Measurement of Electromagnetic Fields from High Voltage Transmission Power Lines in Evbotubu Area of Edo State, Nigeria

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Abstract
For over three decades there has been a growing understanding of the effects of electric and magnetic fields along High voltage Transmission Power lines (HVTPLs). These fields are higher close to the HVTPLs and fall with distance. Magnetic fields vary as the load on the HVTPLs changes whereas electric fields stay roughly constant. HVTPLs generate large values of Extremely Low frequency (ELF) Electromagnetic Fields (EMFs). This research gives an analysis of EMFs emitted by 330kv HVTPLs in Evbotubu Area of Edo State, Nigeria and compare measurements of these EMFs with the international standard threshold values. The magnetic field shows health effect as its exceeds the threshold value at some point while the electric field at all points is still below the limit as recommended by International Commission of Non-Ionizing Radiation Protection (ICNIRP). The research also identifies the implications for a precautionary approach to ELF EMFs and makes practical recommendations for precautionary measures.

Keywords: ELF, EMF, HVTPLs, ICNIRP, Threshold values

1.0 Introduction
Electromagnetic radiations are energies that are propagated through free space or through a material medium in the form of electromagnetic waves, such as radio waves, visible light, and gamma rays. It refers to the emission and transmission of such radiant energy. There are many sources of electromagnetic radiation, both natural and man-made.

Electromagnetic radiations have properties in common with other forms of waves such as reflection, refraction, diffraction, and interference. Moreover, it may be characterized by the frequency with which it varies over time or by its wavelength. Electromagnetic radiations, however, have particle-like properties in addition to those associated with wave motion [1].

Electromagnetic radiations (based on this research work) can be categorized into two groups:

- Ionizing Radiation and
- Non-ionizing Radiation on the severity of the radiations.

Ionizing radiation holds a great amount of energy to remove electrons and cause the matter to become ionized. Thus, higher frequency waves such as the X-rays and gamma-rays have ionizing radiation. However, lower frequency waves such as radio waves, do not have ionizing radiation and are grouped as non-ionizing.
ELF EMFs are produced wherever electricity is generated, distributed or used. There is no doubt that ELF EMFs can have effects on the body if the fields are high enough. Specifically, external EMFs induce internal electric fields in the body tissue, which can interfere with the action of nerves. There is uncertainty as to the exact level of field required to produce these effects, but the threshold for observable induced-field effects on nerves from ELF EMFs is, according to most advisory bodies, above 1000μT and 50 kV/m. Electric fields below this level can also produce indirect effects such as micro shocks and contact currents due to surface charge effects, as evidence has emerged over the last few decades. The question of whether or not ELF EMFs may cause adverse health effects on humans and his immediate environment has become a source of considerable scientific debate [2].

A noticeable source of ELF EMFs radiation is the HVTPLs, which in some instances produce such high losses that they bend the earth's ionosphere. HVTPLs are dangerous because they are constantly losing energy. Because we cannot see electricity, and we do not use to have a detector, we cannot see it oozing. If we have an ELF spectrum analyzer, we could find that ELF EMFs propagate very far, even at long distances, and the intensity will be quite significant from biological viewpoint for long term exposures. Even for people living at distance from HVTPLs, long term exposure may be dangerous. Often it was found that secondary transmission lines, like in the streets, are much worse polluters than the huge HVTPLs. The human body is a living antenna that can absorb and re-emit HVTPLs energy, in the environment. Animals also could contribute to re-enforcing environment electromagnetic loading. So a school full of children and teachers near HVTPLs can become a tremendous new source of electrical energy and a major polluter, not only to the children in the school, but even to people living nearby. The International Radiation Protection Association (IRPA) and ICNIRP recommend that the electric field and the magnetic field strength should be measured for evaluation of electromagnetic radiations pollution from HVTPLs [2].

