

Analysis of Electromagnetic Pollution due to High Voltage Transmission Lines

Aliyu Ozovehe[1] Maina Ibrahim [2] Ali Hamdallah[3]
1. Trifield Technology Limited, Abuja, Nigeria
Tel: +2348022222899 aliyu123oz@gmail.com
2. Physics Programme, Abubakar Tafawa Balewa University, Bauchi, Nigeria
Tel: +60108894322 imaina32@yahoo.com
3.Department of Science and Environmental Education, University of Abuja University, Nigeria
Tel: +234802990670 hamdallah123oz@gmail.com

Abstract
The International Radiation Protection Association (IRPA) recommends measuring the electric field and the magnetic field strength for evaluation of electromagnetic pollution from power lines. This paper, therefore practically examined the fields pollution from 132 kV and 330 kV lines in Bauchi/Gombe areas in Nigeria as a case study. The evaluation is based on the safety limits recommendations of International Committee on Non-Ionizing Radiation Protection (ICNIRP, 1998). In the measurement, Trifield metre was used to measure the fields in the vicinity of the lines with horizontal distance ranging from 0 – 450 m and vertical distance of 1.5 m. In the assessment, general public and occupational exposure levels from the power lines were sampled. For the general public, the highest magnetic flux density and electric field strength measured is 45 mG and 130 V/m which is 4.5 % and 2.6 % of the ICNIRP, 1998 exposure limit. The highest magnetic flux density and electric field strength measured is 100 mG and 130 V/m respectively which correspond to 2 % and 1.3 % of the ICNIRP, 1998 exposure limit for the occupational worker. The result showed that the measured fields are within safety limit.
Keywords: ICNIRP, EMC, Right-of -Way, Safety Distance, Electromagnetic Pollution, Occupational and General Public Exposure.

1.Introduction

A time – varying electric and magnetic fields are induced in the vicinity of alternating current power transmission systems. While electric field is always linked with the presence of charges, a magnetic field always appears when electric current flows. To characterize power line electromagnetic fields, the strength, frequency, and orientation of the electric and magnetic fields have to be determined. Under power lines, the electric field has its major component oriented vertically (perpendicular to the Earth's surface), while the main magnetic field component is horizontal (parallel to the Earth's surface). In the vicinity of transmission lines, the electric field, E and magnetic field, H fields are typically of the order of a few thousands of volts per metre (V/m) and a few hundreds of milligauss (mG), respectively.

High voltage (HV) transmission lines at 50 or 60 Hz are the dominant source of electromagnetic field pollution of extremely low frequency (ELF) in our environment. It has been confirmed that life is not safe under this high HV power lines. Apart from the consequence of electric shock that can happen, the magnetic field created around the wire by the flowing current can have adverse biological effects on human like neurological, cardiovascular disorders and low sperm count in the workers who regularly service the line (Aliyu et al, 2011a and Siaka, 2010).

Hitherto, these HV grids are deployed far away from where there are high human activities. But with increasing growth of our cities and lack of proper enforcement of rules and regulations, home towns have now extended to these grid lines. Therefore, there is need to measure exposure levels in vicinity of the lines for risk assessment.

To mitigate the effect of electromagnetic (EM) pollution from power lines on human beings living/working close to the lines, the authority, Power Holding Company of Nigeria (PHCN) makes it clear that any building constructed along the HV lines must give a right-of-way (RoW) of 15 m and 25 m for 132 kV and 330 kV lines respectively (Aliyu et al, 2011b). Based on this guideline, an attempt is made in this work to measure the magnitude of electric field and magnetic field in the vicinity of the lines at the specified distance and beyond using Trifield metre (model 100XE) for evaluating the fields and compare with ICNIRP, 1998 recommendations in order to access the level of pollution due to the field and to know if the RoW is safe for human beings.

Analysis of electric and magnetic field pollution due to parallel lines of 132 kV and 330 kV HV grids as shown in Figure 1, from Jos through Bauchi (Yalwan Kagadama – Tsakani – Gudum and Substation at Gudum) to Gombe (Gombe – Potiskum and Substation at Gombe) in Nigeria is presented. International/local standards on the assessment of risks from occupational and general population exposure to power line fields are used in the analysis.

2 Electromagnetic Pollution from Power Lines

A major source of extremely low frequency radiation is the high voltage electrical transmission lines. The lines can produce high losses that might bend the earth's ionosphere and long term exposure to the field from the line may result in health risk which makes it a major threat to our health. An animal or human body does not appreciably affect a magnetic field but the field induces subtle electric current within the body. There are two types of electric current caused by magnetic field induction (Zaffanella and Deno, 1978):

- a circulating current inside the object (eddy current); and
- a current entering/leaving the object.

