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GSM signal performance using developed field instrument

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Abstract.
GSM (Global System for Mobile communication) is a digital mobile network that is widely used globally by mobile phone users. The GSM communication protocols used in Base Transceiver Station (BTS) could be harmful to human being and other life forms. It is essential to monitor power radiation levels from time to time of BTS for these systems could emit radiation beyond safety threshold.
Cellular network Base Transceiver Station (BTS) antennas are expected to operate without adverse health effects, they must comply with Electromagnetic Compatibility (EMC) standards as well as safety guidelines relating to exposure of non-ionizing radiation. To understand the behavioral pattern of non-ionizing radiation associated with the electric and magnetic fields of GSM signal, this research study developed a field instrument (i.e., GSM field meter) to measure electric and magnetic fields of two GSM carriers along 91km road network. The study provided a standard to monitoring the GSM carriers radiated signals in terms of service delivery and planning. The study confirmed that the signal strength of MTN is stronger than Airtel along the route covered during measurement. It also showed that the highest electric field created by spike is within regulated standard and does not affect human health.

Keywords: Electric field, Field instrument, Magnetic field, Base Transceiver station

Introduction

Global system for mobile communication (GSM) is a globally accepted standard, or protocol, for digital cellular communication, particularly for mobile cellular radio system operating at 900 MHz, which allows mobile phones to connect to other cells in the immediate vicinity. GSM standards were designed with cell phones in mind, yet it is the most widely used network technology in Internet of Things (IoT) because of its simplicity, affordability, and accessibility [1]. Whilst specialized networks have emerged to address the modern landscape of cellular connectivity, GSM was designed with a moderate level of security—cryptographic imperfections and radiation effects [2]. With decades of built-up infrastructure, GSM-based networks still offer good coverage across the 3G, 4G and 5G networks. However, the GSM communication protocols used in Base Transceiver Station (BTS) could be harmful to human species and other life forms in the ecosystem. The BTS used for these systems could emit radiation beyond safety threshold. Therefore, it is essential to monitor such power radiation levels from time to time. For cellular network Base Transceiver Station (BTS) antennas to operate as intended without adverse health effects, they must comply with Electromagnetic Compatibility (EMC) standards as well as safety guidelines relating to exposure of non-ionizing radiation. The maximum power density of any base station must be 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.

In their study, [3] emphasized the implication of failure to comply with the standards to human health. Many researchers have conducted studies to determine the level of EM field around BST to ensure that the level of EM field does not exceed the limit guidelines. There are other studies, including [4], [5] and [6] that have determined the safety distance that should be recommended as a guide for the development of residential areas and suitable for human activities. Such research is also supported by [6] who thought that a study on electromagnetic fields radiated from cellular phone base station antennas is very crucial to take precautions for human health.
Measuring equipment to determine radiation from GSM mobile communication system is an important factor because of widespread use of mobile phones all over the world. The measurement of power transmitted density of GSM is necessary to determine irregular anomalous and for maintaining the safety of people at the vicinity of the GSM masts.

Whatever the equipment, the radio wave intensity decreases rapidly as it travels away from the antenna. In free space, the intensity decreases to a quarter when the distance is doubled. The intensity reduces much more quickly than that due to the loss of signal strength (also known as 'attenuation') that is caused by having to pass through obstacles such as trees and buildings.
To understand the behavioral pattern of non-ionizing radiation associated with the electric and magnetic fields of GSM signal, this research study carried out measurements of GSM signals

using developed and localized GSM instrument. 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.

Materials and Method

We used the SIM800L GSM/GPRS module, ACS712 current sensor, and Magnetic Hall effect Sensor for the instrument development.

SIM808L is integrated with a high-performance GSM/GPRS engine, a GPS engine, and a BT engine. SIM808 is a quad-band GSM/GPRS module that works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz. SIM808L is designed with power saving technique so that the current consumption is as low as 1.2mA in sleep mode (with GPS engine powered down). SIM808L integrates TCP/IP protocol and extended TCP/IP AT commands which are very useful for data transfer applications.

ACS712 Current Sensor detects the current in a wire or conductor and generates a signal proportional to the detected current either in the form of analog voltage or digital output.

The Hall Effect sensor is a type of magnetic sensor which can be used for detecting the strength and direction of a magnetic field produced from an electromagnet with its output varying in proportion to the strength of the magnetic field being detected. Magnetic sensors convert magnetic or magnetically encoded information into electrical signals for processing by electronic circuits.

The instrument developed in Figure 1 was used to determine the electric and magnetic field strength from base stations of GSM signals from Akure, Ondo State, Nigeria to Akungba-Akoko, Akoko South-East, Ondo state, Nigeria of 91km as shown in Figure 2.

