Review of Computer Engineering Research
2015 Vol.2, No.2, pp.47-64
ISSN(e): 2410-9142
ISSN(p): 2412-4281
DOI: 10.18488/journal.76/2015.2.2/76.2.47.64

RECEIVED SIGNAL STRENGTH IN A MACROCELL IN LAGOS ENVIRONS USING FINITE ELEMENT METHOD

Shoewu, O.[1]† --- Makanjuola, N.T.[2] --- Akinyemi, L.A.[3] --- Ogunlewe, A.O.[4]

[1,2,3,4] *Department of Electronic and Computer Engineering, Faculty of Engineering Lagos State University, Epe Campus, Epe, Nigeria*

ABSTRACT

This paper presents an analysis of received signal strength in a macrocell in Lagos environment using Finite Element Method (FEM). In this paper, six different site locations were covered and subdivided into peri-urban, open suburban, dense urban, open urban, suburban and exurban areas. It was deduced that the experimental values obtained was favourably with the FEM predicted values with the mean prediction error ranging between 6.66dB to 12.89dB while that of standard deviation error is 2.99dB to 8.09dB.

Keywords: Macrocell, Finite element method, Mean prediction error, Base station.

Received: 20 January 2015/ **Revised:** 16 May 2015/ **Accepted:** 20 May 2015/ **Published:** 25 May 2015

Contribution/ Originality

This study reveals the determination of received signal strength from a source point within a macrocell by the use of finite element method. Simulation for the study was achieved using 2D Maxwell's wave equation. Adequate data was collected, analysed and the main idea was to collect data with the TEMS phone by driving in a vehicle and making a lot of calls in the metropolitan area considered. This effort makes it different from other forms of data collection methods used in previous studies.

1. INTRODUCTION

Planning and designing of a system in a wireless communication environment is of utmost importance. To carry out adequate design requires the computation of the link budget for proper call establishment. Any data, voice, Multimedia and any other forms of message in terms of information transmitted between the Mobile Station subscriber and the mobile cellular network applies radio communication technology which then takes away the fixed wiring used in a conventional telephone network installation.

† Corresponding author

Mobile Stations within the cellular network systems are tagged in "cells", which are then provided by the Base Station Systems (BSS). The BSS can provide one or more Cells based on the radio frequency engineers, network planners and manufacturers equipment. Cells are normally assumed to be hexagonal in shape, but in practice they are irregularly shaped as illustrated below. This is as a result of the influence of the surrounding terrain, or the network

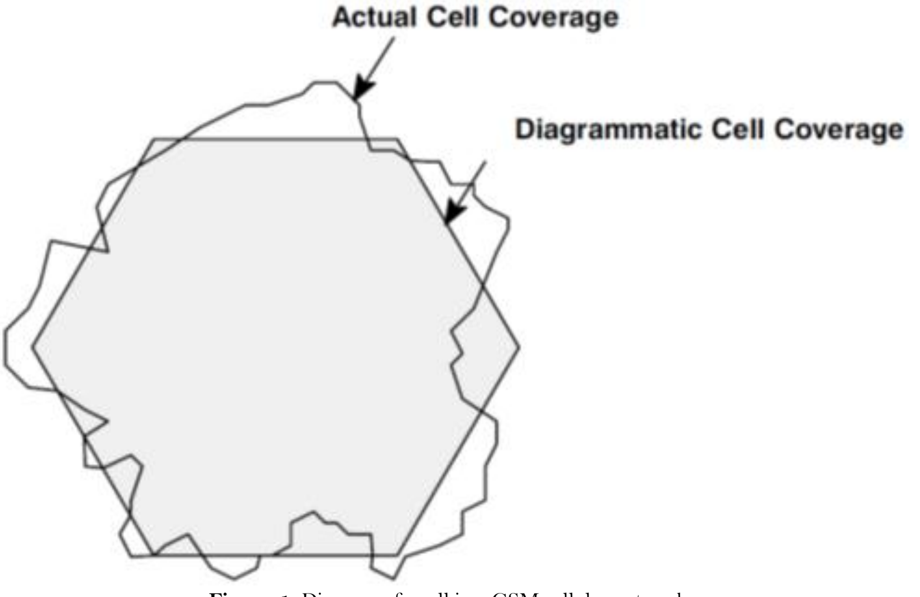

Figure-1. Diagram of a cell in a GSM cellular network.

The number of cells in any metropolitan, rural or urban area is determined by the number of MS subscribers who will be actively operating in that vicinity, and the geographical chart of the area whether hills, lakes, buildings will be adequately taken into considerations while planning network. The highest cell site in terms of size for most GSM networks planning is relatively measured to be seventy kilometres in diameter (the radius is taken to be half of the diameter 35km during the analysis of the cellular network), but this is based on the nature and area the cell is covering and the power of the Mobile Station which can be in between 6 to 10 Watts. However, when the cell site is on top of a rooftop, hilly object or in a mountainous environment with no any form of obstructions for distances, then the radio wave signals travel faster and further than if the cell site was in the centre of a city, with a lot of rooftops, high-rise buildings preventing the path of the radio wave signal to be established(line of sight) thereby leading to lost calls. In cellular network system, large cells are usually deplored and used in remote areas, rural areas, urban areas, suburban area coast line area, and areas with few subscribers. Furthermore, small cells are used, where a low transmission power may be a necessary requirement to reduce the rate of interference in a cellular network system. Small cells currently cover 200m and above. Typical areas that use small cells are Urban areas, regions with low transmission power required, regions with high number of mobile stations.