These current could affect biological processes in the body. The eddy current induced in the body is not conducted to ground and it causes voltage difference within the body which may be as high as 1 mV if the magnetic flux density reaches approximately 0.028 mT (Hauf, 1982). In the vicinity of transmission lines, the electric fields is typically of the order of a few kilovolts per metre (kV/m) and the forces exerted by electric fields on living cell can cause rotation, deformation, destruction of cells because of the conductivity of living tissues (Schwan, 1982).

3 Interaction of Human Body with Electric and Magnetic Fields of Power Lines

Exposure to power line results in internal body currents and energy absorption in tissues as a result of thermo – molecular agitation. This depends on the coupling mechanisms, the frequency (f) and the electrical conductivity of the medium (σ). In magnetic media, permeability (μ) relates magnetic field intensity (H) to magnetic flux density (B) by

$$B = \mu H \quad (1)$$

From Ohm's Law, the current density (J) depends upon the magnetic flux density (B), field frequency (f) derived from Faraday's law of induction and radius of the induction loop (Stuchly and Xi, 1994) and it can be expressed mathematically as

$$J = \pi R f B \quad (2)$$

For electric field, Ohm's Law relates the internal electric field (E) and current density (J) (ICNIRP, 1998a) as expressed in equation (3).

$$J = \sigma E \quad (3)$$

A human body located in an electric field causes perturbation of the field which results in an uneven distribution of the field around the body. The field induces electric currents in the exposed body. The current produced within the body has the same frequency as the external field. Unlike magnetic field, electric field is attenuated by about a factor of 10^6 from the value of the external field within the body (Barnes et al., 1967, Deno, 1977 and Kaune, W. T. and Phillips, R. D. 1980).

Kaune, W. T. and Gillis, M. F. (1981) have shown that the electric - field intensity at the surface of the body and induced currents passing through various segments of the body can be determined by:

- the characteristics of the applied electric field;
- the shape of the body; and
- any conduction currents from the body to the ground.

The magnetically – induced electric currents are greatest at the periphery of the body. The maximum ground level magnetic field strengths associated with overhead transmission lines are of the order of 0.01 – 0.05 mT (it is either on the centre line or under the outer conductors) and are also related to line height. The magnetic flux density decreases in an approximately linear fashion with distance from the conductor (Zaffanella and Deno, 1978; Lambdin, 1978).

4 Standards for Control of Bioelectromagnetic Pollution from Power Lines

The influence of EM radiation on biological matter is referred to as *bioelectromagnetic*. It occurs when electric current is set up in tissues of a living organism which may lead to increase in body temperature as a result of energy deposition (which is the case for people living/working close to power line, as their body is immersed in the fields) causing biological effect. Internal electric and magnetic fields deposited in living organisms are evaluated using *dosimetric* calculation (NRPB, 1993). Any effect of EM energy on a body that is not heat – related is referred to as *athermal* effect. This can equally result to health hazard (Hyland, 1999).

A biological effect is said to have occurred, when exposure to EM waves cause some significant or detectable physiological change in the biological system (WHO, 1998). These effects may occasionally lead to a detrimental health condition (Ike and Ade, 2006).

The most widely accepted standard for *bioeletromagnetic* control was developed by the ICNIRP, the Institution of Electrical and Electronics Engineers and the American National Standards Institute (IEEE/ANSI) (Aliyu et al, 2009). Protection against adverse health effects require that these *basic restrictions* are not exceeded. Table 1 summarizes the *reference levels* for occupational and general public exposure recommended by the ICNIRP.

5 Measurement Method

International and national standards provide exposure limits in terms of electric field strength E (V/m) and magnetic field strength H (A/m) at power line frequencies. The electric and magnetic fields must be measured accurately in order to fully assess the health implications of the field on Human beings. Free body probes and ground reference instruments are the two methods used for electric field measurement (Bracken, 1976, Miller, 1967). In this research, free body probe was used for the measurement of the fields in this research because it does not require a known ground reference for measurements anywhere above the ground. Any measurements of EM pollution should be frequency weighted (that is the product of magnetic field strength times frequency), if the measurement are to gauge whether the current inside the body exceeds a threshold level.

To evaluate the fields from the line, Trifield meter (model 100XE) was employed. The meter combines all features needed for fast, accurate measurements of EM pollution. It independently measures electric and magnetic field and is properly scaled for both, to indicate the full magnitude of the currents produced by each type of field inside the human body.

