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# Comparative Analysis of Power Flux Density of GSM Carriers Along Road Network Using Developed Digital Field Meter

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**Abstract:- Power flux density is the measure of the strength of the high-frequency radiation in the far field, which characterizes the energy flowing through an area vertical to the distribution direction of the radiation. High-frequency radiations are distributed Base Transceiver Station (BTS) and antennae which can be absorbed by biological systems. This paper presents the Comparative Analysis of Power flux density of three major GSM carriers in Nigeria along 91km route of various attenuation rates. Given that the high frequency radiations emitted by BTS and antennae are distributed energy and information over a great distance which can be absorbed by biological systems, it is essential to monitor power radiation levels from time to time ensuring that they are within safety threshold. This measurement was achieved using the developed digital field meter to calculate values of some electromagnetic parameters such as power flux density, electric field intensity and magnetic field intensity. To understand the behavioral pattern of non-ionizing radiation associated with the power flux density due to electric and magnetic field intensity of GSM signal, the developed field instrument (i.e., GSM field meter) was used to calculate power flux density of three GSM carriers along 91km road network. The study provided a standard to monitoring the GSM carriers radiated signals in terms of safety to human being. The study confirmed that the signal strength of MTN mobile network is stronger than the Airtel and Glo mobile networks along the route covered during measurement. The maximum values, even at resonant frequency, are still far less than the International Commission on Non-Ionizing Radiation Protection (ICNIRP) values of 4.5 W/m$^2$ and 9.0 W/m$^2$ for GSM 900 and GSM 1800, respectively.**

***Keywords**:- Power Flux Density, Electric Field, Magnetic Field, Base Transceiver Station, Field Instrument.*

## I. INTRODUCTION

Global system for mobile communication (GSM) being a globally mobile cellular radio system, it has become Internet of Things (IoT) because of its accessibility, affordability, and simplicity [1]. GSM was also designed with level of security to handle radiation effects and cryptographic imperfections [2, 3]. Power flux density is the measure of the strength of the high-frequency radiation in the far field, which characterizes the energy flowing through an area vertical to the distribution direction of the radiation. High-frequency radiations are distributed by Base Transceiver Station (BTS) and antennae which can be absorbed by biological systems [4]. Given that the high frequency radiations emitted by BTS and antennae are distributed energy and information over a great distance which can be absorbed by biological systems, it is essential to monitor power radiation levels from time to time ensuring that they are within safety threshold. The protocols used in BTS and antennae are bound to emit radiation beyond safety values, and which by implication, could affect human life after many years of built-up infrastructure of GSM-based networks. Therefore, power radiation levels must be measured from time to time. In this regards, BTS antennae should be enhanced without affecting human health based on the standard of Electromagnetic Compatibility as well as International Commission on Non-Ionizing Radiation Protection (ICNIRP) values of 4.5 W/m$^2$ and 9.0 W/m$^2$ for GSM 900 and GSM 1800, respectively [5].

A basic equation used for calculating on-axis power density from a large-aperture antenna in the far-field is [4]:

$$S = \frac{P_t G_t}{4\pi d^2} \tag{1}$$

where
$P_t$ = transmitted power (in watts, W).
$G_t$ = far field transmitter gain expressed as a power ratio with an isotropic reference antenna.
$d$ = distance from an antenna to the point of interest (in metre, m)
$S$ = power flux density (in watts per metre square, W/m$^2$).

The quantity $G_tP_t$ in Eqn (1) can be considered as an equivalent effective isotropic radiated power (EIRP), a power that would have to be radiated by a hypothetical isotropic antenna to achieve identical signal level in the direction of maximum radiation of a specific antenna.

Technically, in far-field free air conditions, the power flux density is also related with impedance of free air as in equation 2:

$$S = \frac{E^2}{Z_o} = Z_o H^2 \tag{2}$$

where $Z_o$ is impedance of free air.

The GSM power density depends on three sectors: the transmitted power of base station, the distance of the handheld away from the base station, and the obstacles within the coverage areas. Most of electromagnetic radiation, EMR, assessments were based on the Maximum transmission power of base station, the distance to the base station and surround barriers, as shown by [6] and [7], while [8], [9] and [10] utilized the data of an electromagnetic exposure and constructed a three-dimensional Gaussian mixture model to predict base station electromagnetic exposure. Moreover, in [11] and [12], the accurate calculation was developed and analyzed time variability of electric field level in GSM downlink channels. In this study, we acknowledged that assuming the maximum site configuration is rarely the case in real operational paradigm [4] because there are often trees and buildings in the immediate transmitter vicinity and GSM networks would automatically adjust transmit power to suit the actual transmission situation.

The research has gone further to examine the behavioral pattern of electromagnetic field associated with the power flux density of GSM signal using the developed digital and localized GSM instrument for the measurement. The measurements were carried out along Akure to Akungba-Akoko road of 91km of Ondo State, Nigeria with the location of $7^{0}11'15''$N, $5^{0}13'29''$ and $7^{0}28'43''$, $5^{0}44'27''$ respectively.

