to workers in TV stations (Metro TV and GTV) in Accra, Ghana has been measured (Osei, 2012). The average electric field ranged between 0.12 V/m and 1150 V/m within the premises of GTV and between 0.0006 V/m and 0.0709 V/m within the premises of Metro TV. Average magnetic field of the EFLs varied between 0.06 µT and 9.335 µT in GTV and between 0.04 µT and 6.08 µT and in Metro TV. Occupational exposure quotients of the ELF electric field strength ranged between 0.00012 and 0.115 in GTV and 0.0006 and 0.0709 in Metro TV. Similarly, the occupational exposure quotients of the ELF magnetic field varied between 0.00012 and 0.01867 in GTV and 0.00008 and 0.01216 in Metro TV.

The calculated induced currents from the ELFs for a male worker ranged between 1.8617E-05mA and 0.1784mA in GTV and between 0.0009mA and 0.1099mA in Metro TV. That of a female worker varied between 1.6279E-05 mA and 0.156 mA in GTV and between 0.0008 mA and 0.0961 mA in Metro TV.

Assessment of levels of occupational exposure to magnetic fields radiation among welders in Greater Accra-Ghana was done (Sawyerr, 2015). The extremely low-frequency (ELF) magnetic fields (MFs) measurement results showed that the magnetic flux densities, B from the SMAW process ranged from 4.01 ± 0.72 μT to 196.46 ± 4.86 μT with an average magnetic flux density calculated to be 43.68 μT. The expected induced current density, J_{head} in the head ranged from 0.01 to 0.62 mA/m^2 and that of the trunk, J_{trunk} ranged from 0.03 to 1.23 mA/m^2.

The maximum electric field measured, the maximum current density and the maximum magnetic flux density for workers in Data Centre were all relatively low as compared to the works done on Transmission substations, TV stations and Welder machines. Therefore workers at Data Centre's are less exposed as compared to other work areas mentioned above.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objective of this research work was to determine the level of exposure of workers to Electromagnetic Fields in data centres by measuring the electric and magnetic field intensities, calculating the magnetic flux densities, induced current densities in the body and comparing the estimated levels of exposure to International standards.

The maximum electric field measured in the data centre for each rack are as follows: 6.03E-03 ± 7.54E-04 kVm^{-1} for the first row, 2.03E-03 ± 3.38E-04 kVm^{-1} for the second row, 3.87E-03 ± 1.86E-04 kVm^{-1} for the third row and 5.73E-03 ± 1.92E-03 kVm^{-1} for the fourth row.

The maximum Magnetic flux densities for occupationally exposed workers for each row are as follows: 1.02E-07 ± 1.00E-02 µT for the first row, 3.9E-07 ± 8.77E-03 µT for the second row, 3.73E-07 ± 1.61E-02 µT for the third row and 1.06E-07 ± 5.36E-03 µT for the fourth row.

As stated in the discussion section, it can be seen that the magnetic field increases as a result of the rack being close to a fire panel and an electrical distribution board.

The maximum induced current density for each row are as follows: 6.11E-07 ± 9.17E-03 mA/m^2 for the first row, 2.37E-06 ± 1.50E-02 mA/m^2 for the second row, 1.82E-06 ± 6.47E-03 mA/m^2 for the third row and 6.63E-07 ± 5.36E-03 mA/m^2 for the fourth row.

It can be concluded that since the servers were in rack cabinets, the electric and magnetic fields being produced from these servers were reduced when measuring in front of the racks.

Data obtained are below the basic restrictions for induced current density and reference levels for electric field and magnetic flux density set by the International Commission on Non-Ionizing Radiation Protection.

These results have therefore demonstrated ELF electric and magnetic field levels and exposure conditions to the workers in a data centre.

5.2 Recommendations

5.2.1 Recommendation to Policy makers

Policy makers such as the National Communication Authority (NCA) and the Ministry of Communications should develop and adopt limits for exposure to extremely low frequency electromagnetic fields locally for data centres and other electrical equipment.

5.2.2 To Telecommunication Network Operators

Telecommunication Network Operators should appoint radiation protection officers to check the levels of electric and magnetic fields in their data centres periodically. Also when building or expanding their data centres, radiation protection officers should be appointed in the designing stage of the data centre and to help identify hot spots (areas in the data centres which have high electric and magnetic fields) in the data centre after completion.

5.2.3 To Occupationally Exposed Workers

Workers in the data centre can reduce their exposure by spending less time in the data centre and also by keeping their distances from hot spots in the data centre. They can also run shifts in the data centre.

5.2.4 For Further Studies

Measurement of electric and magnetic field levels for other data centres for Telecommunication Network Operators in Ghana should be carried out. The ELF electric and magnetic fields should be assessed for workers in data centres nation-wide in order to assess their exposure. Further work should be done in relation to the time spent in the data centre.

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APPENDICES

APPENDIX A

Table A1: Quantities and units.

Characteristics	Symbol[a]	SI unit	symbol
Electric field intensity	**E**	Volt/meter	V/m
Magnetic field intensity	**B**	Tesla	T
Magnetic field	**H**	Ampere/meter	A/m
Current density	**J**	Ampere/meter squared	A/m^2
Frequency	f	Hertz	Hz
Charge density	ρ	Coulomb/meter cubed	C/m^3
Conductivity	σ	Siemens/meter	S/m
Current	I	Ampere	A
Charge	q	Coulomb	C
Force	**F**	Newton	N
Permittivity	ε	Farad per meter	F/m
Permeability	μ	Henry per meter	H/m
Permittivity of free space	ε_o	$\varepsilon_o = 8.854 \times 10^{-12}$ F/m	
Permeability of free space	μ_o	$\mu_o = 12.57 \times 10^{-7}$ H/m	

Note: 1 gauss (G) – 10^{-4} tesla; 1 oersta (Oe) = 1 gauss in vacuum or air

[a] vector quantities are displayed in bold type.

APPENDIX B

TIGO

DATA CENTRE

AREA: 67.633 m^2

CONTAINS: 5 AIRCONDITIONERS

4 RACK ROWS

7 RACKS ON EACH ROW

ABOUT 400 SERVERS

TIME: 3:20PM

FREQUENCY RANGE: 5Hz-100 kHz

Table B1: Electric and Magnetic field measurements

FIRST ROW (FIRST RACK) DISTANCE FROM RACK 2.2 FEET (0.671 METERS (m))

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	4.1	37.3	39.5	58.3
	3.6	44.3	32.1	60.9
	5.0	31.5	34.7	55.3
1.0	3.5	32.9	25.4	51.6
	5.5	40.1	31.8	47.9
	4.2	43.6	27.1	55.2
1.5	3.3	37.1	30.2	56.9
	2.1	33.7	18.2	43.9
	2.7	39.6	22.0	40.1
1.6	6.0	37.2	23.3	42.4
	3.3	46.7	19.4	56.7
	3.3	44.2	24.2	52.1
1.7	6.0	58.1	24.0	45.6
	5.4	33.6	26.1	52.4
	6.7	47.1	30.2	49.0

Table B2: Electric and Magnetic field measurements

SECOND RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	3.2	38.1	17.1	51.4
	3.6	35.7	21.2	44.7
	3.1	33.0	24.1	49.0
1.0	2.4	40.3	23.5	49.8
	3.3	38.9	33.5	56.2
	4.0	37.0	26.1	45.2
1.5	4.1	39.1	27.1	55.2
	2.2	46.7	18.2	60.1
	3.6	40.6	20.1	52.8
1.6	3.0	44.3	30.4	50.1
	4.1	32.1	33.6	55.7
	4.7	37.4	24.1	48.1
1.7	4.0	34.6	33.3	46.7
	4.0	40.4	19.4	50.3
	3.8	36.2	27.1	54.1