In the measurement, measures were taken to avoid inaccuracy. The sensor in the metre had to be pointed in the same direction as the field was pointing, otherwise, the reading would be less than the true magnitude of the field strength. At each point maximum signal is measured (that is the worst values) while walking around with the metre held 1.5 m above the ground in the vicinity of the lines. In this report measurement are made in milligauss (mG) for magnetic field and volt per metre (V/m) for electric field.

Human body can shield electric field; therefore, utmost care was taken to ensure the Metre is not covered by human body during the measurement so that the true value of the line electric field can be measured.

In practice, several factors: like the line load; line faults; sensitivity of field – detecting coils inside the metre; the ability of the metre to combine the three coil outputs nonlinearly to give a true magnitude of the magnetic field; the location of the examined position with respect to the line and; environmental factors effect the result. These make it difficult to measure the true value of the exposure levels and that is why some over – estimation is usually allowed in form of 'worst case' situation (Ministry of Environment Italy, 1998).

The field intensity selected for reference or comparison purposes is the unperturbed ground level electric field strength. To avoid the effects of vegetation or irregularities in the terrain, the unperturbed field strength was measured at 1.5m above the ground level.

6 Result

The electric and magnetic field strengths at 1.5 m above ground level from the HV lines were measured between two towers of 132 kV and 330 kV and moving away from the centre of each line. However, the characteristics of the measurement between the two lines varied considerably and these reflect the lines voltage, the distance from the lines and the height of the lines.

The summary of the data collected for magnetic field in Bauchi are shown in Figure 2 – 3 and Table 2 – 3. They provide information on the maximum (20.55 mG, 45 mG) and average (5.8 mG, 8 mG) magnetic flux density under the centre line, at the mid-span of 132 kV and 330 kV lines respectively between the two towers.

Also, Figure 4 provide information on the maximum (35 mG) and average (20 mG) magnetic flux density under the centre line at the mid – span of 132 kV between two towers of the line in Gombe. Figure 5 provide information on the maximum (35 mG) and average (7 mG) magnetic flux density under the centre line at the mid – span of 132 kV moving away from the line in Gombe.

Higher values recorded at 330 kV line shows that people living close to the line are prone to higher magnetic flux density than those living close to 132 kV line. It is interesting to point out that the lowest magnetic flux density for both 132 kV and 330 kV were recorded during indoor measurements, while the highest magnetic flux density for both 132 kV and 330 kV were also recorded during outdoor measurements.

Figure 6 – 7 and Table 2 shows the data collected for electric field. It provides information on the average (42 V/m and 63 V/m) and maximum (40 V/m and 130 V/m) of electric field strengths for 132 kV and 330 kV line respectively.

Also, Figure 8 provides information on the average (22 V/m) and maximum (110 V/m) of electric field strengths for 132 kV line in Gombe between the two towers. However, 10 m away from the outer line of 132 kV, the electric field becomes 10 V/m and it dies down to zero further away from the line.

7 Discussion

The highest and lowest magnetic flux density measured is 35 mG and 4 mG from 132 kV line and 45 mG and 6 mG from 330 kV line. These correspond to 3.5 % for 132 kV line and 4.5 % for 330 kV line of the ICNIRP, 1998 exposure limit for the general public. Thus, there is no health risk to human activities under the lines or close to the lines. Also, occupational exposure limit is below ICNIRP, 1998 safety limit under the power lines as we recorded 0.7 % for 132 kV line and 0.9 % for 330 kV line.

The magnetic field recorded at the closest building and the last building to the lines shows a large variation covering two orders of magnitude, from 0.2 mG to 3.9 mG and from 0.2 mG to 15 mG for 132 kV and 30 kV lines respectively. These correspond to 1.5 % and 0.39 % of the ICNIRP 1998 exposure limit for the general public which is also safe. However, it is important to note that these buildings have violated PHCN RoW because the buildings are as close as 6.5 m and 8 – 10 m away from 132 kV and 330 kV lines respectively. At the RoW, the magnetic flux density is 3.8 mG which is 0.38 % of the ICNIRP, 1998 reference levels for general public exposure for 132 kV line and 4 mG which is 0.4 % of the ICNIRP, 1998 reference levels for general public exposure for 330 kV line. Samples of the data are shown in Table 2 – 3.

