Comparative Analysis Of Base Transceiver Station (BTS) and Power Transmission Lines Effects On The Human Body In the Lagos Environs, Lagos State, Nigeria.

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ABSTRACT
This paper presents the Comparative Analysis of Base Transceiver Station (BTS) and Power Transmission Lines Effects on the Human Body in Lagos Environs. This was achieved using the measured and calculated values of some electromagnetic parameters such as power density, and electric field intensity. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure limit for BTS antennas is $0.1 \text{ W/m}^2$ ($100 \text{ mw/m}^2$). For values of radiating power of the base station antenna ranging between 33Watts to 100Watts, the power density experienced in the vicinity of the antenna ranges from 0.8 mW/m$^2$ to 280 mW/m$^2$. The health effect of the antennas is at its peak when the base station antenna is transmitting at 100Watts. At radiating power of 100Watts, the mean power density was found to be 39 mW/m$^2$, and the Root Mean Square Error (RMSE) value was 73 mW/m$^2$. The distance away from the base station that is safe for residential purposes was found to be 16.m. The safety guideline by ICNIRP for exposure to overhead high voltage power line is 10kv/m, the electric field around the power line ranges from 0.016KV/m to 0.46 KV/m. The mean electric field was found to be 0.056KV/m, and the Root Mean Square Error (RMSE) value was 0.12KV/m. The highest value of electric field intensity measured in the vicinity of an overhead power line was found to be far below ICNIRP limit of exposure. The results obtained in this research can help in the proper town planning and allocation of land space for residential and commercial purposes, so as to reduce the number of health hazard related to electromagnetic radiation from these two common sources. Also, the health risks associated with exposure to electromagnetic radiation, especially at distances very close to the electromagnetic source are discussed and the public are advised to avoid residing near these sources.

Keywords: Power transmission lines, Environment, Base Transceiver Station, Electromagnetic radiation & Radiating power.

1. INTRODUCTION
There is a rise in the use of electric power dependent gadgets in Nigeria. Consequently, several transmission power lines are being installed all over the country to meet electric power demands [3]. Also, in the past decade, because of the need to communicate, the use of mobile telephony has also increased rapidly. There are over a thousand base stations in Lagos. This is so due to the desire of network providers to meet the demands of the increasing number of telephone users [4]. Some adverse effects are being reported as a result of living in the vicinity of Base Transceiver Station (BTS) and overhead power lines. Migraine, insomnia (lack of sleep), amnesia (memory loss), and sudden movement of body parts are some of the effects being reported [3,7].
A. Power Density in the Vicinity of a BTS Calculation.
The Power Density (P.D) of an antenna can be mathematically expressed as [11];

$$R_i = \frac{1}{2} \pi \sigma [R \times R]$$

Figure 1: Pictorial view of a Base Transceiver Station in Ikeja Lagos State

Figure 2: Pictorial view of a Power Line along Ikeja Lagos State
Where, \( \mathbf{E} \) and \( \mathbf{H} \) are the electric and magnetic field intensity of the electromagnetic waves.

\[
\mathbf{E} = 10^{-7} \, \text{V/m} \\
\mathbf{H} = 120 \pi \times 10^{-7} \, \text{A/m}
\]

Then, the total electric field intensity due to the base station antenna is;

\[
\mathbf{E}_{\text{total}} = \sqrt{3N \mathbf{P}_{\text{rad}} G R}\]

Where

\( N \) is the number of carriers (antennas),
\( \mathbf{P}_{\text{rad}} \) is the radiated power,
\( G \) is the radiation gain for a pattern antenna,
\( R \) is the distance from the base station.

Then substituting equation (7) in equation (2) it gives:

\[
\mathbf{P}_d = \frac{30NP_{\text{rad}}G}{R^2Z_0}
\]

The following formula enables the calculation of equivalent power density \( (P_d) \) to be made and assumes field impedance \([5]\),

\[
\mathbf{P}_d = 0.0796 \frac{\mathbf{P}_{\text{rad}}}{R^2} \times 10^{12}
\]

Where

\( G \) in equation (9) is the gain of base station antenna in dB. The simplest case of application is the one when human is exposed to a single base station antenna, \( (N=1) \).