In cellular network [1], there is no definite and specific solution when planning the type of cell to be used. Network operators normally use large cells to cut cost in terms of installation and maintenance of the equipment , but now dawns on them that in order to provide a quality service to their prospecting subscribers and customers, some factors are worthy of considerations such as terrain, transmission power required, received power, cable loss, path loss etc. Macro cells are large cells for remote and sparsely populated areas. To determine the appropriate prediction and optimal coverage of a network the radio signal is a necessity.

However, path loss [2] calculations are used in many radio and wireless survey analysis for determining signal strength at various locations. The signal strength can be determined mathematically and these computations are often undertaken when preparing coverage or system design activities. Radio transmission in mobile communication usually takes place over irregular terrain [3]. The terrain profile of a particular area needs to be considered for estimating the pathloss. It is common place in literature, that a number of propagation models are available to predict pathloss over irregular terrain. Since all these models aim to predict the strength of signal at a particular receiving point, the methods vary widely in their approach, accuracy and applicability. It is important to note also, that most of these models are based on systematic interpretation of measurement data obtained in the classified service area. In this paper, the use of finite element method will be employed in the analysis of the received signal strength. In Emagbetere and Edeko [4] the study considered two sites. This work is set to consider a metropolitan terrain of six sites.

2. DESCRIPTION OF INVESTIGATED AREA OF STUDY

As earlier stated in the previous chapter, the prediction of the signal strength level from a base station in this work, is mainly carried out by using finite element method embedded in the PDE Tool of matlab, to solve Maxwell' s wave equation [5]. In its elliptical form by reducing it to Helmholtz equation, which has the time variable replaced. The simulated values at varying distances are obtained and compared with measured values from an actual macrocell domain.

The areas taken and investigated during this study were Trade Fair, Ejigbo, Obalende, Ogba Oluwole Estate and Orile, all in Lagos State, Nigeria.

3. METHODOLOGY

This entails retrieving the received signal strength at varying distances in a macrocell environment from a base station (source point), and comparing it with simulated values from the PDE tool of Matlab.

Optimization is basically the only way to keep track of a network by looking deep into statistics and collecting/analyzing drive test data. Drive testing is the most common way to analyze Network performance by means of coverage evaluation, system availability, network capacity, and network retainability and call quality. Therefore, the main objective of a drive test is to collect data from a serving cell and its neighbours within the Macrocell so as to aid finding and analyzing the problems in the network.

A check list of the hardware equipment and software to be used were made, before the drive test was carried out. The hardware equipment used were -

- A laptop and a USB Hub.
- License dongle for TEMS software 9.1
- TEMS handsets, charger, and data cables
- 2G and 3G SIM cards
- External vehicle mounted GPS with its associated data cable
- An Inverter and the cable terminal
- Battery (for GPS) and the battery charger

While the software requirements were -

- TEMS Investigation Software version 9.1
- HASP Emulator (for TEMS 9.1)
- PC Suite (T68i, Z800, and K800)
- GPS driver

The main idea was to collect data with the TEMS phone by driving in a vehicle and making a lot of calls in the area considered. This was done during normal daylight hours so as to reflect normal network conditions. Calls were made from the TEMS mobile handset or phone to the PSTN in order to collect both GSM speech and GPRS drive test data. During this process, the TEMS software on the laptop was made to record these measurement activities on the Logfile, which can be played back at a later time to retrieve the data recorded from the drive test. The calls made, were approximately the duration of an average call as derived from the operations and maintenance center (OMC) statistics, allowing 10secs of idle time between them. GPRS data calls were as well set according to the average data call length for the network. The Laptop and the USB hub were used mainly to organise other equipment in the system. It is the platform in which the TEMS software was utilized.

The inverter which is a major component of the Power Source, inverts the 12 Volts DC source of the vehicle to a higher AC voltage in this case of 240 Volts. The inverter was used to charge the batteries for both the Laptop and GPS. The dongle or licensed key can be described as a device essentially needed to activate the TEMS software for use. The Global Positioning System GPS, was used determine the position of the system on a universal map software installed on the laptop known as the Map Info. It provides location tracking for the system through the use of global navigational satellites.

4. THE INVESTIGATED ENVIRONMENT

Areas in which the investigations were carried out are Trade Fair, Ejigbo, Obalende, Ogba Oluwole Estate and Orile, all situated in Lagos State, Nigeria.

