

# Evaluation of the Distribution of Terrain Roughness Index for Terrestrial Line of Site Microwave Links in Uyo Metropolis

Akinloye Bolanle Eunice<sup>1</sup>, Simeon Ozuomba<sup>2\*</sup>, and Ezenugu Isaac A.<sup>3</sup>

<sup>1,2</sup>Department of Electrical/Electronic and Computer Engineering, University of Uyo, AkwaIbom, Nigeria.

<sup>3</sup> Department of Electrical Engineering, Imo State University (IMSU), Owerri, Nigeria.

<sup>1</sup>bolanle\_ayomi@yahoo.com, <sup>2</sup>simeonoz@yahoo.com, <sup>3</sup>isaac.ezenugu@yahoo.com

\*Corresponding Author: <sup>2</sup>simeonoz@yahoo.com

## Abstract

*In this paper, the distribution of terrain roughness index in Uyo metropolis is presented. The path (elevation) profiles of various regions or areas in Uyo are captured and then used to compute the terrain roughness index. According to the results, the terrain roughness index of the five signal paths studied within Uyo metropolis are 5.12m, 8.13m, 17.08, 18.63m and 21.11m. Generally, terrain roughness index less than 50ft or 15m is considered smooth terrain whereas those above 50ft or 15m are considered rough terrain. Therefore, among the five paths considered in this study, two paths smooth terrains while three paths are rough terrains of varying degrees of roughness. In all, Uyo metropolis has both smooth and rough terrains which will present different degrees of multipath fading for wireless signals.*

**Keywords:** Terrain roughness index, path profile, elevation profile, multipath fading, geoclimatic factor.

**Subject Codes:** 68U01.

## 1 Introduction

Available studies show that terrain roughness index significantly affect the value of geoclimatic factor and hence, the multipath fading and link availability due to multipath fading [1, 2, 4, 5]. The relationships between the terrain roughness index and the geoclimatic factor and hence the multipath fading and link availability due to multipath fading are captured in the International Telecommunication Union-Radiocommunication (ITU-R) Rec. P.530 [4, 6,7,8,5].

Researches have also shown that wireless signals experience higher multipath fading in smooth terrains than in rough terrains [9, 10, 11]. Among the various models for predicting multipath fading, namely, Barnett-Vigants fading model [12, 13, 2], Morita Model [14, 2], and Rec. ITU-R P.530 Model [2, ITU, 2013), the fade depth experienced by wireless signals increases with increase in

geoclimatic factor [2]. In each of the three models, the geoclimatic factor for smooth terrain is higher than that of rough terrain. The geoclimatic factor over water surface is higher than both the one on smooth surface and rough surface [2]. In this wise, careful selection of the signal path is essential, especially for line-of-sight communication systems. In the telecommunication industry, the terrain roughness index is one way of characterising the roughness of different environments. In the Morita Model [14, 2], certain constant values are used to define the terrain roughness. In the Barnett-Vigants fading model [12, 13, 2] certain constant values are used to define the combined terrain roughness and climatic condition of the environment. However, in the ITU Rec. ITU-R P.530 Model [2, 15], terrain roughness index is used to specify the roughness of the environment.

According to [3] terrain roughness index ( $S_a$ ) is defined as the standard deviation of terrain heights (m) or terrain elevations (in meters) within a 110 km x 110 km area mentioned in Rec. ITU-R P.530 [6, 1, 2, 15, 3]. In this paper, the path (elevation) profiles of various regions or areas in Uyo are captured and then used to compute the terrain roughness index. The focus of the paper is to determine the distribution of terrain roughness index in Uyo metropolis. This result obtained from this paper is relevant to network planners who may will to know or select the signal path with minimum multipath fading.

## 2 Methodology

The expression for terrain roughness index can be expressed with respect to the distance in kilometres and the elevations in meters and also with respect to the distance in miles and the elevations in feet. In this section the analytical expressions for determining terrain roughness index with respect to distance in kilometres and elevations in meters are presented. Let the distance in kilometres at the transmitter be  $d_{km(tx)}$  and the distance in kilometres at the receiver be  $d_{km(rx)}$ . The distance can be measured from the transmitter or from the receiver. Also, let  $n_j$  be the total number of kilometres in the distance between the transmitter and the receiver, thus:

$$n_j = \lfloor d_{km(tx)} - d_{km(rx)} \rfloor \quad (1)$$

$\lfloor \ ]$  Stands for rounding down to the nearest integer.

