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# An Improved Practical Measuring Technique for Wireless Cellular Signal Path Loss Forecast in the African Terrain

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**Abstract:** Several studies on cellular signal path loss measurements at various locations under varying geographical and environmental circumstances in Africa have been conducted. Most of the techniques used, if not all, do not give consideration to the peculiar Africans' road networks and building patterns, valleys, and hills that usually prevent the driving of motor cars within them when taking the signal strength measurements. The article presents an improved technique for wireless cellular signal strength measurement for better path loss prediction. The approach adopted for measurement is the regular grid outdoor foot technique. The technique was tested at various locations in the Ilorin metropolis and proved to be a better method of obtaining signal strength measurements. Although some of the signal strength values coincided with respect to distance when both methods were used, the drive test method overvalued the signal strength for study locations that were not in line of sight with the BTSs. These values range from 2 dBm to 8 dBm. If this technique is adopted, measurements will be taken in all vital locations that may not be accessible by means of a motor car drive test method, and more accurate values of the cellular signal strength will be obtained for better path loss prediction.

**Keywords:** BTS, Cellular Services, GSM, MU, Path Loss, RSSI



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## 1. INTRODUCTION

Today, wireless cellular services are used by millions of people worldwide, and the number of active subscribers' lines in Africa, particularly in Nigeria, is over 220 million [1]. One of the most important features of the propagation environment is the propagation path loss. Path loss forecasting is requisite in the prediction of received signal intensity, interference, link budget design and evaluation, and cell size prediction [2]. Path loss is the decrease in the energy density of a radio wave as it travels through space [3] as cited in [4]. Path loss may be due to many effects, such as free-space loss, reflection, refraction, diffraction, terrain, vegetation, the distance between a base station transceiver (BST) and mobile unit (MU), height, and location of transmitting and receiving antennas [3] as cited in [4]. Path losses are predicted with the aid of the path loss models. The propagation model is defined as the mathematical expressions, diagrams, and/or procedures employed to depict the radio-signal properties of a particular environment [5], [6].

There are two categories of propagation models: deterministic and empirical (statistical). The forecasting of radio path loss and coverage by means of a deterministic model depends on the employment of scientific laws guiding wave transmission. When applying this method, all factors within the particular environment must be examined. That is, it is necessary to extensively investigate every credible signal contribution so as to ascertain the error-free value for a given environment. The deterministic technique required sophisticated computations and a significant amount of topographically acquired information [7]. If well composed, the results are usually exact or very close to the environment's real path loss.

Empirical techniques for forecasting signal path loss make use of calculated mean values acquired from the analysis of the attenuation of signal connections [7]. These mean values are then used in the forecasting model to produce estimations based on the frequency and propagation path separation. The Free Space, Plane Earth, Egli, COST-231-Hata, and COST-231-Walfisch-Ikegami (COST-231-WIM) models are among the empirical models that are most often exploited and accepted in modern research and application [8].

Several studies on cellular signal path loss measurements at various locations under varying geographical and environmental circumstances in Africa have been conducted. Most of the techniques used, if not all, do not give consideration to the peculiar Africans' road networks and building patterns, valleys, and hills that usually prevent the driving of motor cars within them when taking the signal strength measurements. The article presents an improved technique for wireless cellular signal strength measurement for better path loss prediction. The approach adopted for measurement is the regular grid technique, as it best suits the peculiar road networks and building patterns in African terrain. With this technique, if adopted, measurements will be taken in all vital locations that may not be accessible by means of a motor car drive test method, and more accurate values of the cellular signal strength will be obtained for better path loss prediction.

## 2. REVIEW OF RELATED WORKS

Several research investigations on the behaviour of GSM signals in various locations under varying geographical and environmental circumstances have been conducted. The study's findings gave birth to several propagation path loss models for evaluating GSM service quality. The resulting models are environment-specific [8].

The authors in [9] accessed the quality of service rendered by four GSM providers in Canaan Land, Ogun State, Nigeria. Measurements were taken during the drive test. It was discovered that only one of the providers performed better, one performed very poor while the remaining two are in-between.

The researchers in [10] conducted experiments on six propagation models so as to create a suitable path loss model to enhance the path loss forecast for LET in a very large and less densely populated area of Ghana. The data measurement was collected through drive tests with the aid of a Genex probe attached to phones through the USB port of a computer. In conclusion, reformed equations that could be used for better LET perdition in Ghanaian environments were created.

