International Journal of Research Studies in Electrical and Electronics Engineering(IJRSEEE)
Volume 4, Issue 4, 2018, PP 33-41
ISSN 2454-9436 (Online)
DOI: http://dx.doi.org/10.20431/2454-9436.0404004
www.arcjournals.org

Empirical Investigation of Field Strngth Spatial Coverage Variability in Mobile Radio Communication Networks

Anthony. Igbinovia[1], Joseph Isabona[2*]

[1] *Department of Physics, College of Education, PMB 1144 Ekiadolor-Benin, Nigeria.*

[2] *Department of Physics, Federal University Lokoja, PMB 1154, Kogi State, Nigeria.*

***Corresponding Author:** *Joseph Isabona, Department of Physics, Federal University Lokoja, PMB 1154, Kogi State, Nigeria.*

Abstract: *There is the need to continuously assess the coverage area of existing cellular networks' base station (BS) transmitters in a multipath propagation environment. This arises as a result of continuous changes in the radio communication paths due to different propagation mechanisms, changing foliage conditions, equipment deterioration as well traffic growth, all of which impact the radio frequency (RF) performance properties of the operational wireless radio networks. This is also particularly important in this transition shifting phase era in the telecommunication industry where network service operators has been rolling out different multimedia services to meet the subscribers demand. The shift has been fuelled by the technological advancement in the sector, starting from narrowband second generation system networks such as GSM in the early 90's to contemporary mobile broadband UMTS/HSPA/LTE networks. This work aim to practically investigate the spatial variations of electric field strength coverage over some randomly selected UMTS/HSPA BS transmitters operational in a typical Nigerian urban environment. Signal levels were measured with the drive test tools and then adapted to field strength in dBμV/m for coverage evaluation. From the results, the network delivered 70%, 6.7% 5.6%, and 6.7% on primary signal coverage, respectively in BS locations. The results has also pointed out the area around the BS transmitters where the signal coverage might not be strong enough to compensate for multipath fading and interference. The results can be used to exploit the best possible configurations for antenna heights, tilts and engineering parameters setting for all present cells/sectors in the networks.*

Keywords: *Electric field Strength, Spatial variation of field strength, Network coverage area.*

1. Introduction

The performance of modern wireless communication networks is critically influenced by the propagation channels in which they operate and this poses a severe challenge as a medium for reliable high speed communication. One of most key parameters for system performance evaluation wireless communication networks is the received field strength at mobile station (MS) terminals. In radio propagation channels, spatial and temporal variations of signal levels are usually observed on three main scales. The first is signal variation over small areas due multipath fading or fast fading; the second is signal variations over small area average due shadowing or slow fading; and the third is signal variations over very large distances due propagation path loss [1].

Propagation path loss is the unwanted decrease in field strength level between transmitter and receiver due interaction between radio signals and environment. This in turn places limits on the systems coverage area. In general, a MS receiver is able to tolerate loss if field strength level if does not go below the threshold level. The field coverage, therefore, has to be studied to obtain good QoS.

Shadowing is the loss of field strength typically contributed to a diffracted wave emanating from an obstacle between transmitter antenna and receiver antenna [2]. Shadowing causes drops in received power, depending on motion speed, that can last several seconds. If the signal is shadowed by an impenetrable obstacle where the drop level is several tens of dB lower, it is usually called "blockage" instead [1]. As the MS moves in the coverage area of the BS, large blockages such as buildings may chunk the propagation path between the BS and MS causing fluctuations on the received signal level, i.e., shadowing the received signal. Because shadowing relates with the position of large obstacles in the coverage area, it is position-dependent and spatially correlated [3].

On the other hand, multipath fading is a phenomenon caused as a result of the combined effort of constructive and destructive radio propagation mechanisms on the signal components before reaching the receiving antenna. Subject to the nature of the multipath propagation environment, as the signal travel from different routes to the receiver, each with a different phase due to different path length and with different strength, they constructively or destructively interfere and their sum creates variations in received signal. The multipath creates the most difficult problem in mobile radio communication networks.

Moreover, the degree to which the aforementioned factors impact radio propagation also depends largely on the frequency of the radio wave and the polarization [4]. These factors in turn attenuate the field strength coverage area, thus placing limitations on the entire radio services and performance.

