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Electric Field Intensity Around Masts And Transformers In Ijebu Igbo, Nigeria.

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Abstract
In this work, the electric field strength around GSM masts and power transformers in Ijebu Igbo town has been studied. The study sites were carefully chosen based on the presence of masts and transformers in close proximity. The sites are located within residential areas and so, measurements were taken over a distance of ~100m in steps of 10m from the base of each site. The electric field strength at various specified receiver distances was measured using a 3-axis non-directional digital radio frequency (RF) meter which operates in a frequency range of between 10KHz and 8GHz .
In all the sites studied, the electric field intensity reduced with distance away from the base. Also, a maximum value of 1500mV/m was measured at the fifth site (Wema bank), while a minimum value of 502.4mV/m was measured at about 100m away from the same site.
Also, it was observed that all the measurements obtained fall well below the ICNIRP recommended safe level.
Keywords*: Electric field, Mast, Transformers, ICNIRP.*

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I. INTRODUCTION

The last three decades have witnessed a tremendous growth in all aspects of modern technology (Shankar, 2002). Wireless communication, which is a subset of the modern technology involves the transmission of messages via electromagnetic waves which can propagate from the sending device to the receiving device through any medium. With the generation of electromagnetic waves, an electromagnetic field is setup. The intensity of the field at any location depends on a number of factors and can be measured using a field strength meter (Adegboyega et. al., 2014, Akingbade et. al., 2013). Due to the need to communicate, transmission masts which carry antennas are located at various places, to provide signal coverage over the intended region.

As stated earlier, technology has grown at a very fast pace. This is also evident in electric power generation and transmission. With technological advancement, there is an ever increasing demand for electrical energy to power life as we now know it. A major component in the electricity distribution network is the power transformer (Nelkon and Parker, 2001). It has been established that whenever electric current flows through a conductor, an electromagnetic field is set-up. While the direction of the field depends on the direction of current flow, the intensity depends on factors such as the amount of current flowing, the length of the conductor and the number of turns (for coils) (Nelkon and Parker, 2001; Wilson and Buffa, 2000).

It has been established that an electromagnetic field exists around a communication mast. Also, whenever current flows in a transformer coil, there is mutual induction in the secondary coil which eventually leads to the presence of an electromagnetic field around the transformer (Wilson and Buffa, 2000, Kotoye et. al,. 2020).

Previous efforts have studied the field intensity due to communication masts and power transformers differently at various locations (Kotoye et. al., 2020). It has however been observed that there are places where communication masts and power transformers have been sited in close proximity, almost next to each other. As far as we know, little or no effort has been made to study the field strength at those locations. Therefore, this research work is aimed at studying the field strength at such regions and compare the results with those obtained from earlier studies.

THEORETICAL BACKGROUND

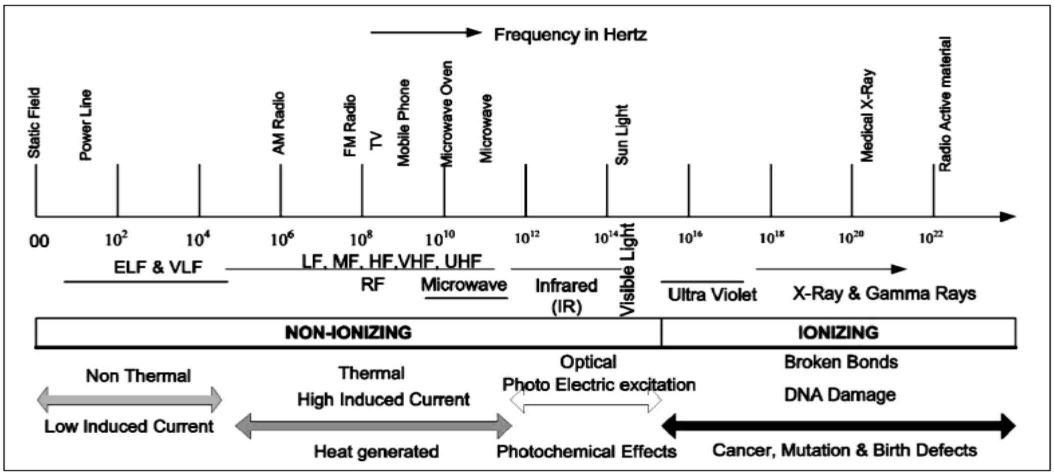

Fig. 1. The electromagnetic spectrum.

Electromagnetic waves are synchronized oscillations of electric and magnetic fields that propagate at the speed of light through a vacuum. They are produced whenever charged particles are accelerated, and these waves can subsequently interact with other charged particles (Garratt, 1994, Wilson and Buffa, 2000). The oscillations of the two fields are perpendicular to each other and mutually perpendicular to the direction of energy and wave propagation, forming a transverse wave. Electromagnetic waves are characterized by the frequency and wavelength of their oscillations, which determines their position in the electromagnetic spectrum (Ahern, 2006, Kinsler, 2010).