Figure 1: Digital GSM field Instrument

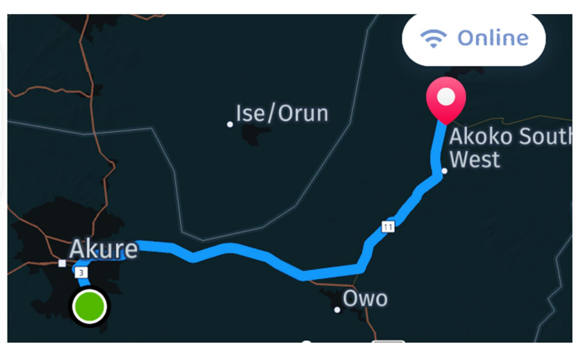

Figure 2: Distance covered of 91km

The research was conducted by using GSM fourth generation (4G) mobile SIM. The SIM of MTN and Airtel mobile communication, being two of the prominent service providers of GSM in Nigeria, were used for the measurement.

Results

The electric and magnetic field measured by the instrument estimated the strength of each service provider of GSM on human body along the road. The spikes are as a result of fundamental frequency signal, the harmonics and alternation which are due to resonance impulse conductor and convection. All these information are generated from the microwave communication and transmission. Figures 3 and 4 display both the electric and magnetic fields pattern of MTN GSM mobile communication while Figures 5 and 6 show the pattern of Airtel GSM mobile communication of 91km.

The results of the magnetic field, Figure 6, showed the near field and fades off as we moved away from BTS. Also, the electric field is the far field that has considerable strength as the instrument moves away from BTS. It is also relevant to state the spike shows the high strength and the lower ones show the fast fading signals as it shows the behavior of signals with time.