2. METHODOLOGY

2.1. Background

There are three critical elements that influence the performance of both voice and data wireless communication networks. They are: radio frequency (RF) signal strength coverage levels; radio interference level (both forward link and reverse link); and available radio channel capacity [5], [6]. To provide any sort of reliable service at the user mobile terminals, the signal strength coverage level of both forward link and reverse link transmissions must be sufficiently above thermal RF noise level. This is to allow for successful retrieval of the modulated information stream [7].

Generally, the signal coverage areas of BS antennas can be categorized into three, namely primary, secondary and fringe areas. The primary coverage area is defined as an area around the BS transmitter where the signal strength is very strong to dominate all forms of interference within its deployment range. Also, it corresponds to the area in which the electric field signal strength is at least 60 dBµV. As opined in [8], the QoS enjoyed in this area can be regarded as Grade A1. The signal strength threshold required for optimal QoS performance is also influenced by transmit power, receiver sensitivity, noise and interference, atmospheric conditions, as well as the physical environment

The secondary coverage area comprises of an area where the field strength is often available for use but not strong enough to completely outweigh multipath interference. According to [9], the secondary coverage area corresponds to the area around the transmitter where the electric field strength is at least 30 dBµV, but less than 60 dBµV.

The fringe areas are the areas along the cell edge of coverage contours where radio signal reception begins to degrade. This is an area where the signal strength is in the range of 0dBµV and 30 dBµV. Such an area may be said to enjoy Grade B2 service [9]

2.2. Related Work

Spatial and temporal variation of field strength coverage analysis on signal broadcasting stations (BS) has been conducted and reported in several papers for different aim and objectives.

In [10], spatial analysis of signal strength variation over wireless communication medium for indoor geolocation system was presented. The authors reported that mathematical formulae do not give accurate result when analyzing signal strength variability in wireless communication. In [11], local field strength measurement campaign has been conducted on a digital terrestrial television COFDM 8K system in Madrid, Spain with the aim of surveying the field strength spatial variation over the coverage area. Similar approach have been employed in [9] and [15] to investigate the spatial variability of VHF/UHF electric field strength signal coverage of television stations transmitters in Niger State and Katsina, Nigeria respectively. In [12], spatial and temporal variation of the RFID accuracy with different numbers of readers was examined to interpolate the location of weak signal area of a warehouse in Hazelmere, Western Australia, using Kriging method. The authors concluded that the ideal gap distance between two readers is 20m.

In [13], spatial distribution of the electric field in northern England and Southern Scotland was carried with the aim of predicting the flow of geomagnetically induced currents (GIC) in power networks. The analysis of their results reveals qualitatively the pervasive effects of electric field distortion in the region. In [14], the conducted signal strength measurements campaign using remote sensing and GIS techniques to estimate and predict signal coverage variation over mobile communication network in coastal district Udupi of Karnataka state, India. It is found that RS and GIS oriented techniques can considerably improve signal strength prediction as compared to existing theoretical free space model.

This study investigates the spatial variations of electric field strength signals captured around four operational UMTS/HSPA base station (BS) transmitters randomly selected in microcellular urban environment. The aim is to determine the level of the propagated signal coverage and quantify its spatial variability in studied microcellular urban environment. This is a major first step towards solving wireless mobile network coverage and service quality issues in the study locations.

The main contribution of this work is the empirical – based evaluation of the propagated signal coverage level and its spatial variability quantification in studied microcellular urban environment with wideband field measurements. Such approach is a major first step towards solving wireless mobile network coverage and service quality issues in the study locations. This is also an important consideration to optimize the planning of on the existing networks and effective deployment of future broadband cellular networks in different radio propagation environmental scenarios.