4.1. Peri-Urban Area

The peri-urban areas can be defined as regions that immediately adjoin an urban area i.e, between the suburbs and the countryside. The investigated area that falls under this category is Trade Fair to the edge of Festac. The coordinates of areas investigated here are-

- Trade Fair- Latitude 06 28 11.11 N and Longitude 003 14 32.14 E
- Edge of Festac Town - Latitude 06 28 11.51 N and Longitude 003 16 34.55 E

4.2. Open Suburban

As the name connotes, these are suburban areas characterized with less morph structural features, buildings, trees etc. The investigated area that falls under this classification is Ejigbo. Its coordinates are

- Ejigbo Latitude 06 32 29.00 N and Longitude 003 32 30.00 E

4.3. Dense Urban

As the name connotes, these are urban areas with high population density. The region treated here is Obalende having coordinates with Latitude 06 27 00.80 N and Longitude 003 24 36.24 E.

4.4. Open Urban

These are urban areas characterized with less morph structural features, buildings, tree cover etc. the region treated here is Ikeja Ogba to Opebi.

- Opebi Latitude 06 35 32.19 N and Longitude 003 24 36.24 E
- Ogba Latitude 06 37 21.08 N and Longitude 003 20 18.17 E

4.5. Exurban

Exurban regions or areas can be described as areas with a high population of affluent people. The area investigated under this category include Oluwole Estate to another area in Ogba.

- Ogba 2 Latitude 06 37 56.80 N and Longitude 003 20 54.80 E
- Oluwole Estate Latitude 06 37 50.60 N and Longitude 003 20 24.00 E

4.6. Suburban Area

This is an area that can be described as been strictly residential. This region include areas like Orile with coordinates

- Orile Latitude 06 38 06.50 N and Longitude 003 18 14.60 E

5. EXPERIMENTAL EQUIPMENT SETUP

As earlier stated in the methodology above, the major hardware equipment employed to collect and record data on the R.F measurements taken are:

- A laptop with the TEMS 9.1 Software on it.
- License dongle for TEMS software 9.1

- TEMS Sony Ericsson handsets/Phones
- GPS
- An Inverter with the Power Source.

Pictorial view of the Sony Ericsson TEMS phone used and the USB dongle for TEMS software.

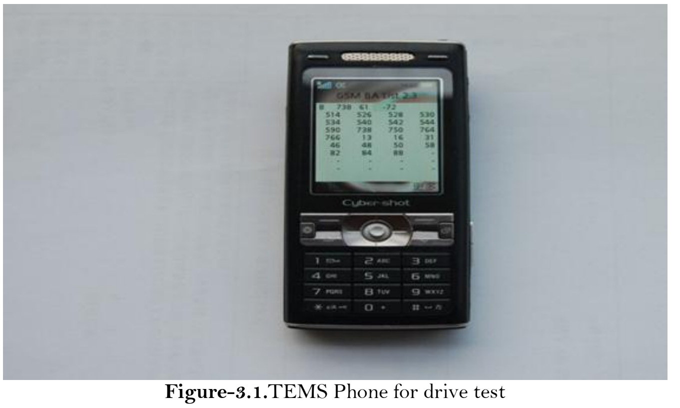

Figure-3.1.TEMS Phone for drive test

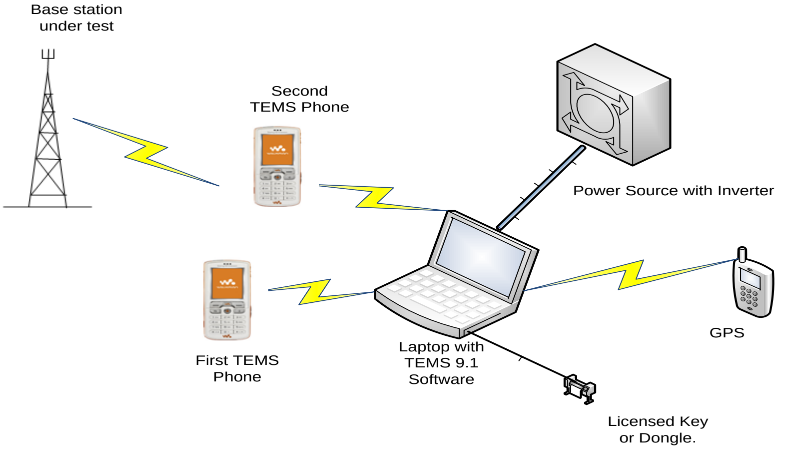

Figure-3.2. Diagram of Experimental Set up of Hardware tools Used.