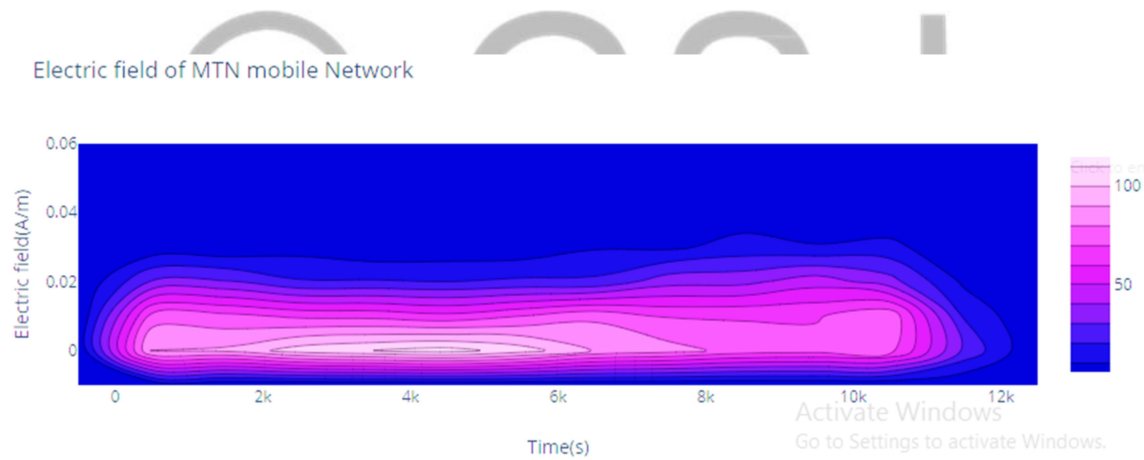

Figure 3: Electric field pattern of MTN mobile

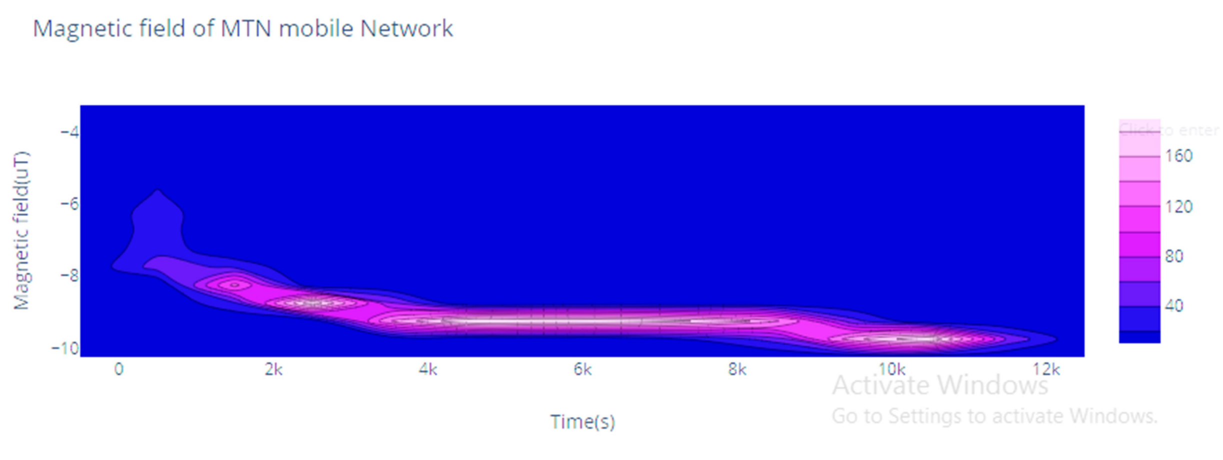

Figure 4: Magnetic field pattern of MTN mobile

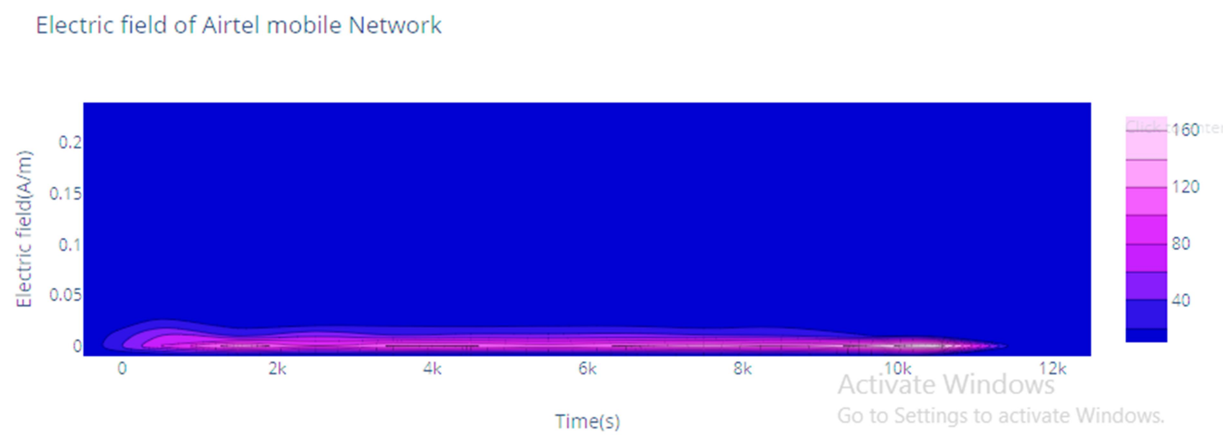

Figure 5: Electric field of Airtel mobile

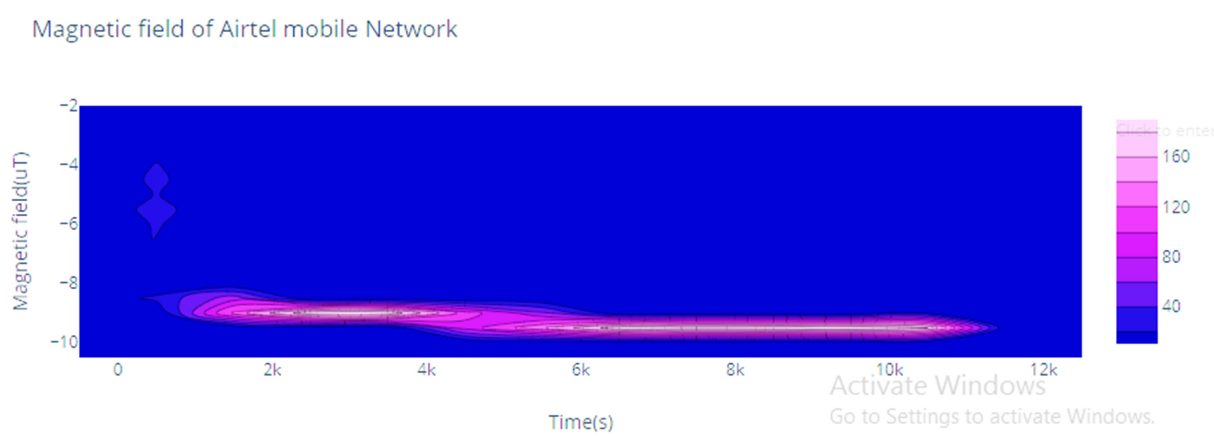

Figure 6: Magnetic field of Airtel mobile

Discussion

Radiofrequency electromagnetic fields allow the transport of large data volumes through vacuum and air, through solid matter to a certain extent, at a very fast rate—up to the speed of light—over large distances. Through these large distances of 91km, the signals are relayed by a communication network that comprises of base stations and other fixed wired network(s) along the road. Both the electric and magnetic fields are strongest close to an operating electrical source. In real-time, the magnetic field strength ($|f_s|$) decreases very rapidly with distance from the source and can be calculated (that is, as the inverse square of the distance, d, i.e., $|f_s| = d^{-2}$). At d=0, that is at base station, maximum radiation exposure occurs. As such, the developed measuring instrument received optimum signal strength**.** However, within close residential and business blocks, on the other hand, magnetic fields will vary as they are produced by electric currents whenever an appliance is operating, i.e., there is no magnetic field when an electrical appliance is turned off. From the figures, it is pertinent to confirm that the strength of electric and magnetic of MTN GSM mobile is much stronger than Airtel GSM mobile along the road of 91km being considered.

The strength of the electric field depends on the base station voltage, and since residential and business blocks are large and widely spaced, the electrical field strengths would vary or fluctuate.

Conclusion

The GSM field meter has successfully been developed locally to measure GSM's electric and magnetic field. The instrument confirmed that the signal strength of MTN is stronger than Airtel along the route covered during measurement. It also showed that the highest electric field created by spike is within regulated standard and does not affect human health. The continuity of the measurement was achieved due to repeated BTS along the distance covered.

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