2.3. Measurement Campaign

Measurements campaign was conducted with drive test tools. Drive testing is a method of measuring and assessing the cell coverage, and service quality of a mobile radio network. It is implemented by using drive test tools to take measurement of radio network performance around a given location with the use of a car. The test tools consisted of Sony Ericson Mobile handset, Test cable, Laptop, Socket, Compass, Power inverter, Global Positioning System GPS, MapInfo digital maps and a Vehicle. For the measurement procedure, a Sony Ericson Mobile phone was connected to a laptop running the TEMS software. This application acquires signal strength samples from a moving subscribers' point of view around the investigated BS transmitters. The accuracy of the received signal strength is within 1dB. Average height of the investigated BS antenna ranged from 32 – 45 meters above ground level, with comparatively same transmit power. In all the study locations, BS was equipped three sectored antennas with inbuilt features, which enables them to radiate in three directions at 1800MHz. Location of the BS antenna was a parameter for site selection.

Four BS locations, namely location 1, 2, 3 and 4 were randomly selected for this study and depended on the accessibility of the testing to a particular location and outside building façades.

All measurement values which were recorded in dBm and were converted to field strength data in dBμV/m for coverage evaluation with the formula expressed in equation (1) to (3) as given by [16]:

$$\mathrm{Pr} = G\left(\frac{\lambda}{4\pi}\right)^2 \frac{E^2}{30} \tag{1}$$

Since $\lambda = \frac{C}{f}$, where λ is the wavelength in meter, C being the speed meter/second, and f the frequency in Hertz, then equation (1) can be rewritten as:

$$\mathbf{Pr} = G\left(\frac{C}{4\pi f}\right)^2 \frac{E^2}{30} \tag{2}$$

The expression in equation (2) can rearranged and written in dBμV/m as:

$$E(\mathrm{dB\mu V/m}) = \mathrm{Pr}(dBm) + 20\log(MHz) - G(dB) + 77.2dB \tag{3}$$

3. Result and Analysis

In figures 1-4, the electric field strength obtained from measured signal data is plotted as a function of transmitter-receiver distance at each measurement and study location. As expected, it is observed that the field strength attenuates and decreases as receiver moves away from the base station transmitters with high variations in the measured data values.

The large variation in field strength is an indication that the area is highly shadowed with obstructions. The variations may also be attributed to moving objects (e.g cars, persons), density of mobile phones users and differences in physical parameters such as the base station transmit power and type height, in the area.

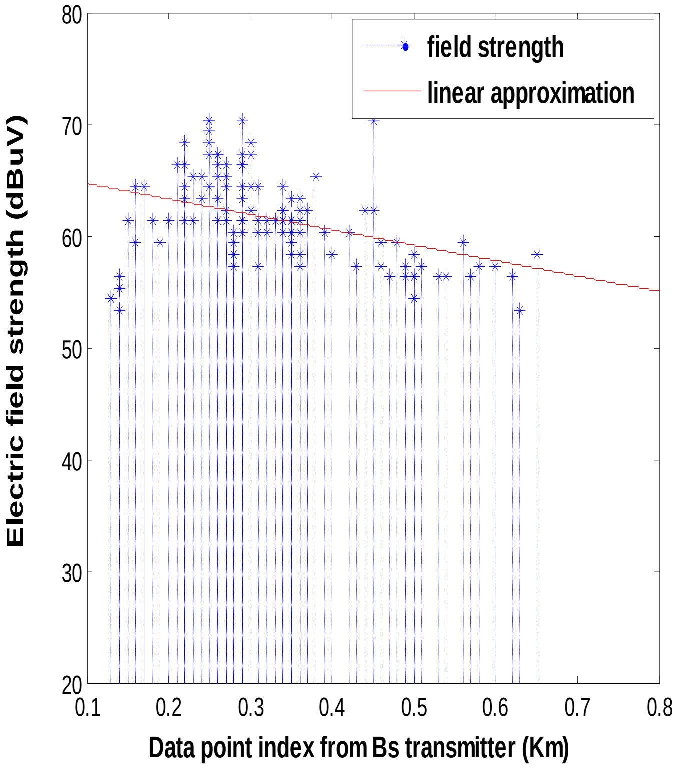

Figure1. *Electric field strength versus transmitter-receiver distance, location 1*