Let  $d_{km(j)}$  be the distance in kilometres at the  $j$ th kilometre, where  $j = 1, 2, 3, \dots, n_j$ .

Let  $E_{m(j)}$  be the elevation in meter at the  $j$ th kilometre, where  $j = 1, 2, 3, \dots, n_j$ .

Let  $M$  be the mean elevation in meters of all the  $E_{m(j)}$  where  $j = 1, 2, 3, \dots, n_j$ .

Hence,

$$M = \frac{\sum_{j=1}^{j=n_j} [E_{m(j)}]}{n_j} \quad (2)$$

Let  $S_{a(m)}$  be the terrain roughness index in meters and  $\sigma$  be the standard deviation of the path profile. Then

$$S_{a(m)} = \sigma = \sqrt{\left[ \frac{\sum_{j=1}^{j=n_j} [E_{m(j)}]^2}{n_j} - M^2 \right]} \quad (3)$$

### 3 Description of the Study Tools and Procedure

Terrain roughness index is computed from elevation data for the given terrain studied. The elevation data set for the given location is generated using Geocontext Online Elevation software available at: <http://www.geocontext.org/publ/2010/04/profiler/en/>. The elevation data is generated by entering the longitude and latitude of the start point (transmitter) and end point (receiver) of the line of site path into the source and destination coordinates textboxes on the Geocontext online elevation software. The elevation data set generated by the Geocontext online elevation software includes 512 data points specified by:

- i. Longitude and latitude
- ii. Distance of each of the data point (Longitude and latitude ) from the starting point's longitude and latitude
- iii. The elevation at each data point above sea level as the reference plane.

The terrain studied is located in Uyo metropolis in Akwa Ibom state, Nigeria. A common start point is selected for five different lines of site paths, each with path length of about 21Km. The common start point is at University of Uyo Town Campus at Ipka Road in Uyo metropolis. Path 1 and Path 4 pass through ravine; the two paths are close to each other and their end point is also very close to each other. The two paths are selected to examine how the differences in topology in a given terrain can be considered in selecting alternative path for wireless signal. The other three paths are selected to be at about  $90^\circ$ ,  $180^\circ$  and  $270^\circ$  from Path 1.

The procedure adopted for the study is as follows:

- i. The start point and end points of the five different paths are identified and their longitude and latitude are obtained using Google map. Specifically, with the use of Google map's distance tool, the paths coordinates are selected such that each of the path is approximately 21Km long.
- ii. The 521 elevation profile data points are generated using the Geocontext online elevation software available at: <http://www.geocontext.org/publ/2010/04/profiler/en/>.
- iii. The Kilometre mark points are identified on the 521 elevation profile data points for each of the path. The Kilometre mark points captures the elevation data at each kilometre apart along the path. So, for the 21 Km path, a total of 21 Kilometre mark points are captured. In particular, for the terrain roughness index computation, the end point of the path is not included in the Kilometre mark count. As, such, only the first 20 of the Kilometre mark points are used in the terrain roughness index computation.
- iv. For each of the five paths, the graph of elevation (in meters) versus distance (in meters) for the 521 elevation profile data points is plotted along with the graph of the elevation (in meters) versus distance (in meters) for the 20 data points for the Kilometre mark points.
- v. Five-in-one graph of the elevation (in meters) versus distance (in meters) for the 20 data points for the Kilometre mark points for all the five paths are plotted for comparative analysis.