In [11] the path loss modelling by looking into the services of some LTE operators was verified. A drive test was conducted to obtain the field-measured data in Ondo, Nigeria. Findings pointed out that legacy models under predict the path loss in the study region.

An improvement of the 4G network in Lagos, Nigeria was worked on in [12]. Measurements were conducted through a drive test with the aid of TEM 15.0 loaded on the laptop and interfaced with the Sony Ericsson W995. A modified model called GSA was created. It was concluded that the modified model would give better performance if used in Lagos environments.

Also, the authors in [13] investigated the TVWS network in a large populated area of Onitsha, Nigeria, for path loss forecasting using NTA as a case study. Measurements were conducted using software for about 90 days using a drive test with the aid of a Spectrum Analyzer interfaced to a laptop installed with Touchstone RF. The path loss exponent was obtained for the NTA Onisha and was used to develop a new model. It was concluded that the new model, when compared with the common empirical models, performed better in Onshina.[14] examined the path loss forecast between five major empirical path loss models and the measured data obtained in a highly populated, medium populated, and very low populated areas of Dar es Salaam, Tanzania. Measurements were acquired during the drive test. The results revealed that four out of the five the models under estimated the path loss forecasted in all regions consider, while only ECC-33 model one model gives best path loss forecast for medium populated but over-predicted pathloss in highly populated area. Furthermore, it was said that the availability of several propagation models implies that none of them are precisely and accurately capable of forecasting path loss in environments other than those for which they were designed.

In [15] the path loss forecast between three empirical path loss models in a highly populated area of Uyo, Nigeria was investigated. Measured data was acquired during the drive test. The result reveals that the MSE decreases in value in order from free space to Hata and Egli at 16.24 dB, 8.40 dB, and 2.37 dB, respectively, and it was suggested that Hata's model is the most precise and accurate path loss forecast model for Uyo environments.

Similarly in [16] a comparison between four path loss models in a medium-populated area in Kano, Nigeria was conducted. The signal strength measurement was acquired during drive tests with the aid of the Ericsson Test Mobile System (TEMS) around nine BTS of a GSM network. Measurements from the BTSs were used to evaluate the data used for forecasting errors. The result indicated that the COST-231 Walfisch-Ikegami models provide the best results, given the mean prediction error values.

The researchers in [17] verified the performance evaluation of radio propagation models on the GSM network in the highly populated region of Lagos, Nigeria. A drive test was carried out to obtain the actual signal strength values in the study region. The result stated that the COST 231-Hata model forecast gives RMSE and SD values that are very close to the ones obtained on the live network for the medium-populated region. It also gives the lowest values of RMSE and SD for the highly populated region. It was suggested that the COST-231-Hata model be the most precise and accurate path loss forecast model for the highly populated region of Lagos.

Also, the authors in [18] investigated two empirical propagation models in order to develop adaptive and suitable propagation path loss models for two cities in Nigeria. A driving test was done to acquire the signal strength measurements along the major roadways in the two cities. The findings were matched to the values foreseen by the Okumura-Hata and COST-231-Hata models. At 900 MHz, the MSE was from 0.8 to 5.04 dB for the Okumura-Hata model and from 0.6 to 4.76 dB for the COST-231-Hata model.

Conclusively, in [19] a performance examination on five path loss models in the densely populated area of Yenagoa was carried out, Nigeria. Measurements were obtained during the drive test using TEMS 15.3.3 loaded on the laptop and interfaced with the Samsung S5 Galaxy. The result stated that the Ericsson model is the appropriate model for the study environment.

The assessments of relevant research discussed on the method used for signal strength measurement employed in the calculation of path loss for the purpose of studies on the performance analysis of different empirical models on cellular radio propagation in Africa reveal a dearth of relevant studies. It is evident from the assessments of the existing works that all the authors obtain the actual field data values (signal strength) by driving a motor car along the study region. Even though some of the signal strength values accessible by the car drive test may be obtained correctly, it may have an effect on the accuracy of the measured values due to the fact that the method does not give room to access many of the important locations, such as clustered regions, valleys, and high hilly areas where measurement needed to be conducted due to the poor/unmotorable road networks and irregular building patterns in Africa. The aim of this study is to provide a better approach for reliable signal strength measurement values for the purpose of comparing path loss forecasts between empirical path loss models and data obtained through measurement in African environments. To bridge the gap created by car drive test methods, several research procedures that seem to be vital are:

i. Investigating a low valley location area where a motor car cannot pass through by bike or foot;
ii. Investigating high-hill locations where a motor car cannot pass through by foot; and
iii. Investigating the building's congested locations, areas where a motor car cannot pass through by foot.