## II. MATERIALS AND METHOD

The circuit of the field instrument developed for this measurement, as shown in Figure 1, is composed of ACS712 current Sensor, Magnetic Hall Effect Sensor UGN3503U, SIM800L GSM module; ATMEGA328P Microcontroller programmed C++ and Micro C IDE and LM2596 DCDC Buck Converter for development of the power flux density (S) resulting from electric field (E) and magnetic field (H) GSM signal performance equipment. The developed field meter has a time base of 5s which can receive both uplink and downlink signals from Base Transceiver station of GSM providers. Data logger was incorporated to store data on electric and magnetic fields from BTS which was used to calculate the power flux density of GSM signal with MTN, GLO and Airtel mobile carrier SIMs being used. The outdoor measurements were carried out along 91km road network with the three SIMs.

The digital instrument developed, in Figure 1, calculated the power flux density from base stations of GSM signals within 91kM route as shown in Figure 2. The research was conducted by using the SIMs of MTN, Glo and Airtel mobile communication networks.


Fig 1: Digital GSM field Instrument

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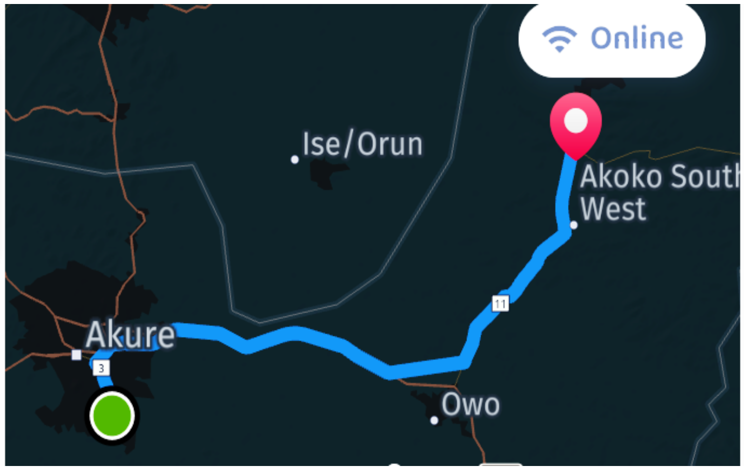

Fig 2: Distance covered of 91km

## III. RESULTS

The power flux density from the antenna of GSM's Base Transceiver Station, BTS, measured by the instrument calculated the strength of each GSM's signal along the road. The spikes are because of resonant frequency signal detected by the instrument. All the information is generated from the electromagnetic radiation range of communication and transmission. Figures 3, 4 and 5 display the power flux density pattern of MTN, GLO and Airtel GSM mobile communications along 91km route.

The lower values depicted the fast-fading signals as it shows the behavior of signals with time while spike shows the higher field strength at resonant frequency.

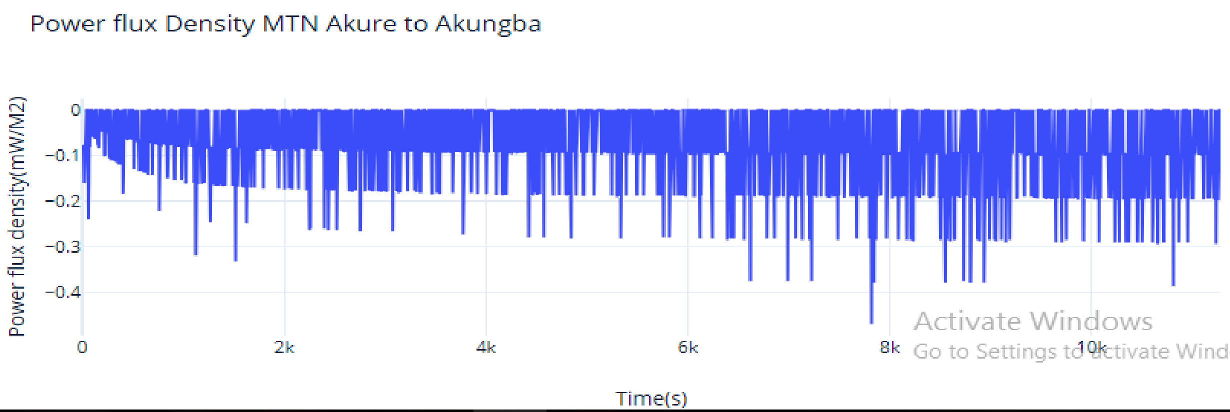

Fig 3: Power flux density pattern of MTN mobile Network from Akure to Akungba Akoko