Figure 1 shows the arrangement of electromagnetic (EM) waves in order of increasing frequency from left to right. On the far left, there is the field due to static field from direct current and power line with frequencies in the order of 0Hz and 10^2Hz-10^4Hz respectively (David, 2005). These are in the Extremely Low Frequency (ELF) and Very Low Frequency (VLF) regions. On the far right, there are fields due to medical X-Ray and radioactive materials with frequencies in the order of 10^{20}Hz to 10^{22}Hz. These are otherwise called ionizing radiation.

The characteristics (generation and propagation) of EM waves are guided by the 4 Maxwell's equations.

$$\boldsymbol{\nabla x} E = \frac{\delta B}{\delta t} \qquad (2.1)$$

$$\boldsymbol{\nabla} x H = J + \frac{\delta D}{\delta t} \qquad (2.2)$$

$$\boldsymbol{\nabla}. D = \rho \qquad (2.3)$$

$$\boldsymbol{\nabla}. B = 0 \qquad (2.4)$$

Electromagnetic fields in the environment are usually characterized by their flux density. Magnetic field can be specified in two ways- magnetic flux density *B*, expressed in tesla (T), or as magnetic field strength *H*, expressed in ampere per meter (A m^{-1}).

For linear materials, the two quantities are related by the expression:

$$B = \mu H \qquad (2.5)$$

Where μ is the magnetic permeability in vacuum or air.

The power density (ρ), which is the rate of flow of electromagnetic energy per unit surface area (usually expressed in W/m^2 or mW/cm^2), decreases rapidly as the distance from the source increases and can be written as:

$$\rho = \frac{E^2}{\eta} \qquad (2.6) \text{ or}$$

$$\rho = EH \qquad (2.7) \text{ or}$$

$$\rho = \eta H^2 \qquad (2.8).$$

Where E is the electric field intensity and η is the field resistance taken as 377Ω for free space (in air) (Mousa , 2009).

A transformer is an electrical device used to transfer an alternating current or voltage from one electric circuit to another by means of electromagnetic induction. Depending on the number of turns of wire in the primary and secondary coils, a transformer can either step-up or step-down incoming current as desired. As established by

Oersted in 1820, when current flows through a conductor, an EM field is set-up. It is therefore expected that as current flows through the transformer coils, an EM field whose intensity will depend partly on the amount of current flowing will be set-up.
The guiding equation is written as

$$E = N\frac{\delta\varphi}{\delta t} \qquad (2.9)$$

Equation (2.9) is the statement of Faraday's law which states that whenever there is a change in the flux linking a circuit, an electric field is set-up (Wilson and Buffa, 2000).

II. MATERIALS AND METHODS

For this work, observation data was obtained by direct measurement of the electric field intensity at four different mast and transformer locations within Ijebu Igbo. At those locations, there are communication mast and a power transformer in close proximity (≤ 5m apart). Since the selected sites are within the city center, it was difficult to take measurements over a long range devoid of interference from other sources of EM waves.
Measurements were taken from those locations over a distance of ~ 100m at an interval of ~10m using a Tenmars-196 Field Strength Meter. Since the field intensity around a transformer depends on the flow of current, measurement was subsequently taken whenever there was a supply of public power.

III. RESULTS

Table 1 below shows the values of the measured electric field with distance.

Distance(m)	Location1(mV/m)	Location2(mV/m)	Location3(mV/m)	Location4(mV/m)
10	1110.14	1312.4	1441.5	1500.2
20	989.63	1334.5	1291.2	1472.7
30	856.93	1124.3	1408.4	1322.5
40	911.45	1012	1318.1	1214.6
50	920.9	908.5	1284.2	1104.5
60	730.44	802.4	1200.3	902.5
70	720.9	722.5	1250.4	804.7
80	614.1	675.2	1200	705.7
90	600.3	576.5	1111.8	624.8
100	567.12	440.5	1012.5	502.4

