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Path Loss Propagation Characteristics at 2.7 GHz in Sapele, Nigeria

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ABSTRACT

A study was conducted to examined the path loss propagation characteristics of Global system for mobile communication signals in Sapele, Nigeria. Fifteen different environments were investigated, which provided a comprehensive representation of the city. The Received Signal Strength Indicator (RSSI) was measured at varying distances from the base station for each environment. The data was then analysed to regulate the propagation exponent path loss and characteristics path loss. The path loss in Sapele was found to range from 2.9 to 4.2, with an average of 3.2. A Proposals and advice provided for enhancing the quality of GSM services in the Sapele metropolis.

1. INTRODUCTION

One of the most important characteristics of the propagation environment is the path (propagation) loss. A precise assessment of propagation losses serves as a solid foundation for selecting optimal base station locations and establishing an appropriate frequency plan. Zreikat and Djordjevic (2017). Understanding these losses enables the efficient determination of field signal strength, Signal-to-Noise Ratio (SNR), and carrier-to-interference, facilitating effective decision-making in wireless communication system design. Bhaskaraiah and Srinivasulu (2015).

The enormous growth in mobile cellular networks raises the need for a reliable network planning tools to speed the process from network design to implementation. Enyi (2021). Many macro radio coverage-planning tools include simple path loss prediction algorithms, including prediction of diffraction loss and clutter loss. These algorithms give good prediction for flat and modest rolling areas. However, for all areas dominated by hills and mountains, these algorithms will fall short of giving good prediction. Agadi and Umar (2019).

The quality of coverage of any wireless network design depends on the accuracy of the propagation model. In order to ensure precision in design, propagation models are derived from signal strength measurements conducted within the designated area. Ogunjide et al., (2020). The performance of any wireless network hinges on the precision of the underlying propagation model used for its design. Emagbetere and Edeko (2009). This accuracy is determined

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through signal strength measurements conducted within the specific region of interest. Numerous countries have gathered their own propagation data, including exponent path loss, for their cities (Linus,2011). Examples include the United Kingdom, Saudi Arabia, and Malaysia. GSM service was introduced in Nigeria in 2001, but customer satisfaction in Sapele remains low Enyi (2019). This study aims to design a model that can aid in network planning to address customer complaints in Sapele. This research is particularly pertinent to Sapele, a city in Nigeria.

Omorogiuwa and Edeko. (2009) studied the strength of 1800MHz signals in mountainous areas of Nigeria, including Igarra in Edo State and Ajaokuta and Okene in Kogi State. They found that the exponent path loss was 3.58, indicating a weaker signal than would be expected in less challenging environments."Ubom et al. (2011) created numerical path loss simulations applicable to urban and suburban areas in South-South Nigeria. A modified Hata model, derived using statistical methods, demonstrated effectiveness in the South-South region of Nigeria.

This paper addresses radio wave propagation in mobile communication by determining path loss characteristics in Ilorin, Nigeria. Using a Spectrum Analyzer, measurements at 900MHz across twelve environments reveal a path loss exponent of 2.60, explaining the low GSM signal quality and network issues. Recommendations aim to enhance GSM services in Ilorin. (Ogungbayi and Abdulkarim, 2012). According to Ogungbayi et. al (2014), their work analysing radio wave propagation in mobile communication, particularly the propagation path loss characteristics at 900MHz in the urban terrain of Ilorin town, Nigeria. Measurements were taken using a Spectrum Analyzer at various distances in twelve different environments within the Ilorin metropolis. The research found a path loss exponent of 2.60 for Ilorin, indicating low GSM signal quality and occasional network failures in the area.

This study explores and contrasts radio signal propagation models at 3.8 GHz for varied terrains. Notably, the Free Space model exhibits identical urban path loss (119 dB) for 18 m and 34 m transmitter antenna heights. The Egli model shows the highest rural path loss. Ultimately, a new empirical model is proposed for urban and rural settings. Zakaria and Ivanek (2017).