<table>
<thead>
<tr>
<th>Table 1: Recommended Limits for Electric and Magnetic Fields Strength. (ICNIRP, 1998)</th>
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<tbody>
<tr>
<td>Organization</td>
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<td>ICNIRP</td>
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<td>European Union</td>
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2.0 Electric Transmission

The conveyance of electric power from a power station to consumer’s premises is known as electric supply system. Electric power transmission is the bulk movement of electrical energy from a generating site such as a power plant, to an electric substation. The interconnected lines which facilitate this movement are known as a transmission network. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. Therefore an electric supply system consists of three main components; The Power Stations, The Transmission System and The Distribution System.
Electric power is produced at power stations which are usually located far away from consumers. It is then stepped up and transmitted over long distances from the power stations to load centres by means of conductors known as transmission lines. We have primary and secondary (or sub-) transmission stages. Finally, power is distributed to a large number of consumers through a distribution network. We also have primary and secondary (sub-) distribution stages. The electric supply system can be classified into:

- Alternating Current and Direct Current Systems
- Overhead and Underground Systems.

The underground systems are rarely used for power transmission because of some obvious disadvantages, though overhead systems also have its disadvantages. The transmission and distribution stages are very important to electric power system, because without these stages the generated power cannot get to the final consumers [3].

The Nigerian transmission network comprises of over 11000km of transmission lines (over 5000km of 330KV transmission lines and 6000km of 132KV transmission lines). It also has about 24000km of 33KV sub-transmission lines and 19000km of 11KV distribution lines together with 22500 substations all over the country [4].

In the vicinity of transmission lines, the electric field, \( E \) and magnetic field, \( H \) are typically of the order of a few thousands of volts per metre (V/m) and a few hundreds of milligauss (mG), respectively. HVTPLs at 50 or 60 Hz are the dominant source of ELF EMFs radiations pollution in our environment. It has been confirmed that life is not safe under HVTPPLs. 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 [5] and [6].

**Bioelectromagnetic** is the influence of electromagnetic radiation on biological matter. 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 HVTPPLs 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; any effect of electromagnetic energy on a body that is not heat related is referred to as athermal effect. This can equally result to health hazard. A biological effect is said to have occurred, when exposure to EMFs cause some significant or detectable physiological change in the biological system. These effects may occasionally lead to a detrimental health condition. The most widely accepted standard for Bioelectromagnetic control was developed by the ICNIRP, the Institution of Electrical and Electronics Engineers and the American National Standards Institute (IEEE/ANSI). Protection against adverse health effects require that these basic restrictions are not exceeded [1], [7] and [8].

### 3.0 Theoretical Background

Electromagnetic radiations released are related to the temperature of the body. Stephan-Boltzmann Law says that if this body is a black body, one which perfectly absorbs and emits radiation, the radiation released is equal to the temperature raised to the fourth power. Therefore, as temperature increases, the amount of radiation released increases greatly. Bodies that release radiations very well also absorb radiations at certain wavelengths very well.
Wavelengths are also related to temperature. As the temperature increases, the wavelength of maximum emission decreases.

Electromagnetic radiations which are form of energy emitted and absorbed by a body that act as a wave travelling through space are described in terms of its wavelength, frequency, or energy. All electromagnetic energy travels at the speed of light (c = 2.998×10⁸ m/s), so wavelength (λ) and frequency (ν) are inversely related:

\[ c = \lambda \nu \]  \hspace{1cm} (1)

Long waves have a low frequency and short waves have a high frequency. The wavelength and frequency also indicate the energy of the wave. The relationship between wavelength and energy, E, is described by the equation:

\[ E = \frac{hc}{\lambda} \]  \hspace{1cm} (2)

Where h is Planck’s constant (h = 6.625×10⁻³⁴ Js) and c is the speed of light.