Table B3: Electric and Magnetic field measurements

THIRD RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	2.3	33.7	27.8	37.4
	2.1	31.0	23.1	45.2
	2.6	34.6	18.7	42.7
1.0	1.4	39.4	16.9	52.1
	1.4	42.7	24.2	43.6
	1.4	40.4	28.6	40.1
1.5	1.0	46.1	20.1	45.5
	2.2	39.6	17.9	55.2
	2.2	44.4	26.2	42.4
1.6	1.0	40.2	22.0	38.6
	1.8	47.2	30.4	47.5
	1.0	39.5	26.2	52.1
1.7	0.8	37.2	33.5	57.4
	0.6	45.5	19.2	60.1
	0.6	42.1	27.1	54.0

Table B4: Electric and Magnetic field measurements

FOURTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	49.0	16.3	50.6
	0.8	45.2	28.7	42.6
	0.6	40.7	25.7	44.0
1.0	1.1	42.4	35.3	36.2
	1.1	47.2	30.2	36.7
	1.1	47.2	21.1	40.4
1.5	1.8	45.4	23.7	37.1
	1.6	42.1	33.2	33.1
	1.2	42.6	28.6	35.5
1.6	2.6	46.4	24.0	40.1
	3.0	49.0	30.1	48.2
	2.7	45.3	34.2	40.1
1.7	2.7	49.7	45.6	54.2
	2.7	50.6	39.2	40.2
	2.7	49.2	40.1	53.6

Table B5: Electric and Magnetic field measurements

FIFTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.5	44.5	15.2	46.2
	0.5	36.2	23.5	50.2
	0.5	49.0	19.0	41.4
1.0	0.8	47.3	29.4	45.7
	0.8	43.1	33.6	48.3
	1.0	44.7	24.1	46.7
1.5	1.8	42.1	24.2	48.1
	2.1	38.6	27.4	53.7
	2.1	40.5	18.4	45.2
1.6	1.8	44.3	38.4	52.4
	2.2	41.2	32.1	55.2
	2.0	38.6	28.9	49.4
1.7	1.8	39.0	37.3	50.6
	2.4	45.7	34.6	56.2
	2.2	47.2	34.1	47.7

Table B6: Electric and Magnetic field measurements

SIXTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	40.6	35.3	42.1
	0.8	37.9	32.7	39.4
	0.8	34.6	39.6	44.8
1.0	0.8	34.3	40.0	36.3
	1.0	46.7	38.2	31.0
	0.8	31.0	41.2	34.2
1.5	0.5	46.2	34.2	36.5
	0.5	42.9	30.1	39.0
	0.8	39.0	37.8	33.7
1.6	1.0	40.1	20.1	38.1
	0.8	38.6	33.6	40.4
	0.8	41.7	34.7	35.4
1.7	0.8	42.1	34.5	40.6
	1.0	46.7	36.2	46.2
	1.0	41.0	27.1	38.6

Table B7: Electric and Magnetic field measurements

SEVENTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.3	46.5	30.1	47.4
	0.2	42.2	24.2	44.2
	0.3	46.1	29.0	41.0
1.0	0.5	37.3	26.3	39.6
	0.5	32.6	33.1	42.8
	0.5	39.2	20.6	46.7
1.5	0.2	38.0	38.8	44.2
	0.2	31.6	26.2	40.2
	0.3	37.4	18.8	45.7
1.6	0.5	40.1	22.0	47.6
	0.3	39.8	28.1	49.0
	0.3	36.2	24.2	44.7
1.7	0.7	39.5	41.2	50.5
	0.7	34.9	32.6	48.2
	1.0	37.2	37.8	49.4

Table B8: Electric and Magnetic field measurements

SECOND ROW (FIRST RACK) CLOSE TO FIRE PANEL AND ELECTRICAL DISTRIBUTION BOARD

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.1	117.4	52.8	182.6
	0.1	101.6	68.1	174.6
	0.2	120.1	70.4	188.2
1.0	0.2	110.3	81.8	239
	0.2	121.5	84.6	266
	0.2	98.4	90.1	252
1.5	0.1	103.1	95.7	269
	0.3	112.5	95.2	271
	0.2	118.0	97.8	252
1.6	0.2	116.7	99.4	266
	0.7	110.8	101.2	270
	0.2	119.6	99.2	270
1.7	0.2	128.2	104.6	273
	0.2	122.2	106.9	264
	0.2	126.4	99.7	262

Table B9: Electric and Magnetic field measurements

SECOND RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.1	83.5	33.6	90.3
	0.2	87.1	38.1	94.1
	0.2	70.3	40.4	88.7
1.0	0.1	90.1	39.5	87.6
	0.1	88.6	41.6	90.1
	0.2	82.2	36.2	84.7
1.5	0.1	89.7	40.4	82.4
	0.1	90.2	44.7	77.2
	0.1	86.4	38.2	79.4
1.6	0.2	88.0	48.6	79.0
	0.1	91.6	47.4	82.6
	0.1	91.0	50.1	76.4
1.7	0.1	94.2	55.7	81.6
	0.2	87.4	49.5	91.2
	0.2	92.1	52.2	82.4

Table B10: Electric and Magnetic field measurements

THIRD RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	79.5	30.6	50.2
	0.6	72.6	34.6	56.7
	0.2	74.7	33.0	52.0
1.0	1.0	64.3	32.1	54.7
	0.6	71.4	36.9	51.6
	0.3	69.0	34.1	59.4
1.5	1.2	67.7	30.4	68.3
	0.7	74.2	30.4	70.2
	0.7	62.1	33.6	65.2
1.6	1.2	70.9	31.0	68.0
	1.2	74.2	29.6	67.4
	1.6	69.0	35.2	74.2
1.7	1.4	66.4	33.4	65.6
	1.2	71.3	37.5	69.2
	1.2	67.4	32.8	67.3

Table B11: Electric and Magnetic field measurements

FOURTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	1.1	57.4	20.3	67.4
	0.6	58.2	19.6	64.2
	0.6	60.1	24.7	65.9
1.0	0.3	52.3	21.2	61.5
	0.2	57.4	26.2	59.3
	0.2	55.7	22.8	66.2
1.5	0.4	57.4	18.1	60.3
	0.2	62.6	20.6	67.0
	0.4	66.7	24.1	62.6
1.6	1.0	53.8	20.9	54.7
	1.0	52.8	26.7	57.2
	1.0	57.3	22.2	59.0
1.7	2.2	66.8	22.7	50.4
	1.7	64.2	18.4	56.2
	2.0	59.4	16.7	54.7

Table B12: Electric and Magnetic field measurements

FIFTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.4	55.6	18.0	60.7
	0.4	52.7	22.6	57.2
	0.4	56.2	27.4	62.1
1.0	1.0	47.0	24.2	55.6
	1.2	50.4	19.2	55.6
	0.7	48.6	22.6	52.8
1.5	1.4	44.2	26.4	54.9
	1.4	49.5	28.2	60.4
	1.7	47.7	21.7	58.7
1.6	2.2	44.2	30.1	61.2
	1.7	41.6	27.4	59.6
	2.2	49.0	22.6	64.1
1.7	1.4	48.5	23.1	57.4
	2.2	48.2	18.2	55.2
	2.2	44.7	29.4	55.9

Table B13: Electric and Magnetic field measurements

SIXTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	46.7	24.3	59.0
	0.8	48.9	22.6	62.7
	1.0	45.2	16.3	55.1
1.0	1.0	48.1	18.6	57.2
	1.0	40.4	26.4	57.2
	1.0	47.7	24.9	59.4
1.5	1.0	42.8	20.1	60.3
	0.7	47.7	19.6	64.9
	0.7	41.9	27.2	58.6
1.6	1.2	39.0	22.0	59.2
	1.0	43.6	29.4	57.6
	1.2	40.8	24.7	56.4
1.7	1.2	42.1	22.0	55.3
	1.2	46.9	24.8	59.4
	1.2	42.2	24.2	52.1