The newly developed Hata-based models can be utilized to enhance the planning and optimization of GSM networks, effectively addressing issues related to service quality. The study further validates the applicability of Hata-Models in radio networks operating in rural environments (Emagbetere and Edeko, 2019). Propagation models are widely employed in network planning, especially for feasibility assessments and initial deployments, as noted by Adenike (2020). However, no prior research has focused on developing a path loss estimate model specifically tailored to the study area. According to Ifesinachi et al., (2021), aimed at develop a practical model for path loss propagation specifically for an LTE network in Onitsha, Nigeria. Measurement data from various locations in the city was collected to developed the model. The study found an exponent path loss is 3.5 and shadowing factors of 8.7 dB. Comparing the model with existing ones, it demonstrated superior accuracy in forecasting path loss in the Onitsha region.

1.2 The Study Area

Sapele is a city located in Delta State, Nigeria, West Africa. It is situated in the south western part of the country, near the coast of the Atlantic Ocean. The exact geographic coordinates of Sapele are approximately 5.8941° N latitude and 5.6764° E longitude.Obodi (2000).

The population of Sapele in 2022 was estimated to be 238,800. This represents a 2.0% annual growth rate from 2006 to 2022. The population density of Sapele is 411.5 people per square kilometre. Obodi (2000). A total of fifteen sites were visited in the environment investigated. The sites are: New Ogorode Road, Omuvwie Road, Catholic mission Road, Jesse sapele road, Atufe road, Cemetery Road, Fonseca Road, Ugberikoko Road, Yoruba Road, Macpherson Road, Awolowo Road, Ikwewu Sapele Road, Market Road and Hause Road. These sites were selected so as to cover all the possible terrain conditions and the available network coverage. Table 1 shows the comprehensive names and site locations of the environment.

2. METHODLOGY

The method used in this research involves a comprehensive study of Sapele metropolis and location of base stations around the town. This is to allow detail knowledge of the investigated environment. The measurements of received signal strength level were taken at a distance (d) in meters from each base-station visited around the town. The RSSI was recorded at a distance interval of 100 meters away from the test points up to a distance of 3,000 meters (3km). The RSSI was measured by using Handset equipped with G-Mon Pro software and a Digital wheel meter measured the distance away from base-station were monitored by a Global Positioning System (GPS).

To ensure a comprehensive investigation, each base-station under study was visited equally within the three climatic seasons (the raining season, the dry season, and the hammattan season) in Nigeria. Signal strength levels were measured along the radio path during each visit. The collected data were analyzed to ascertain the propagation exponent path loss specific to the examined environment.

The locations of the sites and radio paths investigated are listed in Table 1. Fifteen locations were Investigated. The locations were well spread out to reveal all possible topology obtainable in the City. While table 2 shows the Received Signals Strength Indicator for all Environment measured from the investigated sites.