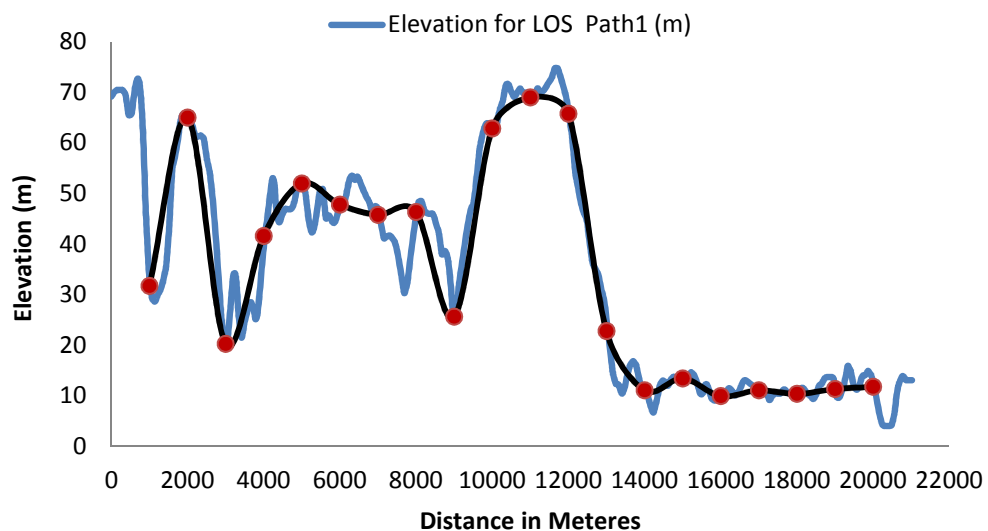
## 4 Results and Discussions

The Google map of the five lines of site paths in Uyo metropolis, Akwa Ibom State, Nigeria is given in Figure 1. According to Figure 1, all the five paths have a single start point, which is located at the center point. The common start point is at University of Uyo Town Campus at Ipka Road in Uyo metropolis. Also, Path 1 and Path 4 are separated by very small angle and the two paths ended almost at the same distance from the common start point. Particularly, Figure 1 is the Google map plot for the 20 data points for the Kilometre mark points for all the five paths.



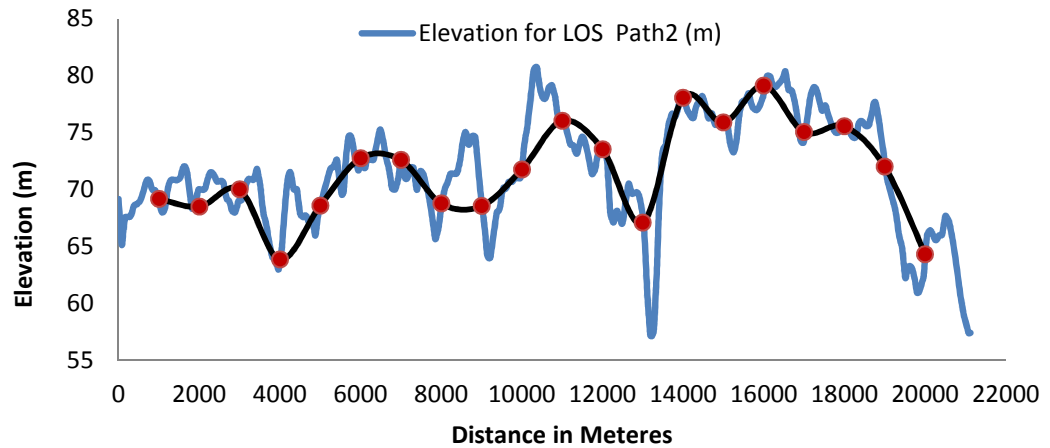
**Figure 1 The Google Map Of the five Line of Site Paths in Uyo Metropolis, Akwa Ibom State, Nigeria**

Figure 2 is the graph plot for (i) the full 521 elevation profile data points for path 1 and (ii) the 20 data points for the Kilometre mark points for path 1. The graph given the elevation in meters versus distance of the data point from the common start point.