## 3. DESCRIPTION OF THE STUDY AREA, MATERIALS AND METHOD OF DATA COLLECTION

### 3.1 Description of the Study Environment

According to [8], as cited in [20], Ilorin is a city in north-central Nigeria with an approximate land size of 89 km$^2$ and is located between latitudes 8.410 N and 8.550 N and longitudes 4.490 E and 4.650 E. It has a population of about 700,000 [20]. It is characterized by a complex landscape owing to the presence of numerous hills and valleys within the city.

### 3.2 Materials and Method of Data Collection

The measuring instrument used was a Tecno Pouvoir 3 Plus Android phone with the Network Signal Info application installed, which was used to record the RSSI value at the research locations. The KAIBITS Software GmbH Network Signal Info program was utilized. Figure 1(a) depicts the measured RSSI acquired with the Tecno Pouvoir 3, whereas Figure 1(b) depicts the GPS location of the mobile phone (Tecno Pouvoir 3) as connected to a base station.

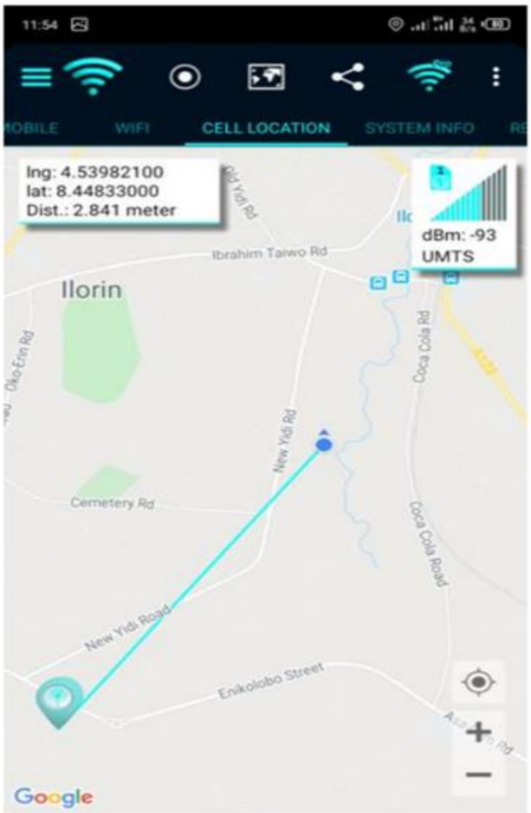


Figure 1(a). The Screenshot of the GPS Location of the Mobile Phone (Tecno Pouvoir 3) as Connected to a Base Station

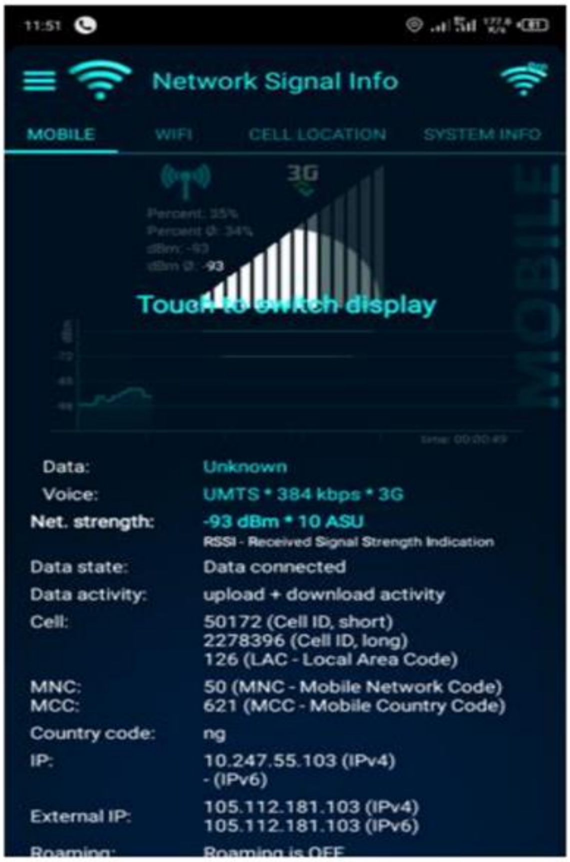


Figure 1(b). The Screenshot of the Measured RSSI Acquired with the Tecno Pouvoir 3