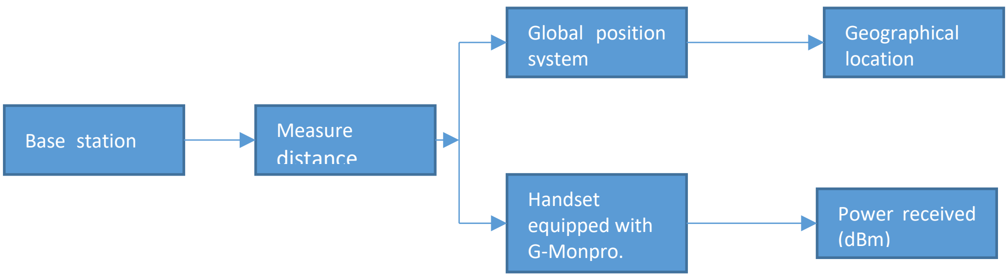

Figure 1: Block diagram of a measurement setup

Table 1: Site locations and environments investigated

S/N	SITES LOCATION	PROPAGATION PATH
Site 1	Sapele power station	New Ogorode Road
Site 2	Christ Embassy church	Omuvwie Road
Site 3	Glory of Christ ministry	Catholic mission Road
Site 4	Okirigwhre motor park	Jesse sapele road
Site 5	Obule maternity and Hospital	Atufe road
Site 6	Mascap Hospital	Cemetery road
Site 7	Rhema medical centre	Fonseca road
Site 8	St. Martins catholic church	Ugberikoko road
Site 9	St. Patrick catholic church	Yoruba road
Site 10	Okotie Eboh Grammar School	Macpherson road
Site 11	Our Lady of Apostle nursery school	Reclamation road
Site 12	St. Hanna new Jerusalem ministry	Awolowo road
Site 13	Okparavero memorial hospital	Ikwewu sapele road
Site 14	Central hospital sapele	Market road
Site 15	Sapele central mosque	Hause road

Table 2a: Received Signals Strength Indicator for all Environments

S/N	Distance(m)	Log of distance	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 8
1	100	2	-82.23	-80.89	-83.48	-81.54	-83.19	-82.54	-81.64	-76.57
2	200	2.3	-85.97	-85.27	-88.42	-86.62	-84.06	-85.07	-85.82	-85.21
3	300	2.47	-89.76	-89.55	-91.47	-87.96	-90.41	-88.56	-87.91	-91.43
4	400	2.6	-97.23	-92.35	-96.88	-94.89	-94.85	-90.85	-93.04	-93.33
5	500	2.69	-92.39	-93.34	-98.33	-97.27	-96.43	-92.94	-96.19	-97.14
6	600	2.77	-101.27	-94.02	-100.48	-101.06	-98.28	-95.33	-101.38	-99.23
7	700	2.84	-101.67	-100.47	-102.97	-104.96	-101.32	-97.63	-103.52	-103.66
8	800	2.9	-110.35	-103.54	-104.21	-108.65	-105.95	-103.26	-104.71	-104.35
9	900	2.95	-117.42	-116.73	-110.09	-110.69	-108.94	-110.57	-109.35	-105.54
10	1000	3	-117.32	-116.27	-118.37	-116.03	-119.77	-121.35	-117.75	-110.69

Table 2b: Received Signals Strength Indicator for all Environments

S/N	Distance(m)	Log of distance	SITE 9	SITE 10	SITE 11	SITE 12	SITE 13	SITE 14	SITE 15
1	100	2	-76.55	-82.11	-77.09	-81.27	-82.57	-79.25	-89.12
2	200	2.3	-80.84	-88.63	-85.69	-86.48	-84.19	-83.78	-90.26
3	300	2.47	-89.13	-91.08	-91.52	-88.91	-88.36	-87.07	-91.88
4	400	2.6	-93.69	-96.25	-97.44	-92.66	-92.77	-95.44	-94.84
5	500	2.69	-96.88	-98.49	-99.86	-98.34	-97.22	-98.67	-100.99
6	600	2.77	-100.96	-100.36	-100.36	-99.83	-99.35	-99.59	-103.57
7	700	2.84	-101.52	-101.88	-105.71	-102.55	-100.11	-100.36	-108.43
8	800	2.9	-102.16	-106.62	-109.65	-105.32	-105.23	-105.72	-114.88
9	900	2.95	-103.23	-110.76	-119.72	-106.11	-107.77	-106.55	-117.92
10	1000	3	-105.44	-115.59	-121.07	-112.49	-110.46	-107.89	-120.11

2.1 Method of Analysis

A Comprehensive Matlab and Microsoft Excel software programming was utilized to evaluate the Received Signal Strength Indicator (RSSI) for the proposed sites. Employing a curve-fitting technique, the average RSSI was plotted against the logarithm of distance (d). The software determined the values of the constant n (exponent path loss) in the chosen equation by employing the best-fitted curve method and straight-line model equation were derived from figures 2 to figures 16 showed below.