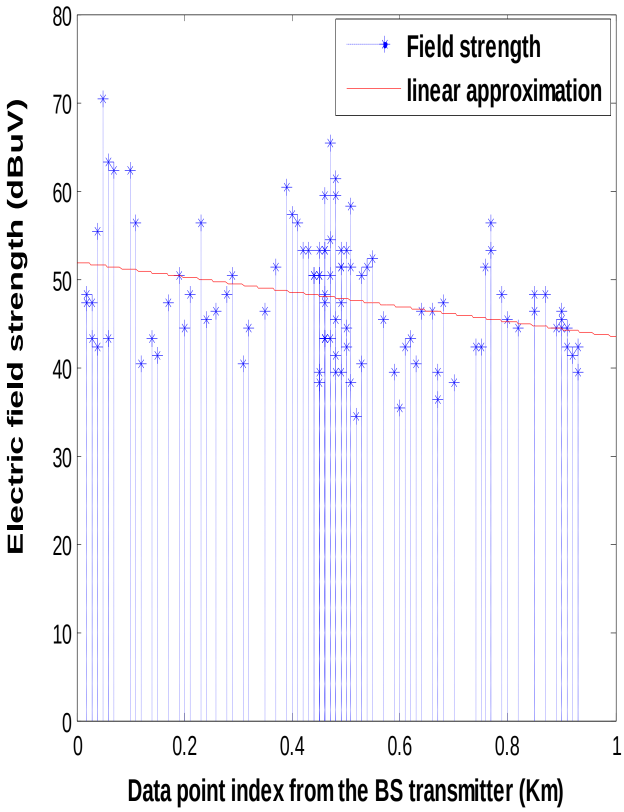

Figure2. *Electric field strength versus transmitter-receiver distance, location 2*

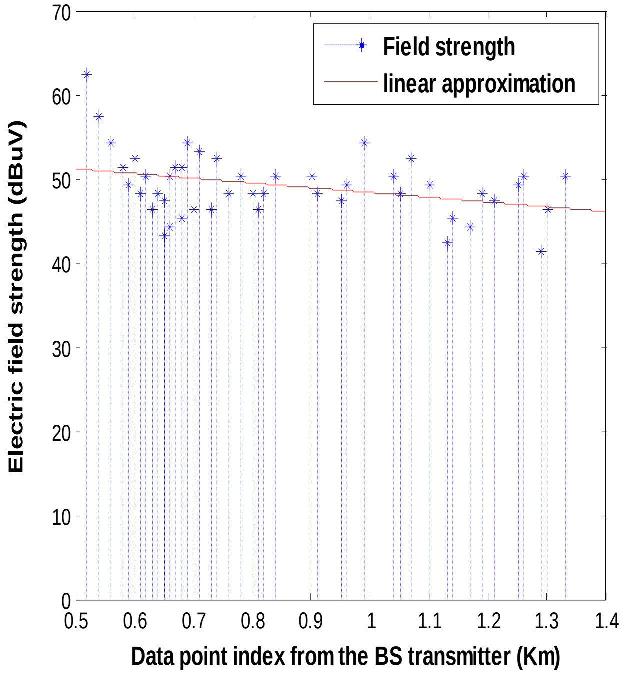

Figure3. *Electric field strength versus transmitter-receiver distance, location 3*

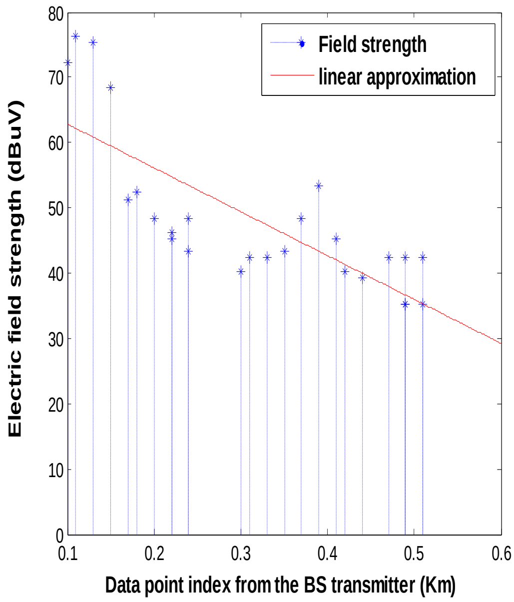

Figure4. *Electric field strength versus transmitter-receiver distance, location 4*