In this new technique, the selection of the research regions (locales) is based on suitable locations that fulfil typical environmental criteria in Africa, particularly Nigeria, in terms of crucial resident attributes such as the building patterns, the unmotorable road networks between builds, and the low valleys and high hills areas that were not adequately taken into consideration while doing path loss determination. For this study, two measuring methods were considered, and measurements were conducted in nine different regions (A1 through A9 in Figure 2) within the Ilorin metropolis. Figure 3 shows the aerial view of the first study region with the clusters of building patterns, regular grid lines and the unmotorable road networks.

In the first study region, signal strength measurements were conducted by using a motor car drive test method along a road in the study region. Signal strength measurements were also carried out at selected spots on the regular grid drawn on the Google map of the research zone along the clustered area where motor cars cannot reach by foot. In the first method, GSM signal strength was measured along the road (green line in Figure 3) within the research zone, beginning at approximately 0.1 km from the foot of the selected GSM operator's base transceiver station (BTS) and continuing at intervals of about 0.1 km up to a distance of about 1.2 km. In the second method, GSM signal strengths were measured at each predetermined spot (doted red spots in Figure 3) on the regular grid drawn on Google map within the research zone, beginning at approximately 0.1 km from the foot of the selected GSM operator's base transceiver station (BTS) and continuing at intervals of about 0.1 km up to a distance of about 1.2 km. All measurements were taken in mobile active mode to guarantee that the phone is in continual contact with the BTS. To do this, calls were launched to a defined number at each point in the research areas, and the received signal strength was monitored and recorded. The methods were repeated for the remaining eight regions within the metropolis.

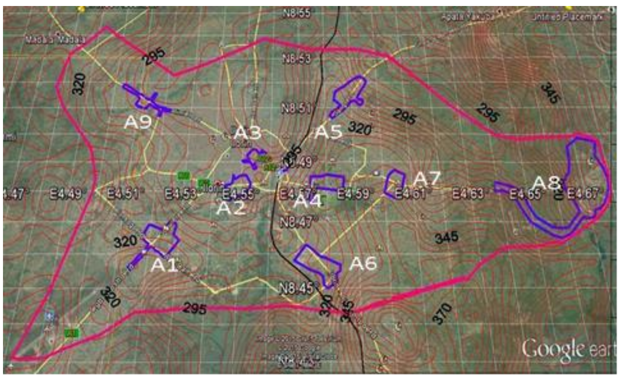


Figure 2. The Selected Nine Regions (A1 to A9) within the Ilorin Metropolis for the Experiments

Figure 3. The Aerial View of the First Study Location with the Cluster Building Patterns and Unmotorable Roads Network

## 4. DATA ANALYSIS RESULTS AND DISCUSSION

### 4.1 Data Analysis

The mobile station (MS) antenna height was 1.5 m, and the base transceiver station (BTS) parameters used to calculate the relevant path loss at the research site are provided in Table 1. The experimental results of the measured signal strengths obtained by using the drive test method along the specified route and by using the regular grid outdoor foot method (the new technique) at selected spots on the regular grid in the study locations in Ilorin metropolis were recorded. The statistical "Ad-in" tool in Microsoft Excel was used to plot the graphs of the signal strength against distance at various regions.

Table 1. Selected Base Station Information

| BTS No. | Height (m) | Elevtion (m) | Long. (m) | Lat. (m) | Freq. (MHz) |
|---|---|---|---|---|---|
| A1 | 30 | 328 | 4.53 | 8.47 | 1820.6 |
| A2 | 33 | 290 | 4.56 | 8.49 | 1826.2 |
| A3 | 28 | 335 | 4.58 | 8.49 | 1820.4 |
| A4 | 30 | 342 | 4.67 | 8.48 | 1851.2 |
| A5 | 30 | 326 | 4.61 | 8.49 | 1841.4 |
| A6 | 28 | 356 | 4.61 | 8.49 | 1855.4 |
| A7 | 30 | 294 | 4.52 | 8.52 | 1820.2 |
| A8 | 28 | 281 | 4.56 | 8.49 | 1854.4 |
| A9 | 25 | 264 | 4.56 | 8.50 | 1826.4 |