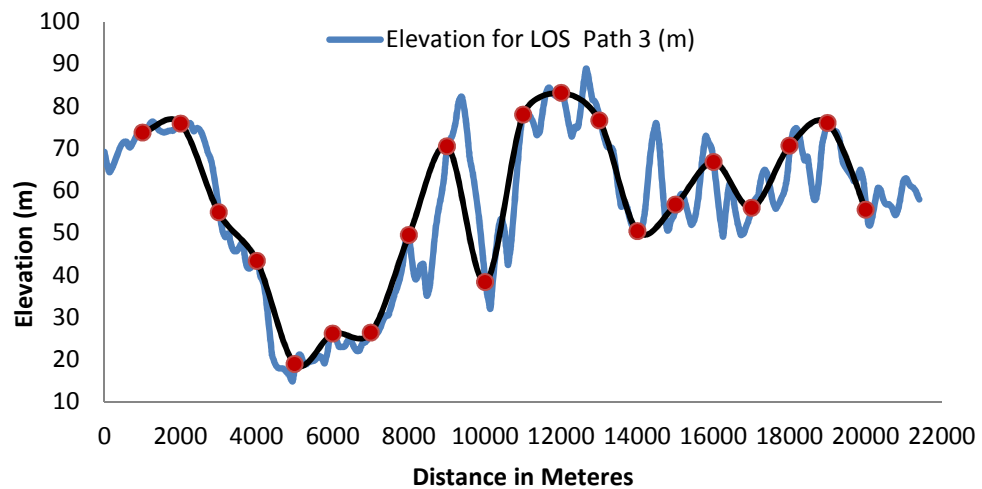


**Figure 2 Elevation in Meters versus Distance in Meters For The Line of Site Path 1 in Uyo Metropolis**

Similar graph the given in Figure 3 for Path 2; Figure 4 for Path 3; Figure 5 for Path 4 and Figure 6 for Path 5. Based on the variations in elevation as shown in the five graphs, Path 1, Path 3 and Path 4 have very high variations in their elevations as compared to Path 2 and Path 5 which show mild variations in their elevation profiles.