Then:

\[
\mathbf{P}_d = 0.0796 \frac{\mathbf{P}_{\text{rad}}}{R^2} \times 10^{12}
\]

Where

\( \mathbf{P}_{\text{rad}} \) is the radiated power (in Watts) emitted by the base station antenna, \( G \) is the antenna gain (in dB) in the direction where the person is placed relative to the antenna.

B. Electric Field Intensity in the Vicinity of a Power Line

The electric field intensity around a power line can be estimated by using the Method of Images, the analysis can be calculated from the figure below. The dashed line signifies the earth surface which acts like a mirror. Everything below the dashed line is the mirror image of the elements above it. Because the earth is a perfect conductor (potential at ground level is equal to zero), estimations are made few metres above the ground level \([1,6]\).

\[
h + \sqrt{h^2 + x^2}
\]

Figure 4: Line current representation of a power line.
Let \( R = \left( \frac{h^2 + x^2}{2} \right)^{\frac{1}{2}} \)

and \( R' = \left( \frac{(h + 2p)^2 + x^2}{2} \right)^{\frac{1}{2}} \)

the expression for the voltage on a power line is given by:

\[
V = \frac{Q}{2\pi \varepsilon_0 \ln \left( \frac{2(h + p)}{r} \right)}
\]

Where \( \varepsilon_0 = \frac{10^{-9}}{22} \ F/m \)

The electric field intensity that will be felt \( x \) metres away from the power line is given by the expression:

\[
E = \frac{Q}{2\pi \varepsilon_0 \ln \left( \frac{1}{R - \frac{1}{R'}} \right)}
\]

Making charge per unit length \( Q \) the subject of the formula in equation 13, we have:

\[
Q = \frac{V \times 2\pi \varepsilon_0}{\ln \left( \frac{2(h + p)}{r} \right)}
\]

Substituting equation (16) into equation (15), equation (15) becomes:

\[
E = \frac{V}{\ln \left( \frac{2(h + p)}{r} \right)} \times \left( \frac{1}{R} - \frac{1}{R'} \right)
\]

Equation (17) defines the electric field experienced around an electric overhead power line.

Where \( V \) is the voltage along the line conductor in KV.

\( R \) is the distance of the observer away from the pole.

\( R' \) is the distance of the observer away from the image.

\( p \) is the height of the exposed person.

\( h + p \) is the height of the electric pole.

\( r \) is the radius of the conductor used by the power line.

3. INVESTIGATED ENVIRONMENT

Lagos is the most populous city in Nigeria. It has a population of about 17.5 million people. Its geographical coordinates are 6°27' N and 3°23' E.

Fig. 5: The Map of Lagos State, Nigeria
4. ANALYSIS OF RESULTS

Tables I, and IV show the results of the measured and calculated power density experienced at distances ranging from 10 to 100m with 10m interval away from the BTS, and the power lines. The radiation power (P) of base station antennas is within the range of 33 watts and 100 watts, at a gain (G) of 5dB. MATLAB software was used for the graphical analysis of the data obtained. Tables II, III, V, and VI show the result of the statistical analysis of the data obtained. The statistical formulae used are given below.

Arithmetic Mean is defined by:
\[ \bar{x} = \frac{\sum(x)}{n} \]

Mean Deviation is defined by:
\[ M.D = \frac{\sum(x - \bar{x})}{n} \]

Table II shows the statistical analysis of the data obtained was also carried out. The results obtained are also tabulated. Root Mean Square Error is defined by
\[ \text{R.M.S.E} = \sqrt{\frac{\sum(x - \bar{x})^2}{n}} \]

Variance is the square of R.M.S.E, and is defined by
\[ \frac{\sum(x - \bar{x})^2}{n} \]

Table 4.1: Power density with respect to the distance from base station antenna located at Ikeja Lagos State. for maximum antenna gain = 5 dB.