Table B14: Electric and Magnetic field measurements

SEVENTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.1	44.2	22.6	55.9
	0.3	49.4	19.4	64.2
	0.2	49.4	26.9	57.2
1.0	0.2	56.7	34.4	60.1
	0.2	54.1	31.2	54.8
	0.3	59.6	28.6	56.8
1.5	0.1	38.3	20.6	44.9
	0.3	34.2	28.4	52.4
	0.2	40.4	22.9	47.2
1.6	0.1	30.1	28.8	59.9
	0.1	36.8	31.2	56.4
	0.1	42.1	30.4	50.2
1.7	0.2	40.5	18.7	57.3
	0.2	39.4	20.6	55.7
	0.1	33.0	25.2	59.6

Table B15: Electric and Magnetic field measurements

THIRD ROW (FIRST RACK)

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.9	42.4	40.0	173.1
	0.7	46.2	46.7	176.4
	0.6	46.2	50.2	169.8
1.0	0.9	43.0	62.4	176.0
	0.6	48.1	67.1	176.8
	0.6	40.7	69.4	174.7
1.5	0.8	47.1	80.4	217
	0.8	42.8	74.9	210
	0.8	41.6	82.1	216
1.6	0.7	67.8	74.1	250
	0.9	54.9	76.7	242
	0.7	66.8	79.4	238
1.7	0.6	97.6	66.1	287
	0.7	94.2	70.6	260
	0.7	96.4	71.0	276

Table B16: Electric and Magnetic field measurements

SECOND RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	50.1	71.4	86.2
	0.8	42.6	67.2	90.6
	0.8	46.7	69.4	84.7
1.0	0.6	49.6	65.7	82.1
	0.6	52.7	72.6	76.9
	0.8	48.2	62.1	80.4
1.5	1.0	47.4	58.2	83.7
	1.0	43.9	54.9	86.9
	1.2	42.6	56.2	75.6
1.6	0.8	52.0	61.0	72.8
	0.8	52.0	55.7	68.2
	1.0	49.7	56.9	61.7
1.7	1.0	46.8	53.1	65.3
	1.2	47.7	58.6	62.1
	1.2	40.6	50.7	67.4

Table B17: Electric and Magnetic field measurements

THIRD RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.4	54.6	56.4	61.2
	0.2	59.1	50.2	66.4
	0.2	52.8	50.2	68.1
1.0	0.8	52.1	52.1	57.3
	0.6	56.4	56.7	62.1
	0.6	53.7	53.6	65.7
1.5	0.8	47.5	54.0	55.8
	0.8	50.8	58.2	52.9
	0.8	45.2	56.9	59.5
1.6	1.2	55.2	47.1	59.0
	1.2	51.9	52.4	64.2
	0.8	49.7	50.6	59.8
1.7	0.8	42.0	49.0	58.7
	0.8	46.8	56.9	62.1
	1.0	40.7	53.7	60.9

Table B18: Electric and Magnetic field measurements

FOURTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	52.1	32.4	66.3
	0.8	49.7	36.4	64.2
	0.6	47.2	34.7	69.7
1.0	0.9	44.4	40.6	65.2
	1.2	46.8	42.9	70.2
	1.2	46.8	40.1	62.7
1.5	1.1	45.3	49.6	56.7
	1.2	50.1	50.4	59.6
	1.2	48.6	46.2	65.9
1.6	1.1	55.6	44.1	67.9
	0.8	52.7	47.5	67.9
	0.7	56.1	49.3	60.6
1.7	1.2	55.2	50.3	70.1
	1.2	59.4	48.7	67.2
	1.2	53.6	52.6	62.5

Table B19: Electric and Magnetic field measurements

FIFTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	1.0	44.3	33.2	57.5
	1.2	56.7	31.9	54.2
	1.2	42.5	37.2	54.2
1.0	0.8	44.1	30.4	48.3
	0.6	40.8	39.2	52.8
	0.6	49.1	33.7	49.0
1.5	1.2	46.4	33.6	50.2
	1.0	44.7	36.2	57.2
	1.0	50.6	36.2	55.8
1.6	1.2	52.5	34.0	50.4
	1.2	54.6	30.8	56.7
	1.4	48.9	36.2	51.2
1.7	1.0	48.3	32.1	47.9
	1.0	40.7	32.9	50.4
	1.0	49.1	34.0	52.9

Table B20: Electric and Magnetic field measurements

SIXTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	1.2	49.2	32.4	57.1
	1.0	43.1	37.2	63.8
	1.2	44.6	37.2	56.4
1.0	1.4	52.4	30.1	60.3
	1.2	40.5	38.4	67.2
	1.2	47.2	32.7	55.9
1.5	0.6	51.6	34.6	48.2
	0.8	54.5	30.4	50.5
	0.9	48.1	33.7	52.1
1.6	1.1	45.7	34.1	42.6
	1.2	52.4	39.0	49.2
	1.1	47.2	39.4	44.7
1.7	1.1	42.9	33.8	44.2
	1.2	44.0	37.7	44.2
	1.2	46.9	35.2	46.3

Table B21: Electric and Magnetic field measurements

SEVENTH RACK AC NEARBY

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	3.7	43.2	30.2	57.3
	3.9	42.7	34.3	54.7
	3.9	40.1	37.1	59.2
1.0	3.5	37.7	39.6	52.1
	3.7	44.9	32.5	54.7
	3.5	48.1	35.9	54.7
1.5	3.3	40.9	28.5	60.0
	3.3	45.7	33.2	58.5
	3.7	43.8	26.8	55.2
1.6	3.6	58.3	22.6	47.8
	3.6	55.2	28.2	50.1
	3.6	52.9	28.5	54.9
1.7	3.7	44.3	26.0	53.8
	3.9	49.2	22.7	49.2
	4.0	40.6	18.9	52.2

Table B22: Electric and Magnetic field measurements

ROW 4 (FIRST RACK) AC NEARBY

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	3.9	33.4	36.3	43.2
	3.4	37.9	32.1	47.5
	3.2	32.6	34.8	44.7
1.0	2.2	39.0	30.2	45.7
	2.9	40.7	35.2	42.1
	2.8	37.2	33.0	48.3
1.5	2.8	37.1	26.3	56.9
	3.0	32.5	30.4	52.1
	3.2	30.2	34.7	49.3
1.6	3.4	37.1	30.1	40.7
	3.4	35.8	33.5	44.1
	3.1	39.4	36.2	42.6
1.7	5.0	40.2	33.0	55.5
	4.7	44.2	33.0	48.7
	4.9	38.4	35.3	52.4

Table B23: Electric and Magnetic field measurements

SECOND RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	2.6	38.2	33.4	45.7
	2.6	33.7	36.1	50.2
	2.6	39.2	36.5	48.4
1.0	2.6	34.5	24.7	47.2
	2.8	36.2	30.4	48.6
	2.6	36.2	28.2	54.2
1.5	3.0	37.1	30.1	40.1
	3.2	40.4	36.9	59.4
	3.2	45.2	39.2	44.3
1.6	3.4	37.1	22.8	49.6
	3.1	44.0	32.6	44.7
	3.2	37.4	30.5	44.7
1.7	3.8	38.6	30.1	50.2
	3.4	43.7	26.7	48.2
	3.4	44.1	29.1	40.5

Table B24: Electric and Magnetic field measurements

THIRD RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	3.2	35.2	22.4	47.9
	2.9	32.7	32.4	50.2
	2.7	36.5	26.7	48.5
1.0	2.7	32.4	30.1	48.2
	2.4	33.0	29.4	44.3
	2.4	36.5	33.7	46.1
1.5	2.2	40.1	32.4	49.3
	2.2	44.7	30.3	42.2
	2.2	40.9	34.7	46.3
1.6	2.2	36.3	32.1	52.1
	2.6	48.9	29.5	49.0
	2.6	45.2	27.1	47.3
1.7	3.0	34.2	33.2	49.7
	2.9	35.2	30.2	54.3
	2.9	45.5	35.5	52.1