Shown in figures 4- 6 and table 1 is the summary of the coverage performance distribution in dBµV in each study location. It can been from the results in table 1 that the BSs delivered 70%, 6.90%, 2.80% and 20.80% primary signal coverage in each study locations respectively. This performance implies that it is only location 1 that the BS a high coverage measure (i.e. 70%) whose signal strength is very strong enough to dominate ordinary interference in the locality at all times. The other three BSs provided about 93%, 97% and 80% secondary signal coverage respectively. In such areas, the service cannot be guaranteed nor be protected against signal multipath interference [9]. Thus, to receive good signals in these areas, it is advised to deploy high antenna gain antennas with heights above the surrounding buildings and obstacles within the area. Also, from the results summary presented in figure 9 and table 1, it is clearly seen that none of the BSs radio signals fall within the fringe service area. The radio network subscribers within this signal coverage area may be said to enjoy Grade B2 service. In that case, the signal strength is greater than 0 dBµV, but less than 30 dBµV.

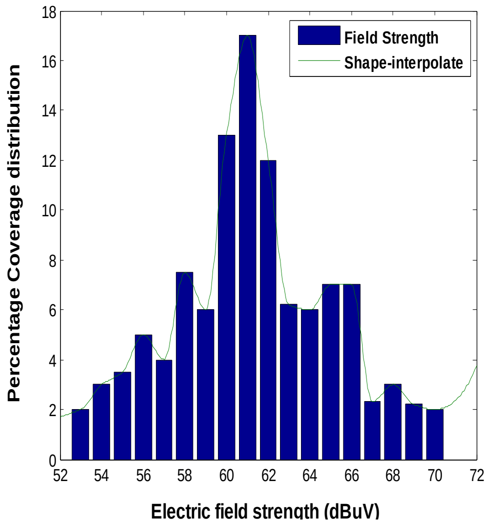

Figure5. *Percentage Distribution of the Field Strength coverage of BS in location 1*

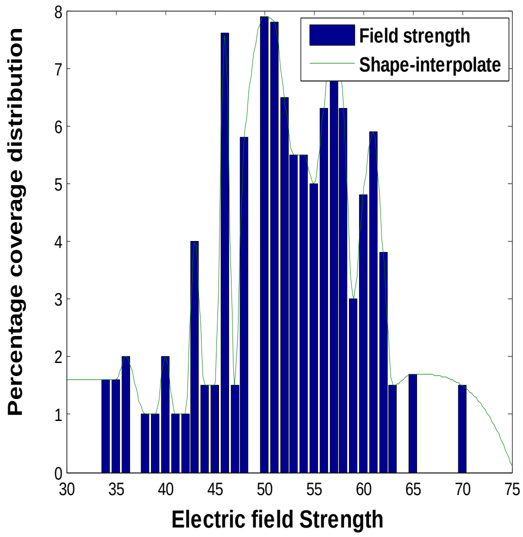

Figure6. *Percentage Distribution of the Field Strength coverage of BS in location 2*

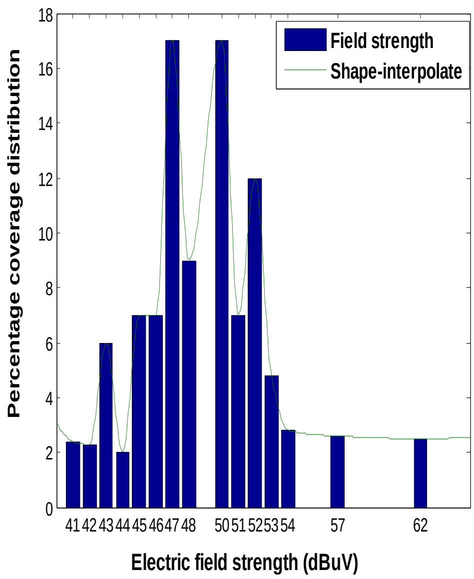

Figure7. *Percentage Distribution of the Field Strength coverage of BS in location 3*