Occupational exposures that occur near HV transmission lines depend on the worker's location either on the ground or at the conductor during live – line work at high potential or in the control room. Measurement in this analysis shows that the maximum, average and minimum magnetic flux density is 100 mG, 48.44 mG and 8 mG respectively. Note that the 100 mG was due to 30/40 mVA transformer in Bauchi. The average magnetic flux density inside control room in Bauchi is 2.5 mG which is below ICNIRP 1998 exposure limit. In Gombe, the average magnetic flux inside control room is 4 mG, 6 mG in offices outside the control room and 100 mG in the vicinity of 150 mVA transformer. It shows that the workers are safe as the maximum flux density is 2 % of the ICNIRP, 1998 occupational exposure limit.

However, there is need for maintenance personnel to restrict their movement around these power transformers because there is sizeable number of scientists that believed that athermal effects of EM radiation may lead to health hazards. Also, living close to the lines may lead to other dangers.

For the electric field, the highest and lowest measurement is 130 V/m and 20 V/m from 330 kV line. These correspond to 2.6 % and 0.4 % of the ICNIRP, 1998 exposure limit for the general public. Also, the highest and lowest electric filed measured is 40 V/m and 10 V/m from 132 kV line. These correspond to 0.8 % and 0.2 % of the ICNIRP, 1998 exposure limit for the general public. Thus, human activities like farming and etceteras are safe under the lines. For occupational exposure, the highest and lowest values correspond to 1.3 % and 0.1 % of the ICNIRP, 1998. Hence, there is no risk to PHCN maintenance personnel working under the line.

The data collected in this analysis from the closest building and the last building to the lines show zero order variation in magnitude, from 10 V/m to 42 V/m for 330 kV. These correspond to 0.2 % and 0.84 % of the ICNIRP 1998 exposure limit for the general public. Therefore, there is no risk for the general public. It is important to note that these buildings have violated PHCN RoW for HV lines because there are buildings 8 m away from 132 kV and 3 m away from 330 kV lines.The details of the data is shown in Table 4.

The electric field decreases in an approximately linear fashion with distance from the conductor .This is the possible reason why PHCN set 15 m and 25 m as RoW for 132 kV and 330 kV line respectively, hoping that the electric field from the lines would be safe at the specified distances from the lines. However, at 25 m from 330 kV line we measured 10 V/m which is 0.02 % of ICNIRP1998 recommendation and at 15 m from 132 kV line we measured 20 V/m which is 0.4 % of ICNIRP1998 recommendation. Hence, the electric field at RoW are safe from both lines.

Measurement in this analysis showed that the electric field is averagely 80 V/m under 132 kV bus bar which is below ICNIRP, 1998 exposure limit. The highest electric field was recorded under 132 kV and 330 kV bus bars. The electric field inside control room is practically zero. Hence, the workers are safe in the control room and under the bus bar.

8 Conclusion

In this paper, the magnitude of electric field strengths and magnetic flux density in the vicinity of 132 kV and 330 kV HV power line have been analyzed for general public and occupational exposure using ICNIRP, 1998 reference levels. The analysis showed that:

- The general public exposure to electric and magnetic field along the power lines is safe. The highest measured exposure 2.6 % and 4.5 % of the reference level for electric and magnetic field respectively;
- The occupational exposure to electric and magnetic field under the power lines, bus bar and control room is also safe. The highest measured electric field was recorded under 132 kV and 330 kV bus bars which was 0.08 % of the reference level while the highest magnetic field measured was 2 % of the reference level due to power transformers;
- PHCN RoW along the power lines have been violated as buildings exist less than 15 m and 25 m away from 132 kV and 330 kV lines respectively. Despite the violation, the electric field strengths and the magnetic flux density outside and inside the buildings are within safety limit. However, there is a huge work to be done by regulatory/law enforcement agents to ensure that the RoW is observed along the power line because there are sizeable number of scientists that believed that athermal effects of electromagnetic pollution may lead to health hazards; and
- The measurement should be carried out in other parts of the country for risk management and comparative analysis.

Reference

Aliyu, O., Maina, I., and Ali, H. (2011a). Analysis of Magnetic Field Pollution due to 330 kV and 132 kV Transmission Lines. Abubakar Tafawa Balewa University Bauchi, Nigeria. Journal of Technology and Educational Research Vol. 4, No. 2, pp. 87-93.

Aliyu Ozovehe ,Ibrahim Maina, Ali Hamdallah (2011b). Analysis of Electric Field Pollution due to 330 kV and 132 kV Transmission Lines. Innovations in Science and Engineering Vol.1, No. 4, pp. 69-73

Aliyu .O, Adekola S. A. and Ade O. (2009). Practical Assessment of Exposure Levels due to Radiations from GSM Base Stations. ICEPT-2009. International Conference on Power Telecommunication, Abuja, Nigeria, October 2009.