<table>
<thead>
<tr>
<th>Distance From Base Station Antenna (Metres)</th>
<th>P=33W G=5dB Power Density (P.D₁) (W/m²)</th>
<th>P=66.7W G=5dB Power Density (P.D₂) (W/m²)</th>
<th>P=100W G=5dB Power Density (P.D₃) (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.074</td>
<td>0.0831</td>
<td>0.18</td>
</tr>
<tr>
<td>20</td>
<td>0.018</td>
<td>0.0207</td>
<td>0.035</td>
</tr>
<tr>
<td>30</td>
<td>0.0078</td>
<td>0.0092</td>
<td>0.017</td>
</tr>
<tr>
<td>40</td>
<td>0.0041</td>
<td>0.0052</td>
<td>0.009</td>
</tr>
<tr>
<td>50</td>
<td>0.0028</td>
<td>0.0033</td>
<td>0.0054</td>
</tr>
<tr>
<td>60</td>
<td>0.0026</td>
<td>0.0023</td>
<td>0.0040</td>
</tr>
<tr>
<td>70</td>
<td>0.0014</td>
<td>0.0017</td>
<td>0.0037</td>
</tr>
<tr>
<td>80</td>
<td>0.0012</td>
<td>0.0013</td>
<td>0.0029</td>
</tr>
<tr>
<td>90</td>
<td>0.0011</td>
<td>0.0010</td>
<td>0.0018</td>
</tr>
<tr>
<td>100</td>
<td>0.00071</td>
<td>0.00083</td>
<td>0.0015</td>
</tr>
</tbody>
</table>
### Table III: Statistical analysis of calculated power density

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>$P=33\text{W}, G=5\text{dB}$ (W/m²)</th>
<th>$P=66.7\text{W}, G=5\text{dB}$ (W/m²)</th>
<th>$P=100\text{W}, G=5\text{dB}$ (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.01137</td>
<td>0.02596</td>
<td>0.04023</td>
</tr>
<tr>
<td>Mean Deviation</td>
<td>0.0139</td>
<td>0.0326</td>
<td>0.05071</td>
</tr>
<tr>
<td>R.M.S.E</td>
<td>0.0207</td>
<td>0.05226</td>
<td>0.0813</td>
</tr>
<tr>
<td>Variance</td>
<td>0.0004</td>
<td>0.00273</td>
<td>0.00661</td>
</tr>
</tbody>
</table>

### Table IV: Electric field strength with respect to distance for power lines located at Ikeja Lagos State

<table>
<thead>
<tr>
<th>Distance From Power Line (Metres)</th>
<th>Voltage= 132KV Electric Field (KV/m)</th>
<th>Voltage=330KV Electric Field (KV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured</td>
<td>Calculated</td>
</tr>
<tr>
<td>10</td>
<td>0.16</td>
<td>0.18</td>
</tr>
<tr>
<td>20</td>
<td>0.035</td>
<td>0.046</td>
</tr>
<tr>
<td>30</td>
<td>0.014</td>
<td>0.016</td>
</tr>
<tr>
<td>40</td>
<td>0.0052</td>
<td>0.00745</td>
</tr>
<tr>
<td>50</td>
<td>0.0028</td>
<td>0.004</td>
</tr>
<tr>
<td>60</td>
<td>0.0016</td>
<td>0.0023</td>
</tr>
<tr>
<td>70</td>
<td>0.0011</td>
<td>0.00146</td>
</tr>
<tr>
<td>80</td>
<td>0.00072</td>
<td>0.001</td>
</tr>
<tr>
<td>90</td>
<td>0.00038</td>
<td>0.0007</td>
</tr>
<tr>
<td>100</td>
<td>0.00022</td>
<td>0.00052</td>
</tr>
</tbody>
</table>

### Table V: Statistical analysis calculated electric field intensity

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>Voltage 132KV</th>
<th>Voltage 330KV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.026</td>
<td>0.066</td>
</tr>
<tr>
<td>Mean Deviation</td>
<td>0.035</td>
<td>0.089</td>
</tr>
<tr>
<td>R.M.S.E</td>
<td>0.053</td>
<td>0.14</td>
</tr>
<tr>
<td>Variance</td>
<td>0.0028</td>
<td>0.018</td>
</tr>
</tbody>
</table>
Table VI: Statistical analysis for measured electric field intensity

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>Voltage 132KV</th>
<th>Voltage 330KV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.022</td>
<td>0.056</td>
</tr>
<tr>
<td>Mean Deviation</td>
<td>0.030</td>
<td>0.078</td>
</tr>
<tr>
<td>R.M.S.E</td>
<td>0.047</td>
<td>0.12</td>
</tr>
<tr>
<td>Variance</td>
<td>0.0022</td>
<td>0.015</td>
</tr>
</tbody>
</table>

5. GRAPHICAL ANALYSIS

MATLAB software was used to carry out the graphical analysis of the data obtained.