### 4.2 Results and Discussion

Figures 4 through 12 show the variation of the signal strength with the distance associated with the BTSs at various study locations obtained by using the drive test method and by using the regular grid outdoor foot method (a new technique) within the study areas in the Ilorin metropolis. It is observed from Figures 4 through 12 that the signal strength decreases with distance when either of the methods was used (drive test and regular grid foot outdoor). It is also observed that the decrease in signal strength with distance is more pronounced with the regular grid foot outdoor method compared to the drive test on a defined route and this can be traced to the impact of the distinctive African road networks and building patterns on the cellular signal strength. Although some of the signal strength values coincided with respect to distance when both methods were used, this can be attributed to the fact that at some points of measurement, there were lines of sight to the BTSs either of the method is used. Figures 4 through 12 reveal that the drive test method overvalued the signal strength valve for study locations that were not in line of sight with the BTSs. These values range from 2 dBm to 8 dBm, as shown in Figures 4 through 8.

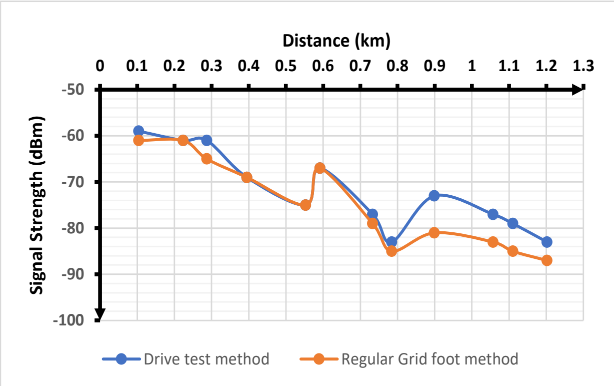


Figure 4. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A1

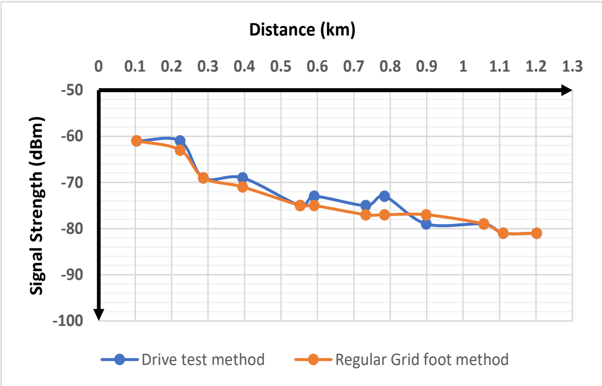


Figure 5. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A2

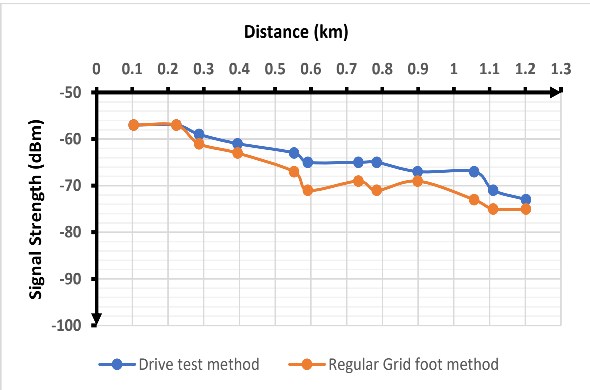


Figure 6. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A3

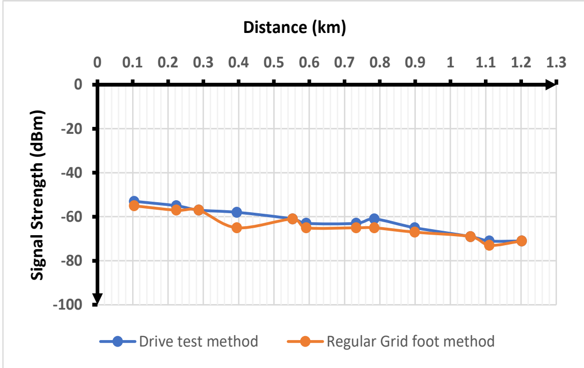


Figure 7. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A4