European Commission (1998). European Commission (1998). Proposal for a Council Recommendation on the Limitation of Exposure of the General Public to Electromagnetic Fields 0Hz -300GHz

Hal, J.(1997). The negative effects of EM fields. Consumer Health. 20(9).

Hauf, R.(1982). Electromagnetic ELF fields. In: Suess, M.J., ed. Non-ionizing radiation protection, Copenhagen, World Health Organization Regional Office for Europe (WHO Regional Publications, European Series No. 10).

Hyland, G.J (1999). Mobile phones and Health' in Scientific Adversary System, London, Vol.II, appendix 15, pp 86-91, 1999.http://www.magnetic-shield.com/litrature.html

Ike M. and Ade O.(2006). On the Hazards of Non-ionizing Radiation. Proceeding of National Conference and Exhibition on Telecommunications and Broadcasting in Nigeria. Department of Electrical and Electronics Engineering, University of Lagos.

Ministry of Environment Italy 1998. Regulations Laying down Standards for Determining the Maximum Levels of RF Compatible with Human Health, Ministry of the Environment. (Italy), DECREE of 10 September 1998, No 381, B/RFE 038.

Lambdin, J. D.(1978). A comparison of measurement techniques to determine electric fields and magnetic flux under EHV overhead power transmission lines, Las Vegas, Nevada, US Environmental Protection Agency (ORP/EAD 78-1).

NEPA news (2000). Health and Safety guideline, October- November 2000.

NRPB (1993). Proposal for limiting exposure to Electromagnetic fields. Fixed System for Telecommunications' pp 26.

Siaka M.(2010). Highlighting the dangers of living under high tension cables. Businessday Newspaper. Thursday 01 July, 2010.

Stuchly, M. A.and Xi, W.(1994). Modelling induced currents in biological cells exposed to low – frequency magnetic fields. Phys. Med. Biol. 39: pp 1319 –1330.

World Health Organization (1998). Electromagnetic fields and public health; physical properties and effects in biological systems. Fact sheet number N 182, 1998.

Zaffanella, L. E. and Deno, D. W.(1978). Electrostatic and electromagnetic effects of ultra –high voltage transmission lines, Palo Alto, California, Electric Power Research Institute (Final report EPRI EL – 802).

Barnes, H.C., Mcelroy, A.J., & Chrakow, J.H. (1967) Rational analysis of electric fields in Live – line working. IEEE Trans. Power Appl. Syst., PAS – 86: 10 – 19.

Bracken, T.D. (1976) Field measurements and calculations of electrostatic effects of overhead transmission lines. IEEE Trans. Power Appl. Syst., PAS-95: 494-504.

ICNIRP (1998a): Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields ''Quantities and Units'' pp 495

Kaune, W.T. & Gillis, M.F. (1981) General properties of the interaction between animals and ELF electric fields. Bioelectromagnetics, 2: 1 – 11.
Kaune, W.T. and Phillips, R.D. (1980) Comparison of the coupling of grounded humans, swine, and rats to vertical, 60 – Hz electric fields. Bioelectromagnetics, 1: 117 – 130.
Miller, C.J. (1967) The measurements of electric fields in live line working. IEEE Trans. Power Appl. Syst., PAS – 85: 493 – 498.
Schwan, H.P. (1982) Nonthermal cellular effects of electromagnetic fields: AC – field induced ponderomotoric forces. Br. J. Cancer, 45(Suppl. V): 220 – 224

Aliyu Ozovehe
Born at Okene in Kogi State of Nigeria on May, 15th 1973. He received his degrees of B.Eng (Electrical Engineering) and M.Sc(Electrical/Electronics) in 1998 and 2006 from Bayero University Kano Nigeria and University of Lagos Nigeria respectively. He lectured in Electrical/Electronics Engineering department of Kaduna Polytechnic in 200/2001, worked with Nigerian Telecommunication Limited(NITEL) between 2001 to 2006 and currently working on Airtel project (cellular network provider in Nigeria) from 2006 to date. He is a Member of Institute of Electrical/Electronics Engineer (2008),Nigerian Society of Engineer (2007), Member Council for Regulation of Engineering in Nigeria (2008) and Nigerian Institute of Electrical/Electronics Engineer(2009). He is pursuing Ph.D degree in Electrical/Electronic Engineering Programme at Abubakar Tafawa Balewa University Bauchi, Nigeria. His major fields are Electromagnetic Compatibility, Radio wave propagation and Teletraffic engineering.