Table B25: Electric and Magnetic field measurements

FOURTH RACK LIGHT BULB NEARBY

HEIGHT	E(V/M)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.4	48.5	18.4	56.7
	0.6	42.7	22.6	53.7
	0.6	44.8	27.5	57.2
1.0	1.7	40.1	24.4	53.6
	1.4	43.7	28.3	55.4
	1.2	44.7	24.5	59.2
1.5	2.0	44.3	30.1	60.7
	2.9	44.0	28.7	58.3
	3.2	47.4	35.3	52.5
1.6	3.5	47.1	39.4	49.8
	3.8	45.3	33.1	53.2
	4.2	42.7	30.6	50.9
1.7	7.5	47.7	40.4	57.6
	5.5	43.3	37.8	55.2
	4.2	47.9	39.0	54.6

Table B26: Electric and Magnetic field measurements

FIFTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.8	33.4	37.6	49.0
	1.2	36.2	33.0	53.6
	1.0	34.7	33.0	52.7
1.0	1.9	32.1	38.2	52.1
	2.2	36.4	34.6	55.7
	2.2	31.7	32.5	55.9
1.5	2.2	32.4	34.8	55.2
	1.8	37.6	36.7	52.6
	1.2	34.9	38.2	50.8
1.6	0.8	33.0	40.5	53.7
	0.8	38.2	34.9	49.7
	1.2	36.9	39.5	52.9
1.7	2.0	34.4	42.1	55.0
	1.7	39.0	44.7	58.3
	1.7	35.4	43.6	54.9

Table B27: Electric and Magnetic field measurements

SIXTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.7	36.2	37.2	48.2
	0.7	39.5	34.5	49.0
	0.7	43.1	38.2	53.7
1.0	0.6	33.4	33.5	50.3
	0.9	36.0	30.7	55.7
	0.9	39.3	35.6	56.4
1.5	1.2	33.8	39.0	54.2
	1.4	35.4	41.5	52.2
	1.2	38.5	38.4	50.7
1.6	1.0	40.1	45.2	53.1
	0.8	44.5	42.7	55.7
	0.8	43.1	40.9	59.2
1.7	0.8	38.2	44.7	49.7
	1.2	42.8	49.4	53.6
	1.2	39.5	47.7	50.5

Table B28: Electric and Magnetic field measurements

SEVENTH RACK

HEIGHT(m)	E(V/m)	B_X(nT)	B_y(nT)	B_z(nT)
0.6	0.4	43.2	40.2	54.3
	0.4	46.4	44.2	57.5
	0.4	47.1	47.8	55.2
1.0	0.3	30.2	36.7	57.8
	0.6	40.3	34.8	59.2
	0.2	37.7	35.1	54.1
1.5	0.4	35.4	33.0	44.4
	0.4	41.2	35.3	40.7
	0.6	38.5	37.9	44.7
1.6	0.4	40.7	44.3	49.1
	0.6	42.1	42.2	49.4
	0.6	42.1	45.7	46.3
1.7	0.6	33.4	42.1	49.1
	0.6	37.3	47.9	50.1
	0.6	34.6	44.2	43.6

Table B29: Mean electric and magnetic fields with their errors.

First Row (First Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	4.23E-03	8.21E-04	3.77E-02	7.40E-03	3.54E-02	4.34E-03	5.82E-02	3.24E-03
1.0	4.40E-03	1.17E-03	3.89E-02	6.30E-03	2.81E-02	3.83E-03	5.16E-02	4.22E-03
1.5	2.70E-03	6.95E-04	3.68E-02	3.42E-03	2.35E-02	7.08E-03	4.70E-02	1.02E-02
1.6	4.20E-03	1.80E-03	4.27E-02	5.69E-03	2.23E-02	2.95E-03	5.04E-02	8.43E-03
1.7	6.03E-03	7.54E-04	4.63E-02	1.42E-02	2.68E-02	3.64E-03	4.90E-02	3.93E-03

Table B30: Mean electric and magnetic fields with their errors.

First Row (Second Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	3.30E-03	3.11E-04	3.56E-02	2.95E-03	2.08E-02	4.06E-03	4.84E-02	3.92E-03
1.0	3.23E-03	9.28E-04	3.87E-02	1.91E-03	2.77E-02	5.99E-03	5.04E-02	6.38E-03
1.5	3.30E-03	1.14E-03	4.21E-02	4.65E-03	2.18E-02	5.41E-03	5.60E-02	4.30E-03
1.6	3.93E-03	9.97E-04	3.79E-02	7.06E-03	2.94E-02	5.58E-03	5.13E-02	4.55E-03
1.7	3.93E-03	1.45E-04	3.71E-02	3.46E-03	2.66E-02	8.04E-03	5.04E-02	4.27E-03

Table B31: Mean electric and magnetic fields with their errors.

First Row (Third Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.33E-03	2.96E-04	3.31E-02	2.16E-03	2.32E-02	5.26E-03	4.18E-02	4.60E-03
1.0	1.40E-03	5.77E-05	4.08E-02	1.95E-03	2.32E-02	6.82E-03	4.53E-02	7.13E-03
1.5	1.80E-03	8.02E-04	4.34E-02	3.89E-03	2.14E-02	4.97E-03	4.77E-02	7.71E-03
1.6	1.27E-03	5.36E-04	4.23E-02	4.92E-03	2.62E-02	4.85E-03	4.61E-02	7.93E-03
1.7	6.67E-04	1.45E-04	4.16E-02	4.82E-03	2.66E-02	8.27E-03	5.72E-02	3.53E-03

Table B32: Mean electric and magnetic fields with their errors.

First Row (Fourth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	7.33E-04	1.45E-04	4.50E-02	4.80E-03	2.36E-02	7.47E-03	4.57E-02	4.93E-03
1.0	1.10E-03	5.77E-05	4.56E-02	3.20E-03	2.89E-02	8.31E-03	3.78E-02	2.65E-03
1.5	1.53E-03	3.57E-04	4.34E-02	2.05E-03	2.85E-02	5.49E-03	3.52E-02	2.33E-03
1.6	2.77E-03	2.47E-04	4.69E-02	2.19E-03	2.94E-02	5.93E-03	4.28E-02	5.40E-03
1.7	2.70E-03	5.77E-05	4.98E-02	8.21E-04	4.16E-02	4.00E-03	4.93E-02	9.14E-03

Table B33: Mean electric and magnetic fields with their errors.

First Row (Fifth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	5.00E-04	5.77E-05	4.32E-02	7.50E-03	1.92E-02	4.80E-03	4.59E-02	5.09E-03
1.0	8.67E-04	1.45E-04	4.50E-02	2.45E-03	2.90E-02	5.50E-03	4.69E-02	1.52E-03
1.5	2.00E-03	2.08E-04	4.04E-02	2.02E-03	2.33E-02	5.27E-03	4.90E-02	4.99E-03
1.6	2.00E-03	2.38E-04	4.14E-02	3.30E-03	3.31E-02	5.58E-03	5.23E-02	3.35E-03
1.7	2.13E-03	3.57E-04	4.40E-02	5.04E-03	3.53E-02	1.99E-03	5.15E-02	4.99E-03

Table B34: Mean electric and magnetic fields with their errors.

First Row (Sixth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	8.00E-04	5.77E-05	3.77E-02	3.47E-03	3.59E-02	4.02E-03	4.21E-02	3.12E-03
1.0	8.67E-04	1.45E-04	3.73E-02	9.56E-03	3.98E-02	1.74E-03	3.38E-02	3.08E-03
1.5	6.00E-04	2.08E-04	4.27E-02	4.16E-03	3.40E-02	4.45E-03	3.64E-02	3.06E-03
1.6	8.67E-04	1.45E-04	4.01E-02	1.79E-03	2.95E-02	9.39E-03	3.80E-02	2.89E-03
1.7	9.33E-04	1.45E-04	4.33E-02	3.49E-03	3.26E-02	5.59E-03	4.18E-02	4.55E-03

Table B35: Mean electric and magnetic fields with their errors.