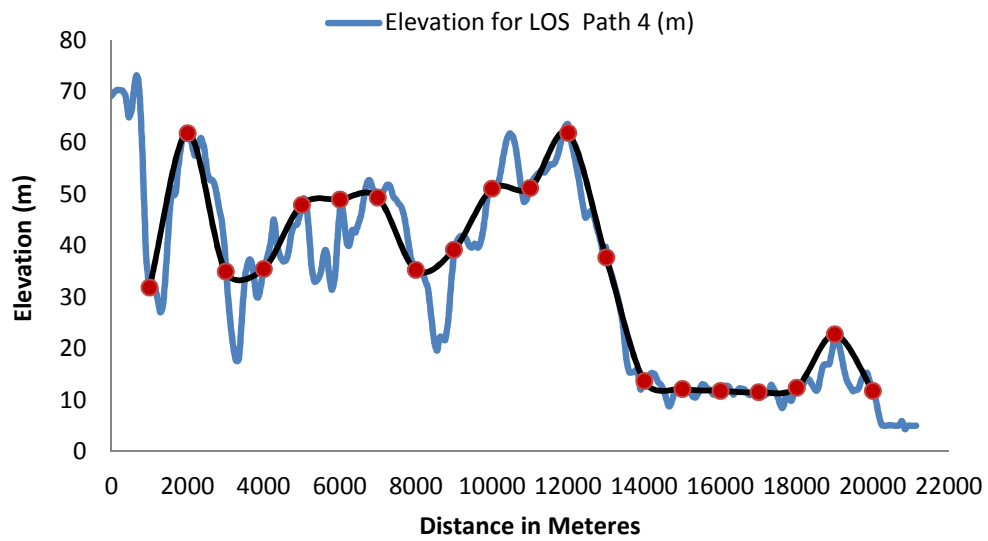


**Figure 3 Elevation in Meters versus Distance in Meters For The Line of Site Path 2 in Uyo Metropolis**



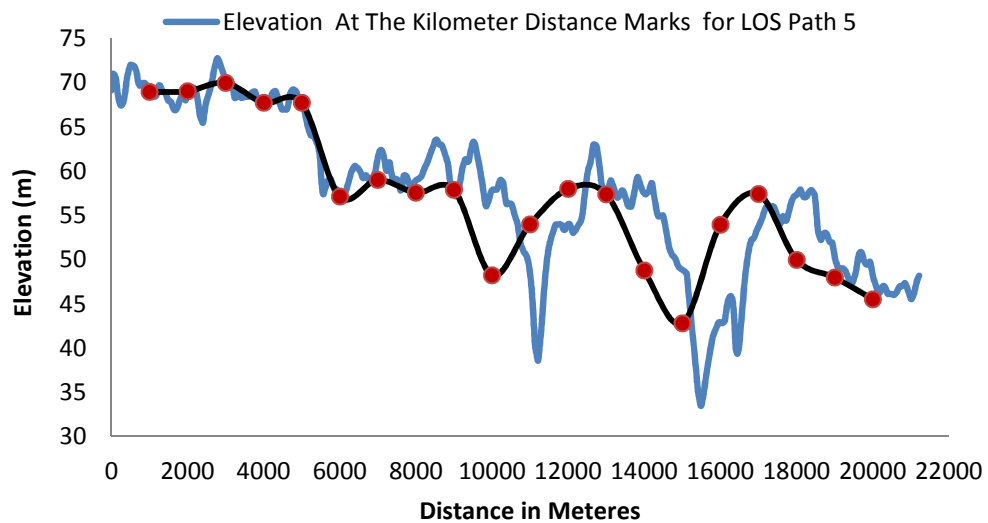
**Figure 4 Elevation in Meters versus Distance in Meters For The Line of Site Path 3 in Uyo Metropolis**

The table and the graph plot for the 20 data points for the Kilometre mark points for all the five paths are given in Table 1 and Figure 7 respectively. The Terrain Roughness Index in Meters is also given in Table 1 and bar chart of Figure 8 for all the five paths.



**Figure 5 Elevation in Meters versus Distance in Meters For The Line of Site Path 4 in Uyo Metropolis**

According to the results in Table 1, Path 2 has the lowest Terrain Roughness Index of 5.12m whereas; Path 1 has the lowest Terrain Roughness Index of 21.11m. Essentially, among the five paths studied, Path 2 is the smoothest path whereas; Path 1 is the roughest path.



**Figure 6 Elevation in Meters versus Distance in Meters For The Line of Site Path 5 in Uyo Metropolis**

According available literature, smother paths tend to present higher multipath fading to wireless signals than the rough terrain. In essence, Path 2 will present the highest multipath fading to wireless signals when compared to the other four paths.

Table 1 The 20 Data Points for the Kilometre Mark point in the five Paths

Distance (m)	Path 1 Elevation (m)	Path 2 Elevation (m)	Path 3 Elevation (m)	Path 4 Elevation (m)	Path 5 Elevation (m)
1000	31.68575	68.4838	73.75299	31.86246	68.96622
2000	64.99406	70	75.83878	61.88184	69.04246
3000	20.21681	63.83657	54.82764	34.94558	70
4000	41.59086	68.57876	43.3659	35.49871	67.7502
5000	51.96056	72.74394	18.9559	47.96029	67.74522
6000	47.805	72.58723	26.13521	49.01006	57.15655
7000	45.75122	68.77907	26.35727	49.38618	59.02235
8000	46.32207	68.53896	49.47253	35.26981	57.59133
9000	25.59465	71.75354	70.44325	39.20508	57.89155
10000	62.85514	76.03184	38.3413	51.10257	48.24907
11000	69.00477	73.53318	77.99403	51.22475	54
12000	65.75185	67.06755	83.10683	61.92402	57.99893
13000	22.75914	78.06748	76.60138	37.69515	57.39184
14000	11.02625	75.89356	50.419	13.68072	48.76924
15000	13.38775	79.13271	56.67532	12.11353	42.82029
16000	9.881839	75.03377	66.76323	11.75838	53.97559
17000	11.03204	75.55434	55.94129	11.48701	57.43724
18000	10.32909	72.01633	70.62914	12.37992	49.99115
19000	11.27607	64.29501	75.99307	22.74559	47.97047
20000	11.7062	57.89917	55.47312	11.71941	45.5367
Terrain Roughness Index in Meters [Sa(m)]	21.11	5.12	18.63	17.08	8.13

On the other hand, Path 1 will present the lowest multipath fading to wireless signals when compared to the other four paths. It is worthy to note that Path 4 has Terrain Roughness Index of 17.08m which is smaller than that of Path 1 despite the fact that the two paths are very close to each other.