Maina Ibrahim
Born in Bauchi State of Nigeria on August, 10th 1970. He received his degrees of B.Tech(Applied Physics) and M. Eng(Electronics) in 1994 and 1998 respectively from Abubakar Tafawa Balewa University Bauchi, Nigeria. He has worked in Abubakar Tafawa Balewa University and Nigerian Telecommunication Limited(NITEL) between 1995 to 2007. By 2007, he rejoined Abubakar Tafawa Balewa University Bauchi. as lecturer in Physics Programme. He is a Member Nigerians Institute of Physics(2000) and Nigerian Society of Engineers(2004). Currently, he is on study leave to pursue Ph.D degree in Electrical Engineering at University Technology Malaysia.His major field is Digital signal processing.

Ali Hamdallah
Born at Okene in Kogi State of Nigeria on February, 20th 1974. He received her degrees of B.Sc (Ed) (Chemistry Education) and M.Ed (Educational Adminstration) in 2000 and 2006 from Ahmadu Bello University Zaria, Kaduna Nigeria and University of Lagos Nigeria respectively. She is a lecturer at Department of Science and Environmental Education, University of Abuja Nigeria from 2007 till date. Her major fields are Child intellectual development and Environmental education.

Figure 1: Jos – Gombe 330 kV (right) line and Jos – Bauchi – Gombe
132 KV (left) power transmission lines of 50-Hz which are 8m apart

Table 1: Reference levels for occupational and general public exposure to time-varying electric and magnetic fields. f as indicated in the frequency range column (50 Hz is used in Nigeria). [European Commission (1998)]

Exposure characteristic	**Frequency range**	**B-field** (μT)	**B-field at 50Hz** (mG)	**E-field strength** (V/m)	**E-field at 50Hz** (kV/m)
Occupational exposure	0.025 – 0.82kHz	25/ f	5,000	500/f	10
General public exposure	0.025 – 0.82kHz	5/ f	1,000	250/f	5

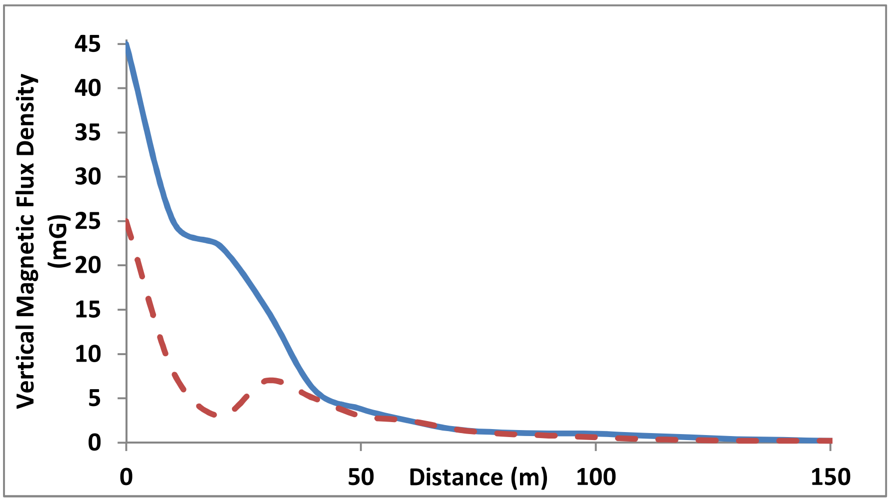

Figure 2: Unperturbed magnetic field at 50 Hz measured under 330 kV (solid line),132 kV (broken line) transmission lines parallel to each. Moving away from the line at Bauchi

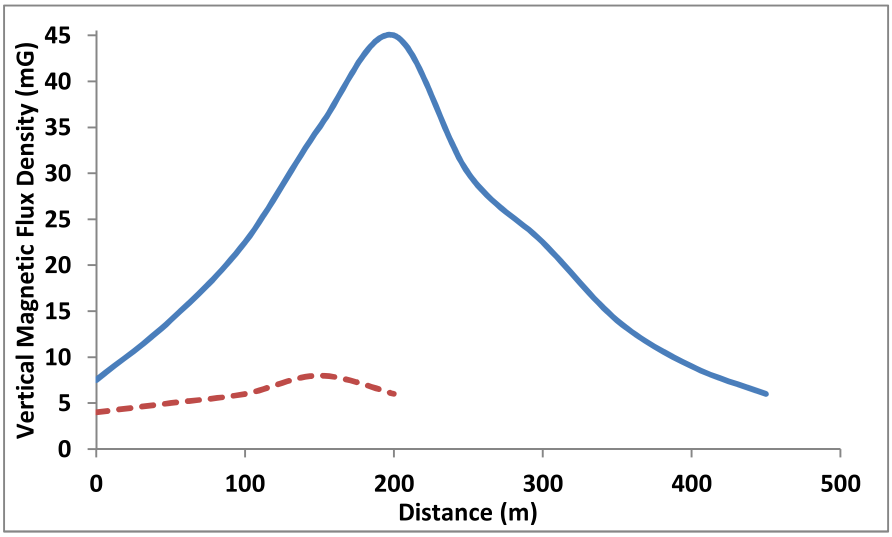

Figure 3: Unperturbed magnetic field at 50Hz measured between two Towers of 330 kV (solid line) and 132 kV (broken line) line in Bauchi