First Row (Seventh Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.67E-04	8.82E-05	4.49E-02	2.74E-03	2.78E-02	3.62E-03	4.42E-02	3.70E-03
1.0	5.00E-04	5.77E-05	3.64E-02	3.92E-03	2.67E-02	7.23E-03	4.30E-02	4.11E-03
1.5	2.33E-04	8.82E-05	3.57E-02	4.08E-03	2.79E-02	1.17E-02	4.34E-02	3.28E-03
1.6	3.67E-04	1.45E-04	3.87E-02	2.51E-03	2.48E-02	3.57E-03	4.71E-02	2.53E-03
1.7	8.00E-04	2.08E-04	3.72E-02	2.66E-03	3.72E-02	5.00E-03	4.94E-02	1.33E-03

Table B36: Mean electric and magnetic fields with their errors.

Second Row (First Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	1.33E-04	8.82E-05	1.13E-01	1.15E-02	6.38E-02	1.10E-02	1.82E-01	7.89E-03
1.0	2.00E-04	5.77E-05	1.10E-01	1.33E-02	8.55E-02	4.88E-03	2.52E-01	1.56E-02
1.5	2.00E-04	1.29E-04	1.11E-01	8.70E-03	9.62E-02	1.59E-03	2.64E-01	1.21E-02
1.6	3.67E-04	3.38E-04	1.16E-01	5.18E-03	9.99E-02	1.27E-03	2.69E-01	2.73E-03
1.7	2.00E-04	5.77E-05	1.26E-01	3.56E-03	1.04E-01	4.25E-03	2.66E-01	6.79E-03

Table B37: Mean electric and magnetic fields with their errors.

Second Row (Second Rack)

Height (m)	E_m/kVm^{-1}	u	B_X(μT)$_m$	u	B_y(μT)$_m$	u	B_z(μT)$_m$	U
0.6	1.67E-04	8.82E-05	8.03E-02	1.02E-02	3.74E-02	3.99E-03	9.10E-02	3.20E-03
1.0	1.33E-04	8.82E-05	8.70E-02	4.85E-03	3.91E-02	3.14E-03	8.75E-02	3.12E-03
1.5	1.00E-04	5.77E-05	8.88E-02	2.38E-03	4.11E-02	3.82E-03	7.97E-02	3.01E-03
1.6	1.33E-04	8.82E-05	9.02E-02	2.23E-03	4.87E-02	1.56E-03	7.93E-02	3.60E-03
1.7	1.67E-04	8.82E-05	9.12E-02	4.02E-03	5.25E-02	3.59E-03	8.51E-02	6.15E-03

Table B38: Mean electric and magnetic fields with their errors.

Second Row (Third Rack)

Height (m)	E_m/kVm^{-1}	u	B_X(μT)$_m$	u	B_y(μT)$_m$	u	B_z(μT)$_m$	U
0.6	5.33E-04	3.57E-04	7.56E-02	4.08E-03	3.27E-02	2.33E-03	5.30E-02	3.88E-03
1.0	6.33E-04	4.10E-04	6.82E-02	4.17E-03	3.44E-02	2.78E-03	5.52E-02	4.54E-03
1.5	8.67E-04	3.38E-04	6.80E-02	6.99E-03	3.15E-02	2.13E-03	6.79E-02	2.91E-03
1.6	1.33E-03	2.73E-04	7.14E-02	3.04E-03	3.19E-02	3.37E-03	6.99E-02	4.35E-03
1.7	1.27E-03	1.45E-04	6.84E-02	2.99E-03	3.46E-02	2.95E-03	6.74E-02	2.08E-03

Table B39: Mean electric and magnetic fields with their errors.

Second Row (Fourth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	7.67E-04	3.38E-04	5.86E-02	1.60E-03	2.15E-02	3.19E-03	6.58E-02	1.85E-03
1.0	2.33E-04	8.82E-05	5.51E-02	3.00E-03	2.34E-02	2.95E-03	6.23E-02	4.07E-03
1.5	3.33E-04	1.45E-04	6.22E-02	5.38E-03	2.09E-02	3.48E-03	6.33E-02	3.93E-03
1.6	1.00E-03	5.77E-05	5.46E-02	2.73E-03	2.33E-02	3.51E-03	5.70E-02	2.49E-03
1.7	1.97E-03	2.96E-04	6.35E-02	4.34E-03	1.93E-02	3.57E-03	5.38E-02	3.48E-03

Table B40: Mean electric and magnetic fields with their errors.

Second Row (Fifth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	4.00E-04	5.77E-05	5.48E-02	2.16E-03	2.27E-02	5.43E-03	6.00E-02	2.91E-03
1.0	9.67E-04	2.96E-04	4.87E-02	1.96E-03	2.20E-02	2.95E-03	5.47E-02	1.87E-03
1.5	1.50E-03	2.08E-04	4.71E-02	3.11E-03	2.54E-02	3.88E-03	5.80E-02	3.25E-03
1.6	2.03E-03	3.38E-04	4.49E-02	4.34E-03	2.67E-02	4.39E-03	6.16E-02	2.63E-03
1.7	1.93E-03	5.36E-04	4.71E-02	2.44E-03	2.36E-02	6.48E-03	5.62E-02	1.30E-03

Table B41: Mean electric and magnetic fields with their errors.

Second Row (Sixth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	8.67E-04	1.45E-04	4.69E-02	2.15E-03	2.11E-02	4.87E-03	5.89E-02	4.39E-03
1.0	1.00E-03	5.77E-05	4.54E-02	5.01E-03	2.33E-02	4.78E-03	5.79E-02	1.47E-03
1.5	8.00E-04	2.08E-04	4.41E-02	3.60E-03	2.23E-02	4.91E-03	6.13E-02	3.76E-03
1.6	1.13E-03	1.45E-04	4.11E-02	2.68E-03	2.54E-02	4.32E-03	5.77E-02	1.62E-03
1.7	1.20E-03	5.77E-05	4.37E-02	3.17E-03	2.37E-02	1.70E-03	5.56E-02	4.23E-03

Table B42: Mean electric and magnetic fields with their errors.

Second Row (Seventh Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.00E-04	1.29E-04	4.77E-02	3.47E-03	2.30E-02	4.35E-03	5.91E-02	5.16E-03
1.0	2.33E-04	8.82E-05	5.68E-02	3.18E-03	3.14E-02	3.36E-03	5.72E-02	3.09E-03
1.5	2.00E-04	1.29E-04	3.76E-02	3.64E-03	2.40E-02	4.63E-03	4.82E-02	4.44E-03
1.6	1.00E-04	5.77E-05	3.63E-02	6.94E-03	3.01E-02	1.41E-03	5.55E-02	5.67E-03
1.7	1.67E-04	8.82E-05	3.76E-02	4.68E-03	2.15E-02	3.86E-03	5.75E-02	2.26E-03

Table B43: Mean electric and magnetic fields with their errors.

Third Row (First Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	7.33E-04	1.86E-04	4.49E-02	2.53E-03	4.56E-02	5.99E-03	1.73E-01	3.81E-03
1.0	7.00E-04	2.08E-04	4.39E-02	4.37E-03	6.63E-02	4.12E-03	1.76E-01	1.23E-03
1.5	8.00E-04	5.77E-05	4.38E-02	3.34E-03	7.91E-02	4.35E-03	2.14E-01	4.41E-03
1.6	7.67E-04	1.45E-04	6.32E-02	8.29E-03	7.67E-02	3.06E-03	2.43E-01	7.08E-03
1.7	6.67E-04	8.82E-05	9.61E-02	1.99E-03	6.92E-02	3.14E-03	2.74E-01	1.57E-02

Table B44: Mean electric and magnetic fields with their errors.

Third Row (Second Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	8.00E-04	5.77E-05	4.65E-02	4.34E-03	6.93E-02	2.43E-03	8.72E-02	3.54E-03
1.0	6.67E-04	1.45E-04	5.02E-02	2.66E-03	6.68E-02	6.16E-03	7.98E-02	3.06E-03
1.5	1.07E-03	1.45E-04	4.46E-02	2.87E-03	5.64E-02	1.92E-03	8.21E-02	6.73E-03
1.6	8.67E-04	1.45E-04	5.12E-02	1.53E-03	5.79E-02	3.21E-03	6.76E-02	6.44E-03
1.7	1.13E-03	1.45E-04	4.50E-02	4.46E-03	5.41E-02	4.68E-03	6.49E-02	3.08E-03

Table B45: Mean electric and magnetic fields with their errors.