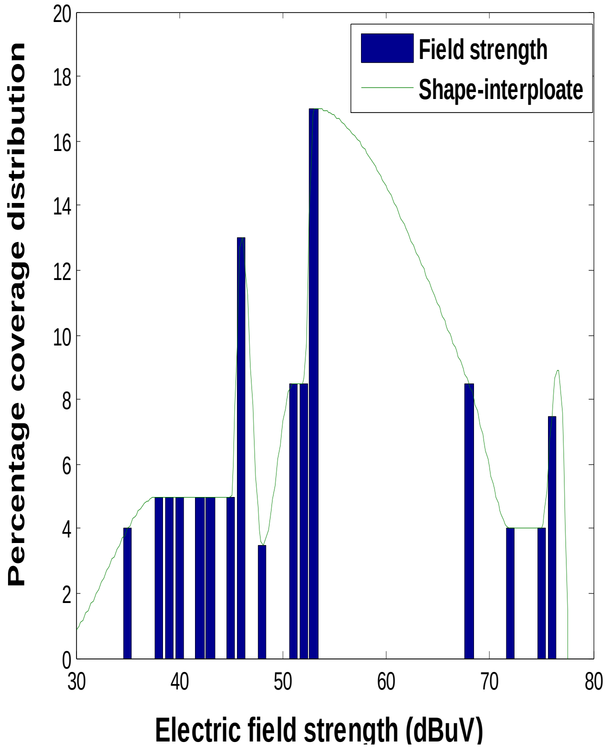

Figure8. *Percentage Distribution of the Field Strength coverage of BS in location 4*

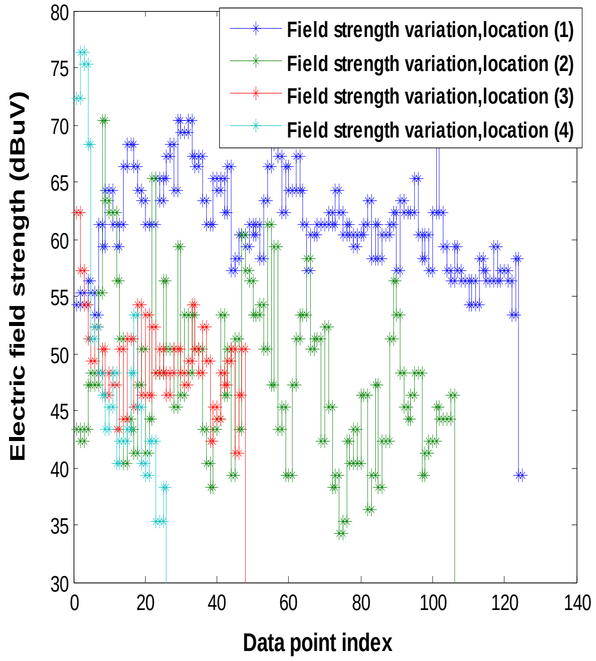

Figure9. *Percentage Distribution of the Field Strength coverage of BS in location 4*

Table1. *A summary of Percentage Distribution of the Field Strength coverage in each BS*

BS location	Primary coverage area, E > 60 dBµV	Secondary coverage area, 60 dBµV > E > 30 dBµV	Fringe coverage area (30 dBµV > E > 0 dBµV)
Location 1	70.30	29.70	NIL
Location 2	6.90	93.10	NIL
Location 3	2.10	97.90	NIL
Location 4	20.80	80.00	NIL

4. CONCLUSION

By investigating of a radio signal, we can better plan and diagnose networks as well as build futuristic networks that adapt to the spatiotemporal radio environment. Such information is needed by the network operators to maintain a reliable communication link and thus, provide good quality of service (QoS) at the mobile station (MS) terminals as well as build futuristic networks that adapt to the spatiotemporal radio environment, it important to carry out. The results has been able to point out locations where the signal coverage area might not be strong enough to overcome interference completely at all times.

It is recommended that the network provider should install additional base stations to increase their service coverage. The base stations transmit power and antenna orientation or elevation can as well be adjusted to boost received signal levels at the mobile terminals. Further measurement campaigns be conducted to test and investigate receiver sensitivity and this is slated for further study.

REFERENCES

[1] Armoogum V., Soyjaudah K.M.S., Mohamudally N., Fogarty T. Propagation Models and Their Applications in Digital Television Broadcast Network Design and Implementation, Trends in Telecommunications Technologies, Bouras (Ed.), 2010.

[2] Saunders, S. R. Antenna and Propagation for Wireless Communication Systems. John Wiley and Son LTD, 2nd edition, 2007.