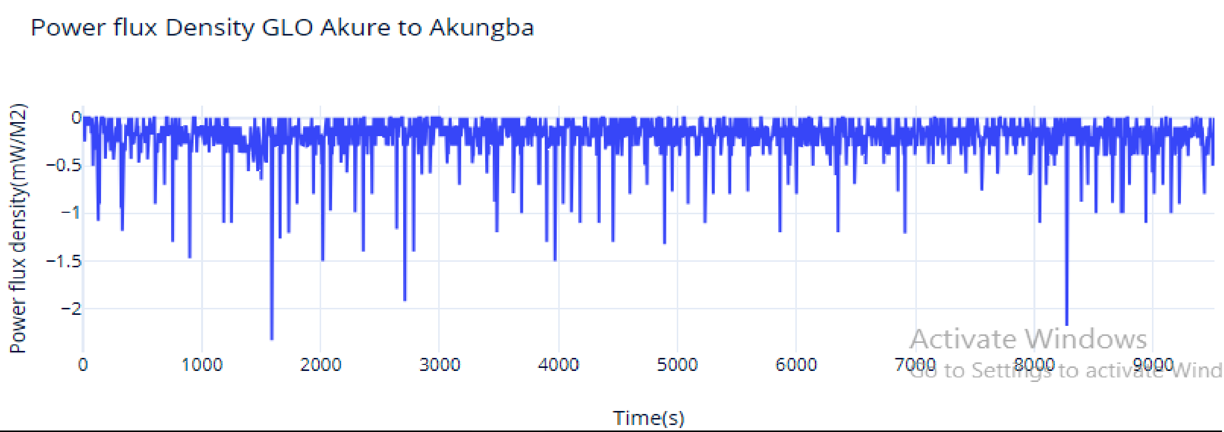

Fig 4: Power flux density of GLO mobile Network from Akure to Akungba Akoko

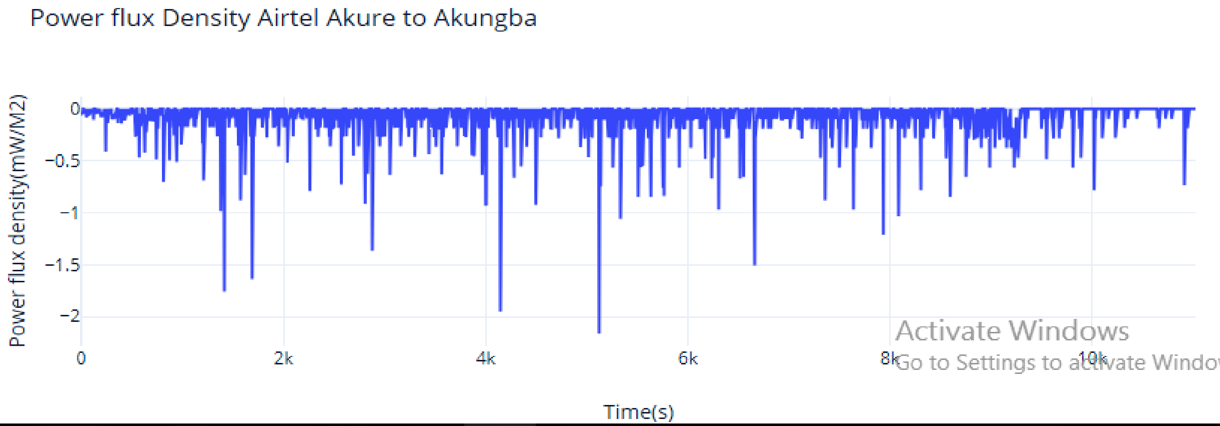


**Fig 5:** Power flux density of Airtel mobile Network from Akure to Akungba Akoko

## IV. DISCUSSION

The results of the developed instrument showed that power flux density were strongest close to the operating BTS. The magnetic field strength decreases very rapidly with distance from the source and can be calculated (that is, as the inverse square of the distance, d, i.e., $|f_s| = d^{-2}$). Comparing the results among the three GSM network providers—MTN, Glo, and Airtel—the results showed the highest power flux density exposure occurred with MTN network with lesser spikes compared with GLO network (2.2mW/$m^2$) from Akure to Akungba followed by Glo network of highest spikes (2.5mW/$m^2$) and Airtel network has the least power flux density also with relatively spikes (2.2mW/$m^2$) with Glo network.

With these large distances of 91km, the signals being received were subjected to series of attenuation at various locations. The three GSM carriers have their unique signal fading for different locations which were determined by the protocols used in BTS. The electromagnetic fields are strongest very close to an operating BTS source of about 10m in which maximum radiation exposure occurs. From the figures, it confirms that the density of power flux of MTN network is the strongest followed by Glo and Airtel GSM mobile has the least power flux density along the road of 91km being considered.

## V. CONCLUSION

Following the need to understand the radiation pattern of GSM signal and effect on human being, a GSM digital field instrument has been developed to measure GSM's power flux density. The instrument confirmed that the power flux density being radiated from antenna of MTN network is the strongest followed by Glo and Airtel networks has the least intensity along the 91kM route. It also showed that even at spikes from antenna, human health is safe. The continuity of the measurement was achieved due to repeated BTS along the distance covered.

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