Third Row (Third Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.67E-04	1.45E-04	5.55E-02	3.75E-03	5.23E-02	4.13E-03	6.52E-02	4.15E-03
1.0	6.67E-04	1.45E-04	5.41E-02	2.51E-03	5.41E-02	2.71E-03	6.17E-02	4.87E-03
1.5	8.00E-04	5.77E-05	4.78E-02	3.25E-03	5.64E-02	2.48E-03	5.61E-02	3.82E-03
1.6	1.07E-03	2.73E-04	5.23E-02	3.20E-03	5.00E-02	3.11E-03	6.10E-02	3.23E-03
1.7	8.67E-04	1.45E-04	4.32E-02	3.71E-03	5.32E-02	4.59E-03	6.06E-02	1.99E-03

Table B46: Mean electric and magnetic fields with their errors.

Third Row (Fourth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	7.33E-04	1.45E-04	4.97E-02	2.83E-03	3.45E-02	2.32E-03	6.67E-02	3.21E-03
1.0	1.10E-03	2.08E-04	4.60E-02	1.60E-03	4.12E-02	1.73E-03	6.60E-02	4.41E-03
1.5	1.17E-03	8.82E-05	4.80E-02	2.84E-03	4.87E-02	2.58E-03	6.07E-02	5.43E-03
1.6	8.67E-04	2.47E-04	5.48E-02	2.12E-03	4.70E-02	3.05E-03	6.55E-02	4.87E-03
1.7	1.20E-03	5.77E-05	5.61E-02	3.46E-03	5.05E-02	2.26E-03	6.66E-02	4.43E-03

Table B47: Mean electric and magnetic fields with their errors.

Third Row (Fifth Rack)

Height (m)	E_m/kVm^{-1}	u	B_X(μT)$_m$	u	B_y(μT)$_m$	u	B_z(μT)$_m$	U
0.6	1.13E-03	1.45E-04	4.78E-02	8.93E-03	3.41E-02	3.19E-03	5.53E-02	2.20E-03
1.0	6.67E-04	1.45E-04	4.47E-02	4.83E-03	3.44E-02	5.13E-03	5.00E-02	2.80E-03
1.5	1.07E-03	1.45E-04	4.72E-02	3.51E-03	3.53E-02	1.73E-03	5.44E-02	4.28E-03
1.6	1.27E-03	1.45E-04	5.20E-02	3.33E-03	3.37E-02	3.14E-03	5.28E-02	3.96E-03
1.7	1.00E-03	5.77E-05	4.60E-02	5.35E-03	3.30E-02	1.10E-03	5.04E-02	2.89E-03

Table B48: Mean electric and magnetic fields with their errors.

Third Row (Sixth Rack)

Height (m)	E_m/kVm^{-1}	u	B_X(μT)$_m$	u	B_y(μT)$_m$	u	B_z(μT)$_m$	U
0.6	1.13E-03	1.45E-04	4.56E-02	3.67E-03	3.56E-02	3.20E-03	5.91E-02	4.72E-03
1.0	1.27E-03	1.45E-04	4.67E-02	6.89E-03	3.37E-02	4.90E-03	6.11E-02	6.58E-03
1.5	7.67E-04	1.86E-04	5.14E-02	3.70E-03	3.29E-02	2.55E-03	5.03E-02	2.26E-03
1.6	1.13E-03	8.82E-05	4.84E-02	4.06E-03	3.75E-02	3.41E-03	4.55E-02	3.89E-03
1.7	1.17E-03	8.82E-05	4.46E-02	2.39E-03	3.56E-02	2.28E-03	4.49E-02	1.40E-03

Table B49: Mean electric and magnetic fields with their errors.

Third Row (Seventh Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	3.83E-03	1.45E-04	4.20E-02	1.92E-03	3.39E-02	4.01E-03	5.71E-02	2.61E-03
1.0	3.57E-03	1.45E-04	4.36E-02	6.15E-03	3.60E-02	4.10E-03	5.38E-02	1.73E-03
1.5	3.43E-03	2.73E-04	4.35E-02	2.79E-03	2.95E-02	3.83E-03	5.79E-02	2.84E-03
1.6	3.60E-03	5.77E-05	5.55E-02	3.13E-03	2.64E-02	3.84E-03	5.09E-02	4.18E-03
1.7	3.87E-03	1.86E-04	4.47E-02	4.98E-03	2.25E-02	4.10E-03	5.17E-02	2.70E-03

Table B50: Mean electric and magnetic fields with their errors.

Fourth Row (First Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	3.50E-03	4.20E-04	3.46E-02	3.30E-03	3.44E-02	2.46E-03	4.51E-02	2.52E-03
1.0	2.63E-03	4.41E-04	3.90E-02	2.02E-03	3.28E-02	2.89E-03	4.54E-02	3.60E-03
1.5	3.00E-03	2.38E-04	3.33E-02	4.06E-03	3.05E-02	4.85E-03	5.28E-02	4.44E-03
1.6	3.30E-03	2.08E-04	3.74E-02	2.11E-03	3.33E-02	3.53E-03	4.25E-02	1.97E-03
1.7	4.87E-03	1.86E-04	4.09E-02	3.43E-03	3.38E-02	1.53E-03	5.22E-02	3.93E-03

Table B51: Mean electric and magnetic fields with their errors.

Fourth Row (Second Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.60E-03	5.77E-05	3.70E-02	3.38E-03	3.53E-02	1.95E-03	4.81E-02	2.62E-03
1.0	2.67E-03	1.45E-04	3.56E-02	1.13E-03	2.78E-02	3.32E-03	5.00E-02	4.28E-03
1.5	3.13E-03	1.45E-04	4.09E-02	4.70E-03	3.54E-02	5.46E-03	4.79E-02	1.17E-02
1.6	3.23E-03	1.86E-04	3.95E-02	4.50E-03	2.86E-02	5.96E-03	4.63E-02	3.27E-03
1.7	3.53E-03	2.73E-04	4.21E-02	3.54E-03	2.86E-02	2.02E-03	4.63E-02	5.91E-03

Table B52: Mean electric and magnetic fields with their errors.

Fourth Row (Third Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	2.93E-03	2.96E-04	3.48E-02	2.23E-03	2.72E-02	5.79E-03	4.89E-02	1.38E-03
1.0	2.50E-03	2.08E-04	3.40E-02	2.56E-03	3.11E-02	2.66E-03	4.62E-02	2.25E-03
1.5	2.20E-03	5.77E-05	4.19E-02	2.84E-03	3.25E-02	2.54E-03	4.59E-02	4.12E-03
1.6	2.47E-03	2.73E-04	4.35E-02	7.48E-03	2.96E-02	2.89E-03	4.95E-02	2.81E-03
1.7	2.93E-03	8.82E-05	3.83E-02	7.22E-03	3.30E-02	3.07E-03	5.20E-02	2.66E-03

Table B53: Mean electric and magnetic fields with their errors.

Fourth Row (Fourth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	5.33E-04	1.45E-04	4.53E-02	3.39E-03	2.28E-02	5.26E-03	5.59E-02	2.19E-03
1.0	1.43E-03	2.96E-04	4.28E-02	2.79E-03	2.57E-02	2.57E-03	5.61E-02	3.30E-03
1.5	2.70E-03	7.23E-04	4.52E-02	2.17E-03	3.14E-02	4.02E-03	5.72E-02	4.87E-03
1.6	3.83E-03	4.10E-04	4.50E-02	2.55E-03	3.44E-02	5.24E-03	5.13E-02	2.00E-03
1.7	5.73E-03	1.92E-03	4.63E-02	3.00E-03	3.91E-02	1.50E-03	5.58E-02	1.83E-03

Table B54: Mean electric and magnetic fields with their errors.