In essence, Path 1 will present the higher multipath fading to wireless signals when compared to Path 1. Generally, terrain roughness index less than 50ft or 15m is considered smooth terrain whereas those above 50ft or 15m are considered rough terrain.

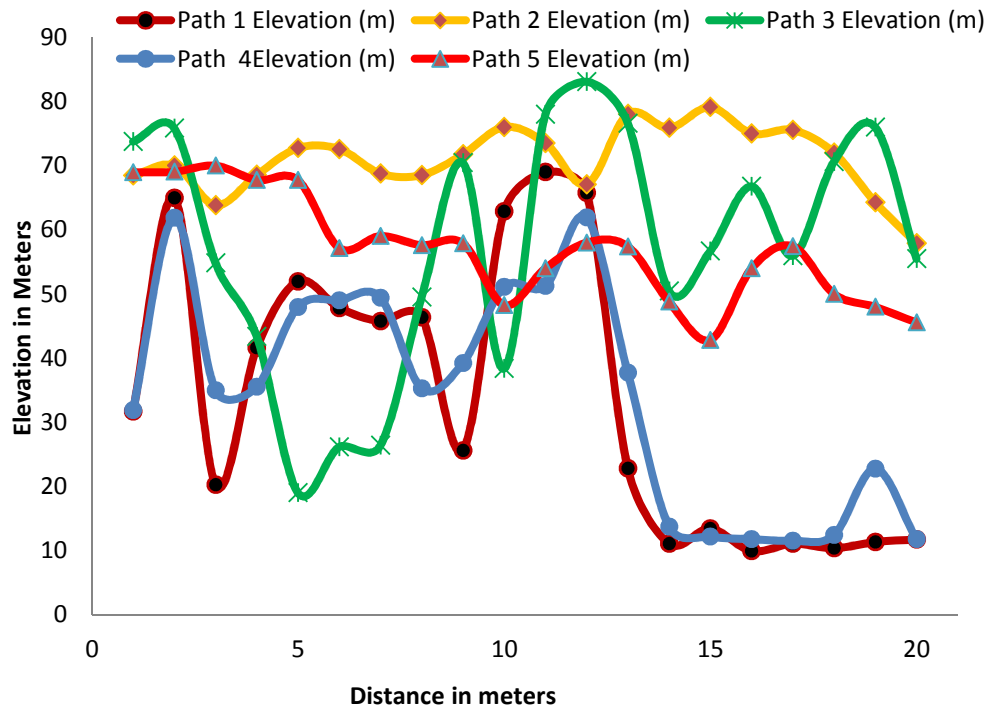


Figure 7 Elevation versus Distance for the Five Routes

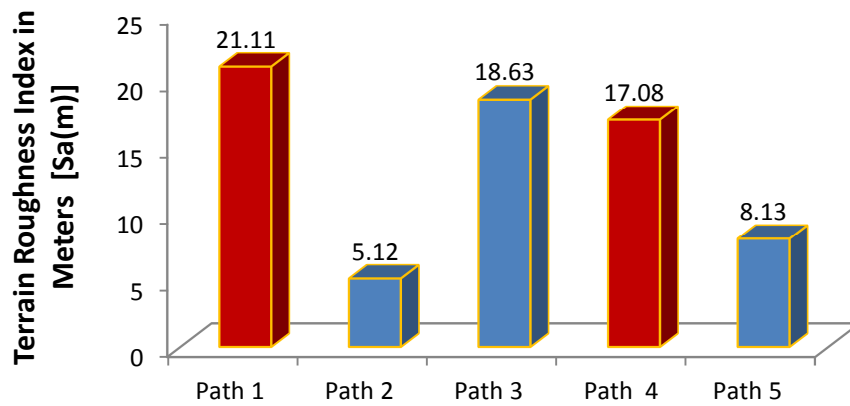


Figure 8 Barchart of the Terrain Roughness Index in Meters [Sa(m)] For The Five Line of Site Paths

Therefore, among the five paths considered in this study, two paths smooth terrains while three paths are rough terrains of varying degrees of roughness. In all, Uyo metropolis has both smooth and rough terrains which will present different degrees of multipath fading for wireless signals.