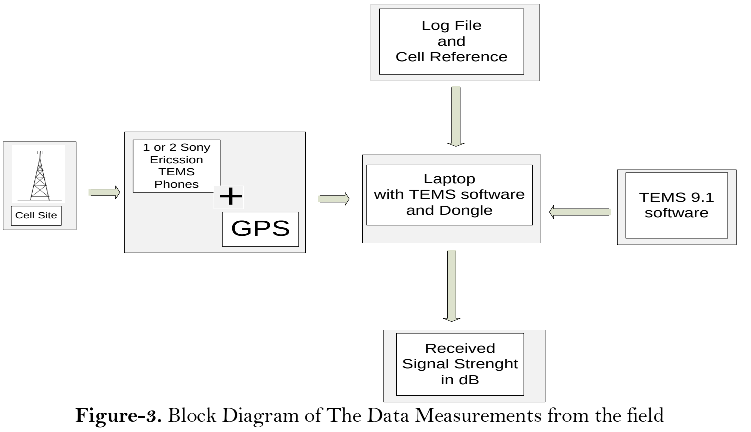

Figure-3. Block Diagram of The Data Measurements from the field

6. RESULT AND ANALYSIS

6.1. Data Collection

Collection of data was carried out, commencing with distances less than 150m from the various base stations considered. The Omni-directional cells were considered in this project research so as to reduce the complexity of the model considered here. After the drive test, the log file containing the recorded data was played back in order to take down the various readings and corresponding measurements needed. For easier data analysis and for the purpose of this research, only the GSM Radio parameters window in the workspace (window beside map in fig 4.1 below) was considered for the measurement taken. The radio parameter window on the workspace shows the received signal strength in dB by the current serving cell. The rule tool in the menu tab of the map window below was used to measure the distance of the RSSL of the serving cell.

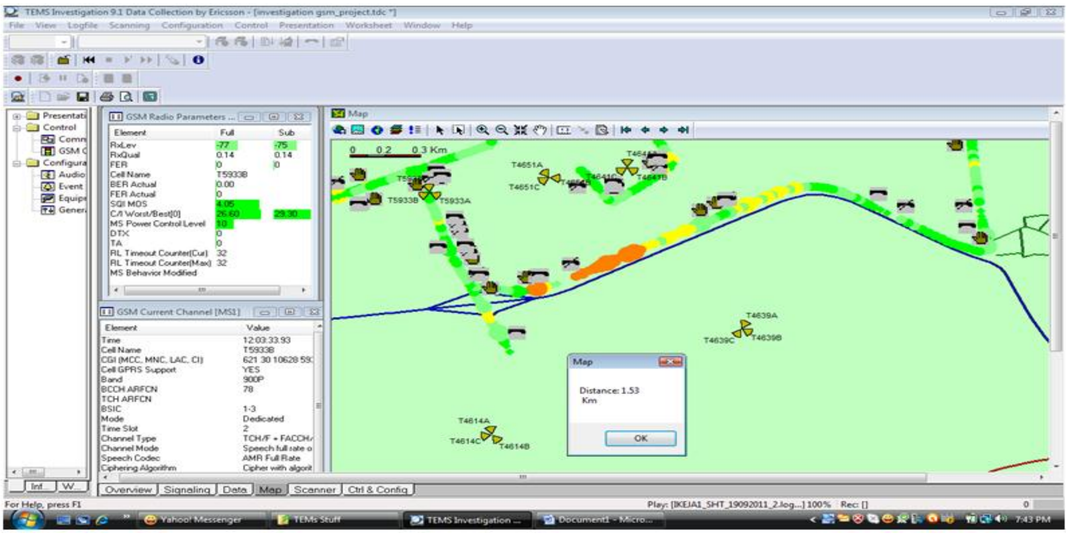

Figure-4. A snapshot of the TEMS software used to capture Rx values in Ikeja

7. DATA OBTAINED FROM FIELD MEASUREMENTS

Tables 4.1 to 4.6 below, show the measured various received signal strength levels at varying spherical distances from the 6 sites that were investigated.

Table-4.1. Data collected at Ejigbo

Distance (m)	Experimental
150	-29.59
650	-34.24
1150	-64.09
1650	-68.23
2150	-70.32
2650	-76.55
3150	-78.03
3650	-93.88
4150	-102.32

Table-4.2. Trade fair Badagry express way

Distance (m)	Experimental
200	-41.98
400	-39.06
630	-47.48
960	-48.90
1090	-52.67
1100	-57.90
1108	-61.07
1160	-63.40
200	-41.98

Table-4.3. Ikeja Ogba

Distance (m)	Experimental
100	-47.09
320	-48.00
540	-48.24
760	-52.00
850	-60.78
980	-62.47
1020	-64.09
1200	-68.23
1420	-73.01
1640	-74.38
1860	-75.00
2080	-78.58

Fig-4.1. Pictorial view of base station at Ogba

Table-4.4. National Obalende

Distance (m)	Experimental measured
100	-37.62
200	-37.80
300	-42.08
400	-46.00
500	-48.56
600	-54.09
700	-57.03
800	-58.00
900	-58.78
1670	-64.90
1708	-71.02
1681	-72.63
1824	-75.61
1966	-78.60
2109	-81.58
2251	-84.56

Table-4.5. Orile

Distance (m)	Experimental measured
160	-40.23
220	-40.99
390	-45.32
486	-54.23
800	-57.33
1000	-61.40
1200	-63.25
1400	-66.00
1540	-71.03

Figure-4.3. Pictorial View of A Base station In Orile.

Table-4.6. Oluwole

Distance (m)	Experimental
176	-40.23
276	-45.08
376	-48.12
480	-53.09
570	-55.00
720	-56.23
782	-57.99
925	-61.07
1072	-63.34

8. DATA ANALYSIS

Charles de Coulomb and his law that describes the attraction and repulsion between electric charges and magnetic poles actually mark the beginning of modern Electromagnetic theory.