Fourth Row (Fifth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	1.00E-03	2.38E-04	3.48E-02	1.62E-03	3.45E-02	3.07E-03	5.18E-02	2.82E-03
1.0	2.10E-03	2.08E-04	3.34E-02	3.01E-03	3.51E-02	3.33E-03	5.46E-02	2.47E-03
1.5	1.73E-03	5.84E-04	3.50E-02	3.00E-03	3.66E-02	1.97E-03	5.29E-02	2.55E-03
1.6	9.33E-04	2.73E-04	3.60E-02	3.13E-03	3.83E-02	3.45E-03	5.21E-02	2.44E-03
1.7	1.80E-03	2.08E-04	3.63E-02	2.79E-03	4.35E-02	1.51E-03	5.61E-02	2.23E-03

Table B55: Mean electric and magnetic fields with their errors.

Fourth Row (Sixth Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	7.00E-04	5.77E-05	3.96E-02	3.99E-03	3.66E-02	2.21E-03	5.03E-02	3.43E-03
1.0	8.00E-04	2.08E-04	3.62E-02	3.41E-03	3.33E-02	2.84E-03	5.41E-02	3.86E-03
1.5	1.27E-03	1.45E-04	3.59E-02	2.76E-03	3.96E-02	1.90E-03	5.24E-02	2.03E-03
1.6	8.67E-04	1.45E-04	4.26E-02	2.60E-03	4.29E-02	2.49E-03	5.60E-02	3.54E-03
1.7	1.07E-03	2.73E-04	4.02E-02	2.74E-03	4.73E-02	2.75E-03	5.13E-02	2.38E-03

Table B56: Mean electric and magnetic fields with their errors.

Fourth Row (Seventh Rack)

Height (m)	E_m/kVm^{-1}	u	$B_X(\mu T)_m$	u	$B_y(\mu T)_m$	u	$B_z(\mu T)_m$	U
0.6	4.00E-04	5.77E-05	4.56E-02	2.40E-03	4.41E-02	4.39E-03	5.57E-02	1.91E-03
1.0	3.67E-04	2.47E-04	3.61E-02	6.06E-03	3.55E-02	1.18E-03	5.70E-02	3.04E-03
1.5	4.67E-04	1.45E-04	3.84E-02	3.35E-03	3.54E-02	2.83E-03	4.33E-02	2.57E-03
1.6	5.33E-04	1.45E-04	4.16E-02	9.35E-04	4.41E-02	2.03E-03	4.83E-02	1.98E-03
1.7	6.00E-04	5.77E-05	3.51E-02	2.31E-03	4.47E-02	3.39E-03	4.76E-02	4.04E-03

Table A2: Resultant field, magnetic flux density and induced current density.

First Row (First Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	7.79E-02	9.17E-03	9.73E-08	6.11E-07
1.0	7.05E-02	8.50E-03	8.81E-08	5.53E-07
1.5	6.42E-02	1.29E-02	8.02E-08	5.04E-07
1.6	6.97E-02	1.06E-02	8.71E-08	2.74E-07
1.7	7.25E-02	1.52E-02	9.07E-08	2.85E-07

Table B57: Resultant field, magnetic flux density and induced current density.

First Row (Second Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	6.36E-02	6.37E-03	7.95E-08	4.99E-07
1.0	6.93E-02	8.96E-03	8.66E-08	5.44E-07
1.5	7.34E-02	8.33E-03	9.17E-08	5.76E-07
1.6	7.02E-02	1.01E-02	8.78E-08	2.76E-07
1.7	6.80E-02	9.74E-03	8.5E-08	2.67E-07

Table B58: Resultant field, magnetic flux density and induced current density.

First Row (Third Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	5.81E-02	7.31E-03	7.27E-08	4.56E-07
1.0	6.52E-02	1.01E-02	8.15E-08	5.12E-07
1.5	6.79E-02	9.96E-03	8.49E-08	5.33E-07
1.6	6.78E-02	1.05E-02	8.48E-08	2.66E-07
1.7	7.56E-02	1.02E-02	9.45E-08	2.97E-07

Table B59: Resultant field, magnetic flux density and induced current density.

First Row (Fourth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	6.83E-02	1.02E-02	8.54E-08	5.36E-07
1.0	6.59E-02	9.29E-03	8.24E-08	5.17E-07
1.5	6.27E-02	6.31E-03	7.84E-08	4.92E-07
1.6	7.00E-02	8.31E-03	8.75E-08	2.75E-07
1.7	8.15E-02	1.00E-02	1.02E-07	3.2E-07

Table B60: Resultant field, magnetic flux density and induced current density.

First Row (Fifth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	6.59E-02	1.03E-02	8.24E-08	5.17E-07
1.0	7.12E-02	6.21E-03	8.9E-08	5.59E-07
1.5	6.76E-02	7.53E-03	8.46E-08	5.31E-07
1.6	7.45E-02	7.30E-03	9.31E-08	2.92E-07
1.7	7.64E-02	7.37E-03	9.55E-08	3E-07

Table B61: Resultant field, magnetic flux density and induced current density.

First Row (Sixth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	6.70E-02	6.16E-03	8.37E-08	5.26E-07
1.0	6.42E-02	1.02E-02	8.02E-08	5.04E-07
1.5	6.56E-02	6.82E-03	8.2E-08	5.15E-07
1.6	6.26E-02	9.99E-03	7.83E-08	2.46E-07
1.7	6.84E-02	8.01E-03	8.56E-08	2.69E-07

Table B62: Resultant field, magnetic flux density and induced current density.

First Row (Seventh Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	6.89E-02	5.86E-03	8.61E-08	5.41E-07
1.0	6.23E-02	9.19E-03	7.79E-08	4.89E-07
1.5	6.27E-02	1.28E-02	7.84E-08	4.93E-07
1.6	6.58E-02	5.04E-03	8.23E-08	2.58E-07
1.7	7.22E-02	5.82E-03	9.02E-08	2.83E-07

Table B63: Resultant field, magnetic flux density and induced current density.

Second Row (First Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	2.24E-01	1.78E-02	2.79E-07	1.75E-06
1.0	2.88E-01	2.11E-02	3.6E-07	2.26E-06
1.5	3.02E-01	1.50E-02	3.78E-07	2.37E-06
1.6	3.10E-01	5.99E-03	3.87E-07	1.21E-06
1.7	3.12E-01	8.77E-03	3.9E-07	1.23E-06

Table B64: Resultant field, magnetic flux density and current density.

Second Row (Second Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	1.27E-01	1.14E-02	1.59E-07	9.97E-07
1.0	1.29E-01	6.57E-03	1.62E-07	1.02E-06
1.5	1.26E-01	5.41E-03	1.58E-07	9.91E-07
1.6	1.30E-01	4.51E-03	1.62E-07	5.09E-07
1.7	1.35E-01	8.18E-03	1.69E-07	5.31E-07

Table B65: Resultant field, magnetic flux density and induced current density.

Second Row (Third Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Current density (mA/m^2)
0.6	9.79E-02	6.09E-03	1.22E-07	7.69E-07
1.0	9.42E-02	6.76E-03	1.18E-07	7.40E-07
1.5	1.01E-01	7.87E-03	1.26E-07	7.94E-07
1.6	1.05E-01	6.29E-03	1.31E-07	4.12E-07
1.7	1.02E-01	4.69E-03	1.28E-07	4.01E-07

Table B66: Resultant field, magnetic flux density and induced current density.

Second Row (Fourth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	9.07E-02	4.02E-03	1.13E-07	7.12E-07
1.0	8.64E-02	5.85E-03	1.08E-07	6.78E-07
1.5	9.12E-02	7.52E-03	1.14E-07	7.16E-07
1.6	8.23E-02	5.10E-03	1.03E-07	3.23E-07
1.7	8.54E-02	6.61E-03	1.07E-07	3.35E-07

Table B67: Resultant field, magnetic flux density and induced current density.

Second Row (Fifth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	8.44E-02	6.53E-03	1.05E-07	6.62E-07
1.0	7.65E-02	4.01E-03	9.56E-08	6.00E-07
1.5	7.89E-02	5.94E-03	9.86E-08	6.19E-07
1.6	8.08E-02	6.71E-03	1.01E-07	3.17E-07
1.7	7.70E-02	7.05E-03	9.63E-08	3.02E-07

Table B68: Resultant field, magnetic flux density and induced current density.