[3] Y. C. B. Silva, T. F. Maciel, and F. R. P. Cavalcanti, Radio Resource Management Performance for the GSM/EDGE Radio Access Network, Optimising Wireless Communication Springer LLC pp. 52-94, 2009.

[4] J. R. Woodroffe and R. L. Lysak, Ultra-low frequency wave coupling in the Ionospheric Alfven resonator: Characteristics and implications for the interpretation of ground magnetic fields Journal of Geophysical Research, vol. 117, pp. 1-10, (3), 2011.

[5] Hall, M.P.M.: Overview of Radio wave propagation. In: Hall, M.P.M. and Barclay, L.W. (Ed); Radio Wave Propagation - (IEE Electromagnetic Wave Series). Peter Peregrinus Ltd, London, United Kingdom, pp. 121 1991.

[6] A. R. Mishra, Fundamentals of Cellular Network Planning & Optimization", John Willey & Sons, Ltd, 2004.

[7] Hongxia Sun and Carey Williamson, "Simulation Evaluation of Call Dropping Policies for Stochastic Capacity Networks", Department of Computer Science University of Calgary, Calgary, AB, Canada T2N 1N4, 2005.

[8] Joseph M. Mom, Nathaniel S. Tarkaa and Cosmas I Ani, The effects of Propagation Environment on Cellular Network Performance American Journal of Engineering Research, Vol.2, Issue-09, pp-31-36, 2013.

[9] Ajewole O.M, Oyedum O.D and Adediji, A.T, Spatial Variability of VHF/UHF Electric Field Strength in Niger State, Nigeria, International Journal of Digital Information and Wireless Communications (IJDIWC) vol. 3(3): 231-239, 2013.

[10] A. Arrinda, M. M Vélez, P. Angueira, D. de la Vega, J. L. Ordiales, Local Area Field Strength Variation Measurements of the Digital Television Signal (COFDM 8K) in Suburban Environments, IEEE Transactions on Broadcasting, vol. 45 (2), pp. 386 – 391, 1999.

[11] A. Akinbolati, M.O. Ajewole , A. T. Adediji and J. S. Ojo, Determination and Classification of Coverage Areas of Terrestrial UHF Television Transmitters in Ondo State, Nigeria, IOSR Journal of Applied Physics (IOSR-JAP),Vol. 7 (4), pp. 16-26, 2015.

[12] X. Liu, J. Shannon, H. Voun, M. Truijens, H. Chi and X. Wang, Spatial and Temporal Analysis on the Distribution of Active Radio-Frequency Identification (RFID) Tracking Accuracy with the Kriging Method, Sensors, vol. 14, pp.20451-20467, 2014.

[13] A. J. McKay and K. A. Whaler, The Electric Field in Northern England and Southern Scotland: implications for geomagnetically induced currents, Geophysics Journal International, vol. 167, pp. 613–625, 2006.

[14] B. Naveenchandra, K.N Loesh, Usha and H. Gangadhara Bhat, Signal Strength Measurements and Coverage Estimation of Mobile Communication Network Using IRS-IC Multispectral and CARTOSAT-1Stereo Images, Geospatial World Forum, January 18-21, Hyderabad, India, 2011.

[15] .Ajayi, G.O. and Owolabi, I. E.: Coverage Area of the 10kW, 702 kHz Medium Wave Transmitter at Minna and Feasibility Studies for full Radio Coverage of Niger State". Technical Report of the Electrical Communication Consultancy Unit (ECCU), Department of Electrical and Electronics Engineering, University of Ife, Nigeria, pp. 1-2, 1979.

[16] J. Isabona and G.P. Isaiah, Computation and Verification of Propagation Loss Models based on Electric Field Data in Mobile Cellular Networks, Australian Journal of Basic and Applied Sciences, 9(31), pp.280-285, 2015.

Citation: *Anthony. Igbinovia , Joseph Isabona, "Empirical Investigation of Field Strngth Spatial Coverage Variability in Mobile Radio Communication Networks", International Journal of Research Studies in Electrical and Electronics Engineering, 4(4), pp 33-41. DOI: http://dx.doi. org/10.20431/2454-9436.0404004*