## 5 Conclusion

Terrain roughness index of various paths in Uyo metropolis are studied. The path or elevation profile of the paths is obtained through online elevation software. The elevation profile data set are used to compute the terrain roughness

index for each of the five paths considered. The results show that there are both smooth and rough terrains in Uyo metropolis. The result is essential for network planners as it provides the requisite information for the selection of the suitable path for line-of-sight communication link.

## References

- [1] Agba, B. L., Ben-Sik-Ali, O., Morin, R., & Bergeron, G. (2011). Recent Evolution of ITU Method for Prediction of Multipath Fading on Terrestrial Microwave Links. *Session 3P7 RF and Wireless Communication, Multipath*, 857.
- [2] Göktas, P. (2015). *Analysis and implementation of prediction models for the design of fixed terrestrial point-to-point systems* (Doctoral dissertation, Bilkent University).
- [3] Goktas, P., Altvntas, A., Topcu, S., & Karasan, E. (2014, August). The effect of terrain roughness in the microwave line-of-sight multipath fading estimation based on Rec. ITU-R P. 530-15. In *General Assembly and Scientific Symposium (URSI GASS), 2014 XXXIth URSI* (pp. 1-4). IEEE.
- [4] Ugwu, E. B. I., Umeh, M. C., & Ugonabo, O. J. (2015). Microwave propagation attenuation due to earth's atmosphere at very high frequency (VHF) and ultra-high frequency (UHF) bands in Nsukka under a clear air condition. *International Journal of Physical Sciences*, 10(11), 359-363.
- [5] Seybold, J. S. (2005). *Introduction to RF propagation*. John Wiley & Sons.
- [6] ITU, (2001) Recommendation ITU-R P.530-9, *Propagation data and prediction methods required for the design of terrestrial line-of-sight systems*, Geneva, ITU, 2001.
- [7] Asiyo, M. O., & Afullo, T. J. O. (2013). Statistical estimation of fade depth and outage probability due to multipath propagation in Southern Africa. *Progress In Electromagnetics Research B*, 46, 251-274.
- [8] Odedina, P. K., & Afullo, T. J. (2009). Multipath propagation modelling and measurement in a clean-air environment for LOS link design application. In *Southern Africa Telecommunication Networks and Applications Conference Proceedings*.
- [9] Kumar, M. P. S., Sumithra, M. G., & Sarumathi, M. M. (2013). Performance Evaluation of Rayleigh Multipath Fading Channel using Rectangular QAM schemes, *IJCSMC*, Vol. 2, Issue. 5, May 2013, pg.346-352.
- [10] Freeman, R. L. (2005). *Fundamentals of telecommunications* (Vol. 92). John Wiley & Sons.
- [11] Freeman, R. L. (2002). *Reference manual for telecommunications engineering*, Electromagnetic Wave Propagation.
- [12] Barnett W. T., (1972) Multipath propagation at 4, 6 and 11 GHz, *Bell System Technical Journal*, vol. 51, no. 2, pp. 321-361, February 1972.

- [13] Vigants A., (1975) Space diversity engineering, Bell System Technical Journal, vol. 54, no. 1, pp. 103-142, January 1975.
- [14] Morita K., (1970) Prediction of Rayleigh fading occurrence probability of lineof- sight microwave links, Rev. Elec. Commun. Lab., vol. 18, pp. 810-821, Nov.-Dec. 1970.
- [15] ITU (2013) Recommendation ITU-R P.530-15, *Propagation data and prediction methods required for the design of terrestrial line-of-sight systems,*" International Telecommunication Union, Geneva, 2013.

Copyright © 2016 Akinloye Bolanle Eunice, Simeon Ozuomba, and Ezenugu Isaac A.. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.