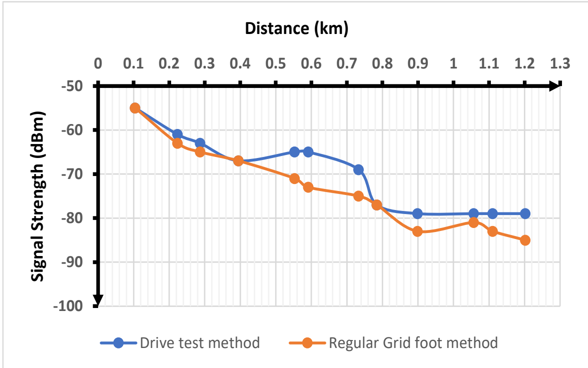


Figure 8. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A5

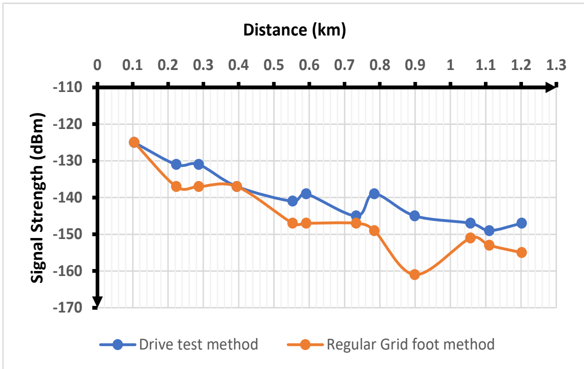


Figure 9. The Signal Strength (RSSI) Variation Against Distance (km) at the Sudy Location A6

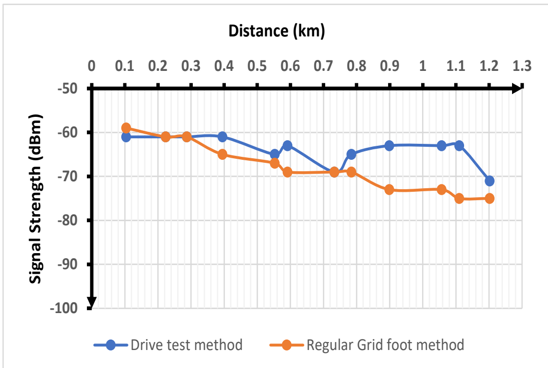


Figure 10. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A7

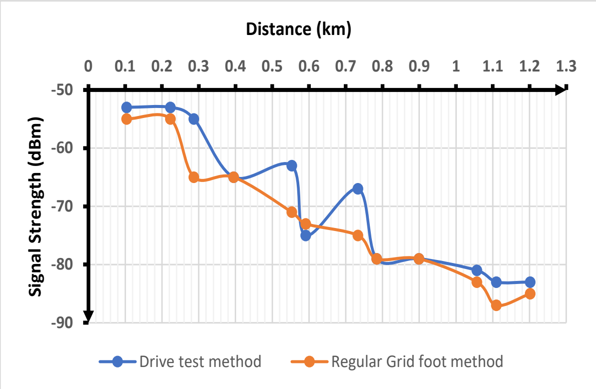


Figure 11. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A8

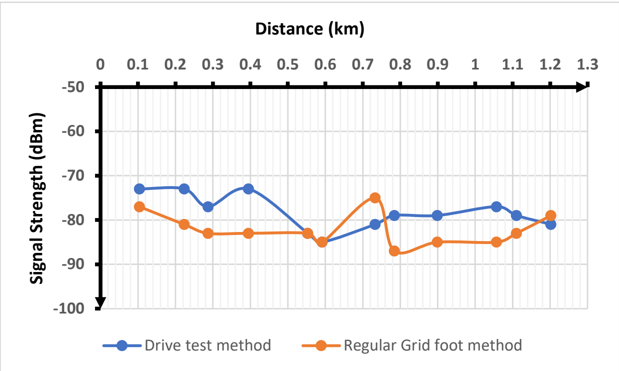


Figure 12. The Signal Strength (RSSI) Variation Against Distance (km) at the Study Location A9

## 5. CONCLUSIONS

This research looks at the trends in wireless cellular signal strength measurement procedures for path loss calculations and predictions in Africa. Several path loss assessments and methods used in obtaining the signal strength were investigated. An improved method that could be used to obtain a better signal strength value in the African environment that will give access to the unmotorable locations due to the clustered pattern of the building's structures, unmotorable road networks between builds, very low valleys, and high hills has been created. This new approach, if adopted, as it suits the distinctive African road networks and building patterns, will provide benefits over the customary common motor car drive-test approach, which might not cover certain inaccessible regions. Another benefit over the motor car drive-test approach is the decrease in systematic errors caused by appropriately data windowing and averaging ascribed to the steady measurement at the same spot being recorded.

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