From Maxwell's 2-D wave equation,

$$\frac{\partial^2 E}{\partial x^2}+\frac{\partial^2 E}{\partial y^2}=\frac{1}{C^2}\frac{\partial^2 E}{\partial t^2} \qquad (1)$$

Where c is the speed of light

Eliminating the time variable so as to have an elliptical equation yields the Helmholtz equation, as shown in equation 2 below.

$$\frac{\partial^2 E}{\partial x^2}+\frac{\partial^2 E}{\partial y^2}+K^2E=0 \qquad (2)$$

K in equation (2) is the wave number expressed as ω/c.

Equation 2 can also be expressed as

$$\frac{\partial^2 E}{\partial x^2}+\frac{\partial^2 E}{\partial y^2}+K^2n^2E=b \qquad (3)$$

Where b is a constant and can be taken to be zero, since a homogenous condition is desired to reduce the complexity of the system and a dirichlet boundary condition is used so as to have the boundary of the problem domain been expressed in terms of the solution E.

$$\frac{\partial^2 E}{\partial x^2}+\frac{\partial^2 E}{\partial y^2}+K^2n^2E=0 \qquad (4)$$

n is the refractive index of the environment got from the pathloss analysis as seen in Emagbetere and Edeko [4].

The elliptical equation in the PDE tool of Matlab is expressed as`

$$-\nabla\,(c\,\nabla\,u)+au=f \qquad (5)$$

Where f is 0(since we are dealing with a homogenous condition) and the variables c and a are the coefficients of the elliptical Partial differential equation.

In the Matlab simulation, the hexagonal geometry of the cell with its boundary conditions was defined. The coefficients "c" was equated as 1, while "a" to $K^2n^2\exp(-K)(x+y)^{1/2}$. Then the mesh specification is initialized and refined to create the finite elements. These were achieved in the graphical User interface of the PDE tool [6] of Matlab to yield the predicted values of the received signal strengths of each site. A model of the Received signal strength against the varying distance was plotted to yield the following plot, which corresponded to all (6) six sites.

Table-4.7. Ogba

Distance (m)	Experimental measured value(db)	FEM predicted value
100	-47.09	-49-67
320	-48.00	-51.90
540	-48.24	-53.00
760	-52.00	-55.23
850	-60.78	-62.45
980	-62.47	-61.78
1020	-64.09	-65.98
1200	-68.23	-71.34
1420	-73.01	-75.89
1640	-74.38	-72.76
1860	-75.00	-76.45
2080	78.58	-80.65

Table-4.8. Obalende

Distance (m)	Experimental measured value(db)	FEM predicted value
100	-37.62	-47.56
200	-37.80	-52.66
300	-42.08	-56.98
400	-46.00	-59.09
500	-48.56	-61.53
600	-54.09	-64.90
700	-57.03	-65.10
800	-58.00	-68.32
900	-58.78	-70.79
1200	-63.04	-74.05
1670	-64.90	-76.02
1708	-71.02	-78.07
1681	-72.63	-79.70
1824	-75.61	-83.56
1966	-78.60	-86.90
2109	-81.58	-92.23
2251	-84.56	-98.78

Table-4.9. Orile

Distance (m)	Experimental measured value(db)	FEM predicted value
160	-40.23	-39.09
220	-40.99	-49.90
390	-45.32	-58.20
486	-54.23	-67.03
800	-57.33	-72.79
1000	-61.40	-76.56
1200	-63.25	-78.66
1400	-66.00	-84.32
1540	-71.03	-89.28

Table-4.10. Ejigbo

Distance (m)	Experimental measured value(db)	FEM predicted value
160	-40.23	-39.09
220	-40.99	-49.90
390	-45.32	-58.20
486	-54.23	-67.03
800	-57.33	-72.79
1000	-61.40	-76.56
1200	-63.25	-78.66
1400	-66.00	-84.32
1540	-71.03	-89.28

Table-4.11. Oluwole

Distance (m)	Experimental measured value(db)	FEM predicted value
176	-40.23	-38.78
276	-45.08	-48.08
376	-48.12	-53.45
480	-53.09	-57.45
570	-55.00	-59.8
720	-56.23	-62.89
782	-57.99	-65.67
925	-61.07	-68.67
1072	-63.34	-75.43

Table-4.12. Trade fair Badagary express way

Distance (m)	Experimental measured value(db)	FEM predicted value
200	-39-88	-47.98
400	-40.03	-48.067
630	-45.45	-58.48
960	-47.89	-62.90
1090	-49.43	-69.67
1100	-58.00	-69.96
1108	-60.22	-71.07
1160	-62.00	-70.4
1206	-64.50	-75.78
1290	-69.08	-78.67
1300	-73.30	-82.89
1580	-75.02	-85.94

The aptness and suitability of this model is evaluated by comparing the experimental measured data with the PDE predicted data to ascertain the accuracy and correctness. The error between the experimental measured value and the Finite element method value is,

Prediction error = Measured data – Predicted data.

Tables 4.13 to 4.18, illustrate the prediction error for each site.