By replacing the constants h and c with their respective values, we see that

\[ E = 1.986\times10^{-25} \text{Jm or Jm}/\lambda. \]

An inverse relationship exists; electromagnetic radiations with shorter wavelengths are more energetic. The relationship between energy and frequency is given by the equation:

\[ E = h\nu \]  \hspace{1cm} (3)

A direct relationship exists; electromagnetic radiations with a higher frequency are more energetic, major sources of ELF EMFs are the HVTPLs. 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.

Interaction of Human Body with Electric and Magnetic Fields of HVTPL exposure to HVTPLs 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).

Radiated coupling results when Electromagnetic energy is emitted from a source, propagates to the far-field, and induces voltages and currents in another circuit. Unlike common impedance coupling, no conducted path is required. Unlike electric and magnetic field coupling, the victim circuit is not in the electromagnetic near field of the source. Radiated coupling is the only possible coupling mechanism when the source and victim circuits (including all connected conductors) are separated by many wavelengths.

Of the four possible coupling mechanisms, \textit{radiation coupling} is the one that seems to get the most attention. The idea that currents flowing in one circuit can induce currents in another circuit that is across the room or even miles away is fascinating to most of us. Maxwell’s treatise on electromagnetism postulated the existence of electromagnetic waves back in 1864. He was able to calculate the velocity of propagation of these waves, and describe wave reflection and diffraction. However, it was twenty five years later before anybody was able to verify the existence of electromagnetic waves. Practical transmitters and receivers were not
developed until the beginning of the 20th century. People viewed electromagnetic radiation as something nearly magical. The theory was difficult to comprehend and the equipment required to transmit and receive signals was fairly complicated.

Presently, we take wireless communication for granted. It is no longer viewed as magical, but the theory is still complex and the equipment used to send and receive signals is still among the most sophisticated of our time. This leads many engineers to believe that electromagnetic radiation is difficult to create and difficult to detect. However, virtually all circuits radiate and most pick up detectable amounts of ambient electromagnetic fields. It is not necessary to attach an antenna to a circuit to make it radiate, the structure and location of most high frequency circuits allows them to act as their own antenna or to couple to nearby objects that act as efficient antennas.

The more difficult challenge for the designers of most electronic products is to design circuits that do not produce too much electromagnetic radiation. In order to understand how and why circuits exhibit unintentional electromagnetic emissions, it is helpful to review a few general concepts related to electromagnetic radiation [9].

4.0 Materials and Method
To measure the fields from the line sensor ED78S electrosmog meter which detects low frequency (LF) magnetic field in units of tesla or gauss, electric field in unit of V/m and high frequency RF EMF strength signal. Also measured LF magnetic field strength is shown on the digital LCD display (with µT and mG). Two LF modes can be selected; (a) LF30 mode (0.1mG-30mG) and (b) LF 600 mode (1mG – 600G). It runs on an alkaline battery (9volts) and measuring tape to measure distances. The study areas were selected base on the local HVTPLs distribution. We took measurements (5m, 10m, 15m, 20m, …100m) of electric and magnetic fields at selected locations along preferred route. Both electric fields and magnetic fields were measured. Each measurement was acquired over a short period. Upon stabilization of a reading, the maximum value was recorded. Continuous measurements were performed at different distances at each measuring points. The measurements were taken at a height of 1.5m above sea level.

The electric field was measured in units of V/m and the magnetic field was measured in units of µT. This instrument meets the Institute of Electrical and Electronic Engineering (IEEE) instrumentation standard for obtaining valid and accurate field measurements at HVTPLs frequencies (IEEE Std. 1308 – 1994, R2001, R2010). Measurements of electric field and magnetic fields were taken horizontally on the preferred Route along a 330kv transmission line that runs through the HVTPPLs road at Evbotubu Area, Edo State, Nigeria.