Figure 6: Comparison of calculated and measured Power Density at 33 Watts against Distance

Figure 7: Comparison of calculated and measured Power Density at 66.7 Watts against Distance
Figure 8: Comparison of calculated and measured Power Density at 100 Watts against Distance

Figure 10: Comparison of Measured Power Density at 33W, 66.7W, and 100W against Distance

Figure 9: Comparison of Calculated Power Density at 33W, 66.7W, and 100W against Distance

Figure 11: Comparison of measured and calculated Electric Field at 132KV against Distance
6. DISCUSSION OF RESULTS

A. Base Station Antennas

The maximum radiating power of base station antennas in Lagos is in the region of 100 Watts, and power density at the immediate vicinity of the antenna exceeds ICNIRP exposure guideline of 0.1 w/m². Most BTS antennas in Lagos environs operate at radiation power P of 100 Watts and Antenna gain G of 5 dB. The highest value of power density measured is 0.28 w/m². This far exceeds the ICNIRP exposure limit (280% of ICNIRP limit), and being exposed to such a value of P.D is totally not safe. The distance at which a power density of 0.1 w/m² will be experienced from a BTS antenna with P=100W and G=5dB is 15.9 m. This implies that it is not safe to live within 15.9 m (approximately 16m) of a BTS.

Figures 6 to 8 are in the form of decaying graph. It shows that the power density decreases exponentially as the distance from the base station increases. A distance of 100 m from the BTS gives a power density of 0.022 w/m², which is just 2.2% of the ICNIRP exposure limit. The farther the exposed person is from the BTS, the safer. The measured value of the power density is lower than the calculated value because of some interference caused by environmental factors [10].
B. High Voltage Power Lines

PHCN (Power Holding Company of Nigeria) is responsible for installation and maintenance of High Voltage power lines in Nigeria. It has specified 15m and 25m as Right of Way (ROW) for 132KV and 330KV lines, meaning no residential or commercial structures should be erected within 15m and 25m of a 132KV and 330KV power line respectively. The ICNIRP exposure limit for overhead power lines is 10KV/m, the highest value of electric field strength obtained from the results is 0.46KV/m, which is just 4.6% of the exposure limit. The amount of voltage capable of having an effect of 10KV/m is in the region of 7000KV, which is practically impossible to implement on power lines. Therefore, the electric field in the vicinity of the power line is safe. However, a sizeable number of scientists believe that its thermal effect poses a considerable level of health risk. Also, considering the high voltage flowing through the conductors, if a conductor should snap and fall on an individual or on a building, it will result in damage of property and electrocution [2, 9, 12].

7. CONCLUSION

The values of electric field intensity around a 132KV and 330KV power lines have been analyzed, the power density in the vicinity of BTS antenna operating with radiation power of 33Watts, 66.7Watts and 100Watts were also analyzed. The analyses obtained from these cases were compared to the ICNIRP exposure guidelines. The analysis showed that, the Right of Way law given by the PHCN along the power lines have been violated as there are residential structures less than 15 m and 25 m away from 132 KV and 330 KV lines respectively. The electric field strengths experienced around both power lines are within the ICNIRP safety limits, regardless of the position of the exposed person. However, it is not advisable to live close to power lines because of the risk of electrocution or fire outbreak if one of the conductors should snap. Some studies have shown that a high number of children diagnosed with leukemia, have their houses close to a power line.

There is an enormous amount of work to be done by National Environmental Standards and Regulations Enforcement Agency (NESREA), the body responsible for enforcing environmental Laws in Nigeria, and Nigeria Communications Commission, the telecommunication industry regulator in Nigeria, to ensure that the Right of Way is obeyed along the power line. The 10 metre distance from residential homes law given to network operators as regards siting of BTS is still violated by some operators. Some houses even have BTS sited in their compounds. Medical reports have shown that radiations from BTS are carcinogenic; they are capable of generating cancer cells in the human body. Some research reports also suggest that they are also capable of causing genetic mutation in human cells, which can result in having children with some form of physical deformity. Short term effects associated with the exposure to electromagnetic radiation include headaches, fatigue, insomnia, rashes and body pain. Long term exposure to electromagnetic radiation can affect the ability to reproduce, these accumulated radiations are capable of damaging genital cells.

REFERENCES