Second Row (Sixth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Current density (mA/m^2)
0.6	7.82E-02	6.90E-03	9.77E-08	6.14E-07
1.0	7.72E-02	7.08E-03	9.65E-08	6.06E-07
1.5	7.87E-02	7.16E-03	9.84E-08	6.18E-07
1.6	7.53E-02	5.34E-03	9.41E-08	2.95E-07
1.7	7.46E-02	5.55E-03	9.32E-08	2.93E-07

Table B69: Resultant field, magnetic flux density and induced current density.

Second Row (Seventh Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	7.94E-02	7.59E-03	9.92E-08	6.23E-07
1.0	8.65E-02	5.56E-03	1.08E-07	6.79E-07
1.5	6.57E-02	7.38E-03	8.21E-08	5.16E-07
1.6	7.28E-02	9.07E-03	9.01E-08	2.86E-07
1.7	7.20E-02	6.47E-03	9.02E-08	2.83E-07

Table B70: Resultant field, magnetic flux density and induced current density.

Third Row (First Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	1.84E-01	7.54E-03	2.31E-07	1.45E-06
1.0	1.93E-01	6.13E-03	2.41E-07	1.52E-06
1.5	2.32E-01	7.04E-03	2.9E-07	1.82E-06
1.6	2.63E-01	1.13E-02	3.28E-07	1.03E-06
1.7	2.98E-01	1.61E-02	3.73E-07	1.17E-06

Table B71: Resultant field, magnetic flux density and induced current density.

Third Row (Second Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	1.21E-01	6.11E-03	1.51E-07	9.47E-07
1.0	1.16E-01	7.37E-03	1.44E-07	9.07E-07
1.5	1.09E-01	7.56E-03	1.36E-07	8.57E-07
1.6	1.03E-01	7.36E-03	1.28E-07	4.03E-07
1.7	9.57E-02	7.16E-03	1.2E-07	3.76E-07

Table B72: Resultant field, magnetic flux density and induced current density.

Third Row (Third Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	1.00E-01	6.95E-03	1.25E-07	7.88E-07
1.0	9.83E-02	6.11E-03	1.23E-07	7.72E-07
1.5	9.28E-02	5.60E-03	1.16E-07	7.29E-07
1.6	9.46E-02	5.51E-03	1.18E-07	3.71E-07
1.7	9.15E-02	6.23E-03	1.14E-07	3.59E-07

Table B73: Resultant field, magnetic flux density and current density.

Third Row (Fourth Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	9.01E-02	4.87E-03	1.13E-07	7.07E-07
1.0	9.04E-02	5.00E-03	1.13E-07	7.10E-07
1.5	9.14E-02	6.65E-03	1.14E-07	7.18E-07
1.6	9.75E-02	6.12E-03	1.22E-07	3.83E-07
1.7	1.01E-01	6.06E-03	1.26E-07	3.95E-07

Table B74: Resultant field, magnetic flux density and induced current density.

Third Row (Fifth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	8.07E-02	9.73E-03	1.01E-07	6.33E-07
1.0	7.54E-02	7.58E-03	9.42E-08	5.92E-07
1.5	8.02E-02	5.80E-03	1.03E-07	6.30E-07
1.6	8.14E-02	6.05E-03	1.02E-07	3.20E-07
1.7	7.58E-02	6.18E-03	9.47E-08	2.98E-07

Table B75: Resultant field, magnetic flux density and induced current density.

Third Row (Sixth Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	8.27E-02	6.78E-03	1.03E-07	6.49E-07
1.0	8.40E-02	1.07E-02	1.05E-07	6.59E-07
1.5	7.91E-02	5.03E-03	9.89E-08	6.21E-07
1.6	7.63E-02	6.58E-03	9.54E-08	2.99E-07
1.7	7.26E-02	3.59E-03	9.08E-08	2.85E-07

Table B76: Resultant field, magnetic flux density and induced current density.

Third Row (Seventh Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	7.86E-02	5.16E-03	9.82E-08	6.17E-07
1.0	7.80E-02	7.59E-03	9.76E-08	6.13E-07
1.5	7.82E-02	5.52E-03	9.77E-08	6.14E-07
1.6	7.98E-02	6.48E-03	9.97E-08	3.13E-07
1.7	7.20E-02	6.99E-03	8.99E-08	2.82E-07

Table B77: Resultant field, magnetic flux density and induced current density.

Fourth Row (First Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	6.64E-02	4.83E-03	8.31E-08	5.22E-07
1.0	6.82E-02	5.04E-03	8.53E-08	5.36E-07
1.5	6.95E-02	7.73E-03	8.68E-08	5.45E-07
1.6	6.57E-02	4.56E-03	8.21E-08	2.58E-07
1.7	7.44E-02	5.44E-03	9.31E-08	2.92E-07

Table B78: Resultant field, magnetic flux density and induced current density.

Fourth Row (Second Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	7.02E-02	4.70E-03	8.78E-08	5.51E-07
1.0	6.74E-02	5.53E-03	8.42E-08	5.29E-07
1.5	7.23E-02	1.37E-02	9.03E-08	5.67E-07
1.6	6.72E-02	8.15E-03	8.41E-08	2.64E-07
1.7	6.88E-02	7.18E-03	8.61E-08	2.70E-07

Table B79: Resultant field, magnetic flux density and induced current density.

Fourth Row (Third Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	6.59E-02	6.36E-03	8.24E-08	5.17E-07
1.0	6.53E-02	4.32E-03	8.16E-08	5.12E-07
1.5	7.01E-02	5.61E-03	8.77E-08	5.51E-07
1.6	7.22E-02	8.50E-03	9.03E-08	2.84E-07
1.7	7.25E-02	8.28E-03	9.07E-08	2.85E-07

Table B80: Resultant field, magnetic flux density and induced current density.

Fourth Row (Fourth Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	7.55E-02	6.63E-03	9.43E-08	5.92E-07
1.0	7.51E-02	5.03E-03	9.39E-08	5.90E-07
1.5	7.94E-02	6.68E-03	9.92E-08	6.23E-07
1.6	7.64E-02	6.16E-03	9.55E-08	3.00E-07
1.7	8.24E-02	3.82E-03	1.03E-07	3.23E-07

Table B81: Resultant field, magnetic flux density and induced current density.

Fourth Row (Fifth Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	7.13E-02	4.47E-03	8.91E-08	5.60E-07
1.0	7.30E-02	5.12E-03	9.12E-08	5.73E-07
1.5	7.32E-02	4.40E-03	9.15E-08	5.75E-07
1.6	7.40E-02	5.26E-03	9.25E-08	2.90E-07
1.7	7.97E-02	3.88E-03	9.97E-08	3.13E-07

Table B82: Resultant field, magnetic flux density and induced current density.

Fourth Row (Sixth Rack)

Height (m)	Resultant (µT)	U	Magnetic flux density (µT)	Induced Current density (mA/m^2)
0.6	7.37E-02	5.71E-03	9.22E-08	5.79E-07
1.0	7.31E-02	5.88E-03	9.14E-08	5.74E-07
1.5	7.49E-02	3.92E-03	9.36E-08	5.88E-07
1.6	8.24E-02	5.05E-03	1.03E-07	3.23E-07
1.7	8.05E-02	4.55E-03	1.01E-07	3.16E-07

Table B83: Resultant field, magnetic flux density and induced current density.

Fourth Row (Seventh Rack)

Height (m)	Resultant (μT)	U	Magnetic flux density (μT)	Induced Current density (mA/m^2)
0.6	8.44E-02	5.36E-03	1.06E-07	6.63E-07
1.0	7.62E-02	6.88E-03	9.53E-08	5.98E-07
1.5	6.78E-02	5.08E-03	8.48E-08	5.33E-07
1.6	7.75E-02	2.99E-03	9.69E-08	3.04E-07
1.7	7.41E-02	5.76E-03	9.27E-08	2.91E-07