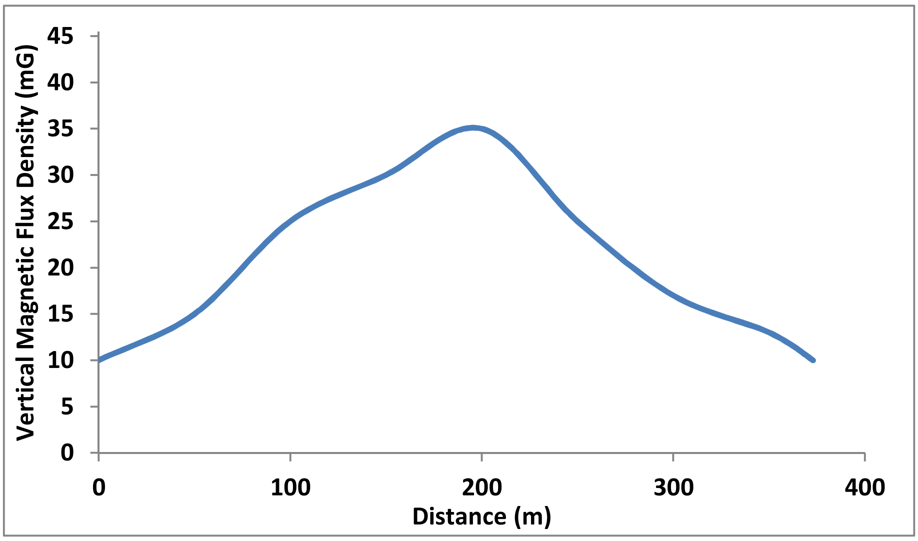

Figure 4: Unperturbed magnetic field at 50Hz measured between two Towers of 132 kV line in Gombe.

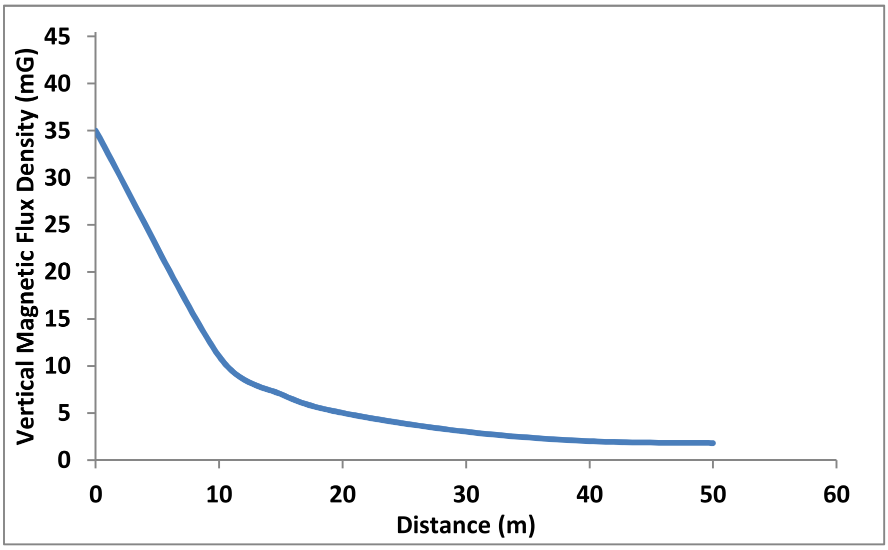

Figure 5: Unperturbed magnetic field at 50 Hz measured under 132 kV transmission line and moving away from the line at Gombe.