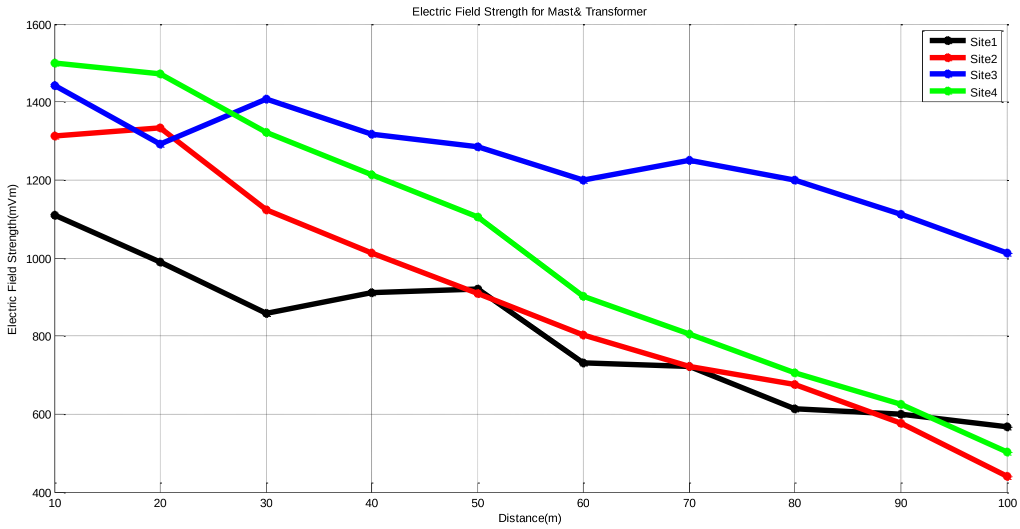

Fig. 2. The plot of electric field strength at selected sites

Generally, it is observed that all the plots in figure 2 have a downward trend. This downward trend is not similar to the plot of the inverse square law.

The plot at Site 1 begins at 1110mV/m at distance 0m, and ends at the value of 567.12mV/m at the distance of 100m.The minimum value of the graph is 600mV/m at distance of 90m, while the maximum value in the plot is 1110mV/m at base of the site.

At Site 2, the plot begins with 1312.4mV/m at distance 0m and ends at a value of 440.5mV/m at 100m. This also corresponds to the minimum value of the graph, while the maximum value in the plot is 1334mV/m at 20m away from the site.

At site 3, the plot begins with 1441.5mV/m at the site and ends at a value of 1012.5 at 100m away. The highest value was recorded at the site, while the lowest value of ~1200mV/m were recorded at 60m and 80m.

At site 4, a value of 1500.2mV/m was recorded at the base, while 502.4mV/m was recorded 100m away. These also correspond to the highest and lowest values for the site.

In a general sense, the plots of Sites 1,2 and 4 show a more rapid downward trend than the plot of Site 3. This means that for the most part, the plot of Site 3 maintained a higher set of values compared to the other plots. It thus finishes at a higher value than the other plots. On the other hand, the plot of Site 1 is observed to have the lowest set of values.

In all the sites under study, a maximum value of 1500.2mV/m was recorded at Site 4, while a minimum value of 1200mV/m was recorded at Site 2.

IV. DISCUSSION

It is well known from theory that electromagnetic field strength reduces with the inverse of the square of the distance away from the source producing it. This is the statement of the inverse square law. The results above however show a generally linear reduction instead of the expected exponential decay. It should be noted that the inverse square law is stated for electromagnetic field propagating in free space or vacuum. In practical terms however, the reduction in field strength may not be exponential due to various factors. Such factors may include atmospheric effects (scattering, absorption, refraction etc), terrain (topography, structures, foliage) and the presence of reflectors and multiple sources of electromagnetic field. Therefore, the linear reduction in the measured field strength can be attributed to the factors listed above.

As stated above, previous efforts have studied the field intensity due to communication masts and power transformers differently at various locations. Comparing the results presented in this report with those from the measurement of electric field intensity around transformers contained in Kotoye et.al., 2019, the results in this work have relatively higher values. In that effort, even though the maximum intensity was ~1900mV/m, the plots exhibited a generally lower profile compared to the result obtained in this work. Also, in a similar work by Olorunfemi et. al., 2016, around GSM masts in Ile-Ife, results obtained show a maximum field intensity of 566mV/m. These results clearly show that electric field intensity is higher when a mast and a transformer are in close proximity than when they are far apart.

According to the World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), in the 400 - 2000 MHz range, maximum values for public exposure to electric field is given by

1.375f V/m (ICNIRP 2009). For GSM masts which transmit in the1800MHz frequency band, the value of the electric field is 59.5V/m.

From our results, the measured electric field intensity in Ijebu-igbo falls far below the ICNIRP threshold.

V. Conclusion

The electric field intensity around communication masts and transformers has been studied in Ijebu-Igbo. Subsequently, this study has provided typical values for EM field intensity associated with GSM technology and transformers. Even though the values obtained are below threshold, care must still be taken to limit the number of sites where both masts and transformers are located. It should be noted that the ICNIRP value has been stated largely for the adult component of the populace. Similar studies are needed in the future to determine the possible effects of these intensity levels on babies/infants.

Competing interest

The authors declare that they do not have any conflict of interest or competing financial interests.

Consent

Not Applicable.

Author contributions

KAA conceived the experiment, coordinated it and analyzed the data; AYM wrote the paper.

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