5.0 Results and Discussion
Tabulated results of the measurements are presented in Tables 1 also in Fig.1, Fig. 2 and Fig. 3.
### Tab. 1: Measured values of Electric and Magnetic Fields around 330kVA HVTPLs

<table>
<thead>
<tr>
<th>Distance (M)</th>
<th>Electric Field, E (V/m)</th>
<th>Magnetic Field, B (µT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.89</td>
<td>0.72</td>
</tr>
<tr>
<td>10</td>
<td>0.75</td>
<td>0.78</td>
</tr>
<tr>
<td>15</td>
<td>0.72</td>
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<tr>
<td>20</td>
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</tr>
<tr>
<td>25</td>
<td>0.50</td>
<td>0.78</td>
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<tr>
<td>30</td>
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<tr>
<td>35</td>
<td>0.48</td>
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</tr>
<tr>
<td>40</td>
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</tr>
<tr>
<td>45</td>
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<tr>
<td>50</td>
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</tr>
<tr>
<td>55</td>
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<tr>
<td>60</td>
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<tr>
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<tr>
<td>70</td>
<td>0.64</td>
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<tr>
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<tr>
<td>90</td>
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<td>0.77</td>
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<tr>
<td>100</td>
<td>0.40</td>
<td>0.56</td>
</tr>
</tbody>
</table>

### Fig. 2: Plot of Electric Field strength around 330KV HVTPL
Fig. 3: Plot of Magnetic Fields strength around 330KV HVTPL

Fig. 4: Plot of Electric and Magnetic Fields strength around 330KV HVTPLs
Tab. 1 show the measurements from the 330KV HVTPLs and Fig. 2, Fig. 3 and Fig. 3 show the graphical representation of the electric and magnetic field measurements at distance of 5m to 100m around the second HVTPLs in Evbotubu Quarters. The electric field is lowest at distance of 60m (0.32V/m) while, the magnetic field is lowest at 100m (0.56 µT). Around Evbotubu Primary School, the field is at normal reference level between 0 to 5m of the HVTPLs, at this point there was no conductor sagging and there is no transformer or mobile phone base station in this area. At a distance of 10m where there is lowest conductor sag, the radiation increased slightly above normal reference level. At a distance of 20m to 45m the level of radiation decreases again to normal reference level. As we gradually moved away from this point, the radiations begin to decrease gradually to normal reference level. The highest recorded at a distance of 5m (0.89V/m) and 50m (1.57 µT) for the electric and magnetic field respectively from the HVTPLs.

6.0 Conclusion and Recommendations

Due to increasing population there have been expansion in villages and towns, many buildings are now constructed near HVTPLs which generate large values of ELF EMFs.

Electric and Magnetic fields were measured in the 330KV HVTPLs in Evbotubu Area, Edo State, Nigeria using electrosmog meter. The results obtained were compared with the standard exposure limits which are set by ICNIRP and other regulatory bodies. The analysis shows that the electric field do not pose any risk to human health if the exposure is for short period, the risk may does exist if the exposure is for a long and continuous period. However, the magnetic field show some level of risk as the values exceeded the standard threshold values. [10]

It was also discovered that the maximum field measurement is recorded at points of lowest conductor sag and from Fig. 4 it shows that where there is drop in electric field also simultaneous drop in magnetic field was observed as a result there is good correlation between electric field and magnetic field within the study area.

We therefore, make the following recommendations based on the results and analysis of this research:

- That the government and other agencies should consider the need for precautionary measures in respect of exposure of people to ELF EMFs.
- That more information be provided to members of the public about exposures and the actions they could take themselves to reduce exposures to ELF EMFs.
- That electricity companies be encouraged to choose the optimal phasing (usually transposed phasing) for all new HVTPLs, and also be encouraged to convert existing HVTPLs where possible and justifiable.
- To stop building any new buildings for residential use and other uses including schools, churches, business centres, etc within specified distances of HVTPLs, and to stop building new HVTPLs within the same specified distances of existing such buildings.
• That measurement should be carried out in other parts of the country for risk management and comparative analysis.

7.0 Acknowledgement
The authors are grateful to Mrs. Gladys Eghonghon Ukhurebor for her tireless effort during the measurement process.

8.0 References