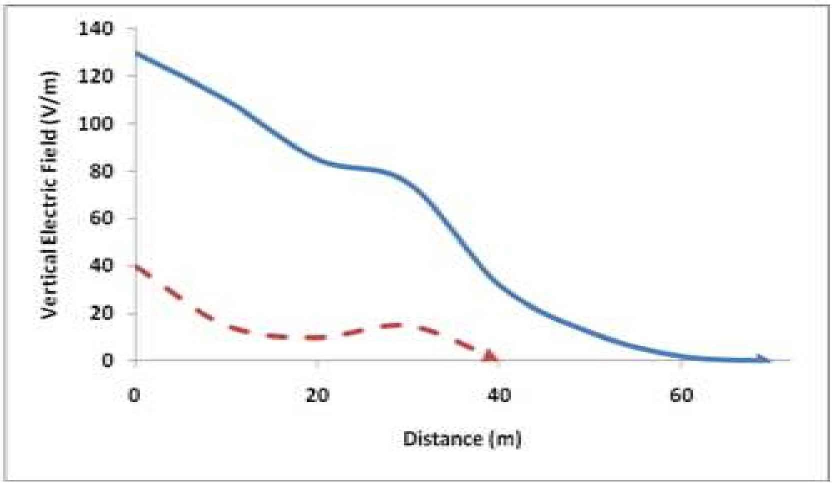

Figure 6: Unperturbed electric field measured under 330 kV (solid line),132kV (broken line),50Hz transmission lines parallel to each other moving away from the centre of the lines in Bauchi

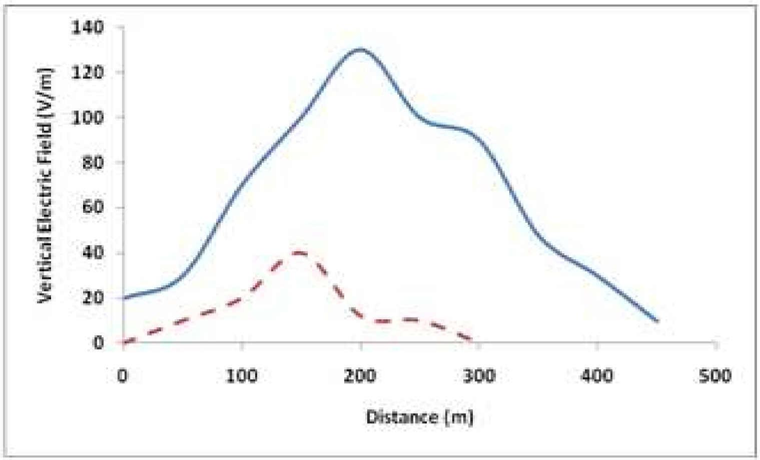

Figure 7: Unperturbed electric field measured between two towers of 330 kV (solid line) and 132 kV (broken line) lines in Bauchi

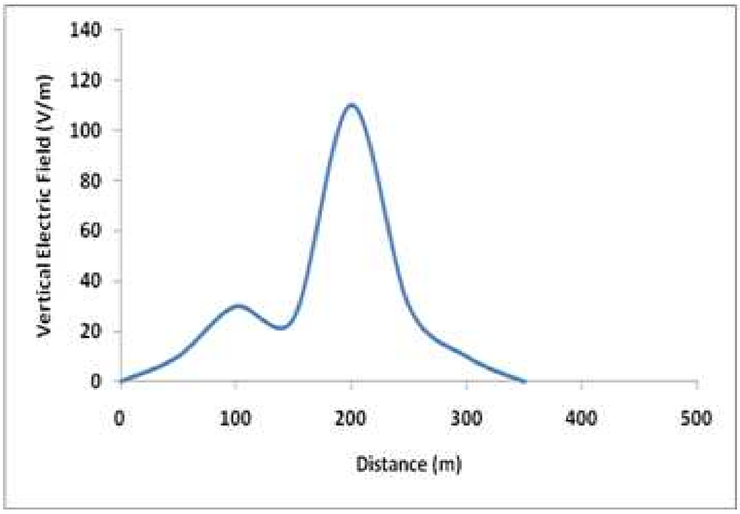

Figure 8: Unperturbed electric field measured between two Towers of 132 kV lines in Gombe

Table 2: Sample of magnetic flux density from 330 kV line in Bauchi

Outside building Magnetic flux density (mG)	Inside building Magnetic flux density (mG)	Distance from the line (m)
15	14	8.5
12	11	
6	5	
9	8	10
15	15	
14	13	

Table 3: Sample of magnetic flux density from 132 kV line in Bauchi

Outside building Mag. flux density (mG)	Inside building Magnetic flux density (mG)	Distance from the line (m)
4.1	4	6.5
3.5	3.2	
4.1	3.5	

Table 4: Sampling of electric field from 330kV line in Bauchi

Outside building Electric field (kV/m)	Inside building Electric field (kV/m)	Distance from the line (m)
30	10	14
42	28	3