Table-4.13. Trade fair Badagary express way

Distance (m)	Experimental measured value(db)	FEM predicted values	Main prediction error
200	-39.88	-47.98	8.10
400	-40.03	-48.67	8.37
630	-45.45	-58.48	13.03
960	-47.89	-62.90	15.01
1090	-49.43	-69.67	20.24
1100	-58.00	-69.96	11.96
1108	-60.22	-71.07	10.85
1160	-62.00	-70.40	8.40
1206	-64.50	-75.78	11.28
1290	-69.08	-78.67	9.59
1300	-73.30	-82.89	9.59
1580	-75.02	-85.94	10.92

Table-4.14. Ogba

Distance (m)	Experimental measured value(db)	FEM predicted values	Main prediction error
200	-39.88	-47.98	8.10
400	-40.03	-48.67	8.37
630	-45.45	-58.48	13.03
960	-47.89	-62.90	15.01
1090	-49.43	-69.67	20.24
1100	-58.00	-69.96	11.96
1108	-60.22	-71.07	10.85
1160	-62.00	-70.40	8.40
1206	-64.50	-75.78	11.28
1290	-69.08	-78.67	9.59
1300	-73.30	-82.89	9.59
1580	-75.02	-85.94	10.92

Table-4.15. Obalende

Distance (m)	Experimental measured value(db)	FEM predicted values	Main prediction error
100	-37.62	-47-56	9.94
200	-37.80	-52.66	14.86
300	-42.08	-56.98	14.90
400	-46.00	-59.09	13.09
500	-48.56	-61.53	12.97
600	-54.09	-64.90	10.81
700	-57.03	-65.10	8.07
800	-58.00	-68.32	10.32
900	-58.78	-70.79	12.01
1200	-63.04	-74.05	11.01
1670	-64.90	-76.02	11.12
1708	-71.02	-78.07	7.05
1681	-72.63	-79.7	7.07
1824	-75.61	-83.56	7.95
1966	-78.6	-86.9	8.30
2109	-81.58	-92.23	10.65

Table-4.16. Orile

Distance (m)	Experimental measured value (db)	FEM predicted values	Main predicted error
160	-40.23	-39.09	-1.14
220	-40.99	-49.90	8.91
390	-45.32	-58.20	12.88
486	-54.23	-67.03	12.80
800	-57.33	-72.79	15.46
1000	-61.40	-76.56	15.16
1200	-63.25	-78.66	15.41
1400	-66.00	-84.32	18.32
1540	-71.03	-89.28	18.25

Table-4.17. Ejigbo

Distance (m)	Experimental measured value (db)	FME predicted values	Main prediction error
150	-29.59	-39.90	10.31
650	-34.24	-67.48	33.24
1150	-64.09	-79.79	15.70
1650	-68.23	-88.87	20.64
2150	-70.32	-94.89	24.57
2650	-76.55	-99.78	23.23
3150	-78.03	-10.71	29.07
3650	-93.88	-109.59	15.71
4150	-102.32	-112.10	9.78

Table-4.18. Oluwole

Distance (m)	Experimental measured value (db)	FEM prediction values	Main prediction error
176	-40.23	-38.78	-1.45
276	-45.08	-48.08	3
376	-48.12	-53.45	5.33
480	-53.09	-57.45	4.36
570	-55	-59.8	4.8
720	-56.23	-62.89	6.66
782	-57.99	-65-67	7.68
925	-61.07	-68.67	7.6
1072	-63.34	-75.43	12.09

The Mean Prediction error and standard deviation error were calculated using Microsoft excel as shown in the table below.

Table-4.19.

size	Mean prediction error	Standard deviation error
Trade fair	1141725	3,46692138
National Obalende	10.84352941	2.512495692
Ejigbo	20.25	8.092944458
Orile	12.89444444	5.66678453
Oluwole	5.563333333	3.712664138
Ikeja Ogbe	6.66	2.99207286

As seen from table 4.19 above, the Mean Prediction error is between 6.66dB to 12.89 dB, while that for the standard deviation error is 2.99 dB to 8.09 dB.

Quite a number of Researchers believe that for a Wireless mobile network to perform well, the standard deviation of error for the Macrocellular propagation prediction characteristic should be between the range of 8 dB to 10 dB [4]. The graphs for the contrast between the experimental measured values and the Finite element predicted values from tables 4.7 to 4.12 are shown below

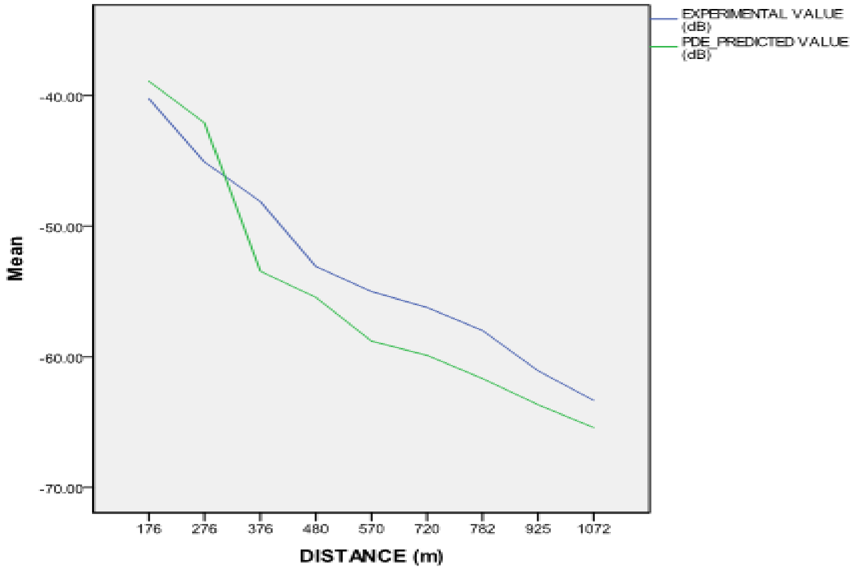

Figure-4.5. Comparism of Received Signal Strength Versus the Distance at Oluwole Estate

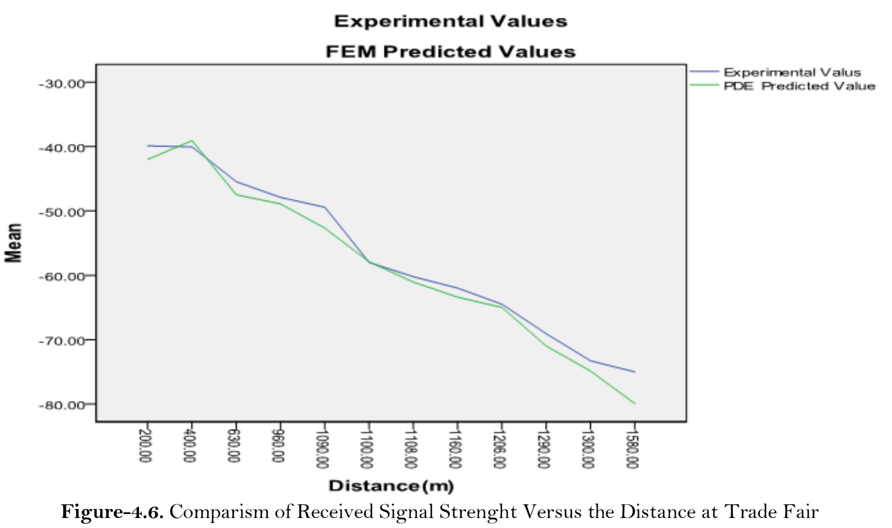

Figure-4.6. Comparism of Received Signal Strenght Versus the Distance at Trade Fair

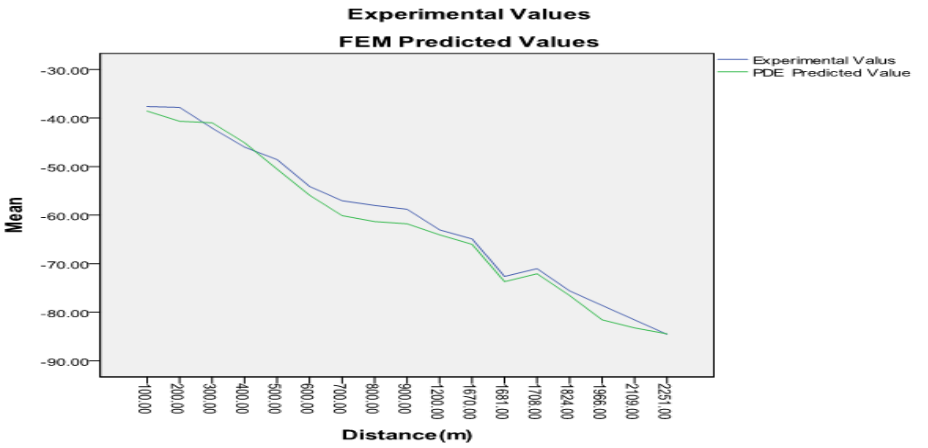

Figure-4.7. Comparism of Received Signal Strenght Versus the Distance at Obalende.

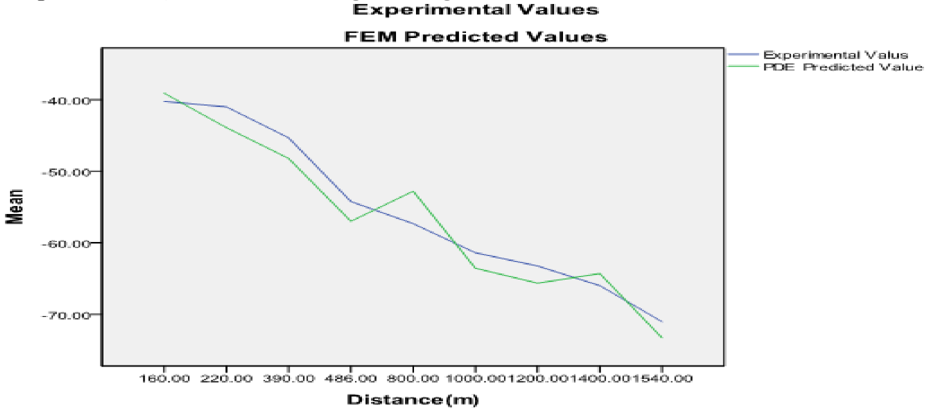

Figure-4.8. Comparism of Received Signal Strenght Versus the Distance at Orile

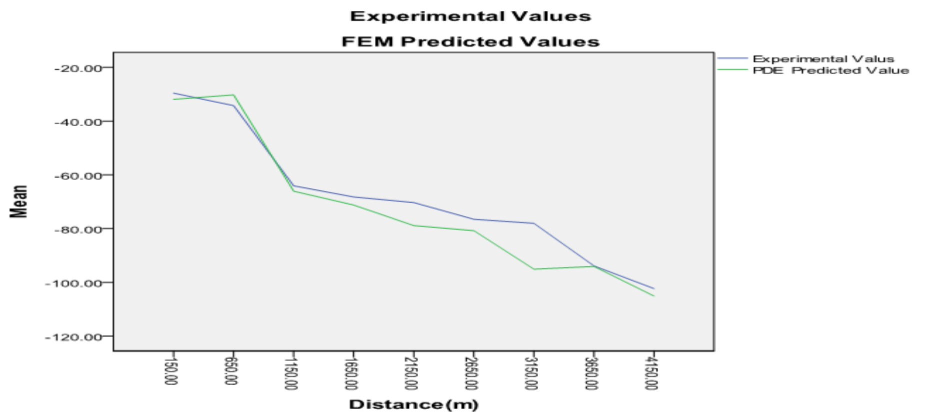

Figure-4.9. Comparism of Received Signal Strenght Versus the Distance at Ejigbo

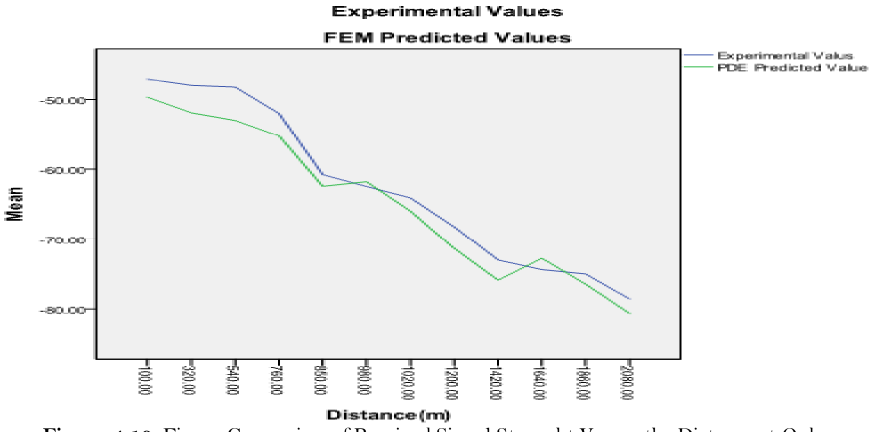

Figure-4.10. Figure Comparism of Received Signal Strenght Versus the Distance at Ogba

9. CONCLUSION

The modeling of the Received Signal Strength from a source point with in a macrocell environment was achieved through the use of the embedded Finite Element method in the PDE Tool of matlab. The 2-D Maxwell's wave equation was simulated for the Macrocellular environments. The model of the Received Signal Strength versus the varying distances was generated resulting in the predicted values of the RSSL through the use of the inherent inverse square law in this relation. The Received Signal Strength level obtained from the model was compared with the measured values from the field to ascertain the viability of the model.

In conclusion, the range of the standard deviation of error of the propagation prediction for this research is within acceptable values of 8 dB to 10 dB. Therefore this model can be proposed as a tool to predict the received Power levels in a macrocellular domain so as to aid GSM network optimization and planning especially in the area of radio frequency.

Funding: This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

[1] T. S. Rappaport, *Wireless communication principles and practice*, 2nd ed. Austin: University of Texas, 2003.

[2] O. Shoewu, L. A. Akinyemi, J. O. Emagbetere, and F. O. Edeko, "Pathloss in Nigerian rural vegetation area: A case study of Igbaraoke, Ondo State," *The Pacific Journal of Science and Technology*, vol. 15, pp. 180 - 187, 2014.

[3] O. Shoewu and F. O. Edeko, "Propagation loss determination in cluster based GSM base station in Lagos environ," *Int. Trans, of Electrical and Computer Engrs. Systems*, vol. 2, pp. 28 - 33, 2014.

[4] J. O. Emagbetere and F. O. Edeko, "Finite element method of predicting GSM radio power received in a macrocell environment," *International Journal of Engineering Research in Africa*, vol. 2, pp. 63 - 72, 2010.

[5] F. Daniel, *A student guide to Maxwell's equations published in United States of America*. New York: Cambridge Press, 2008.

[6] Mathsworks, "Partial differential equations toolbox user's guide propagation prediction models for wireless communication systems by Magdy .F. Iskander, Zhengging Yun," *IEEE Transactions on Microwave Theory and Techniques*, vol. 50, 2002.