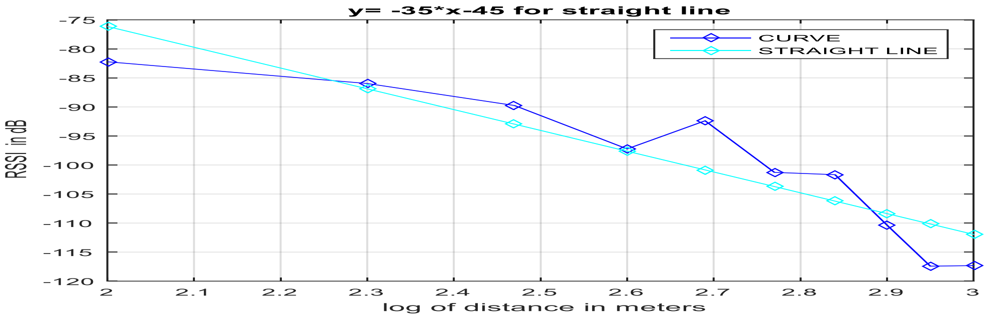

Figure 2: RSSI in dB verse log of distance in meter for Site 1

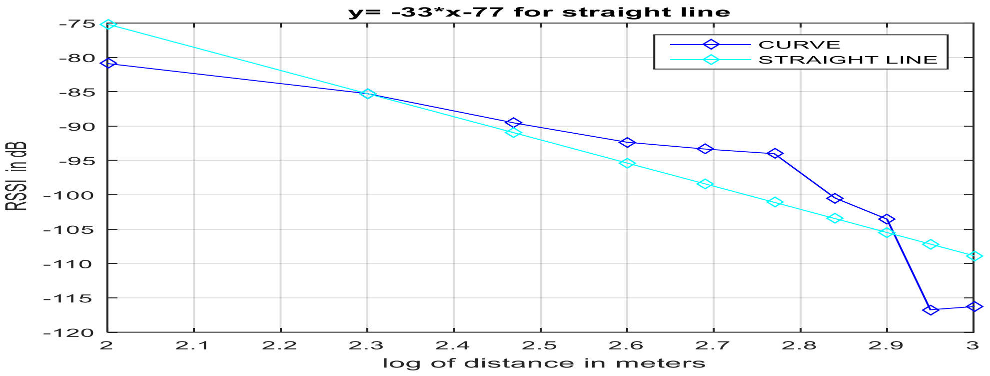

Figure 3: RSSI in dB verse log of distance in meter for Site 2

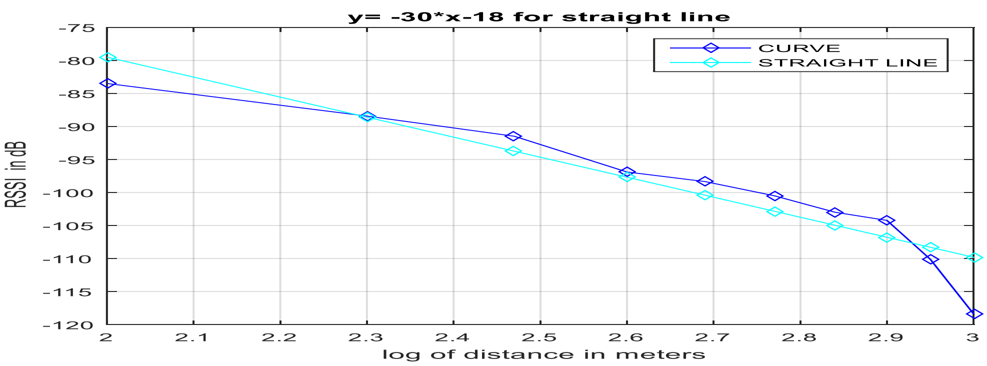

Figure 4: RSSI in dB verse log of distance in meter for Site 3

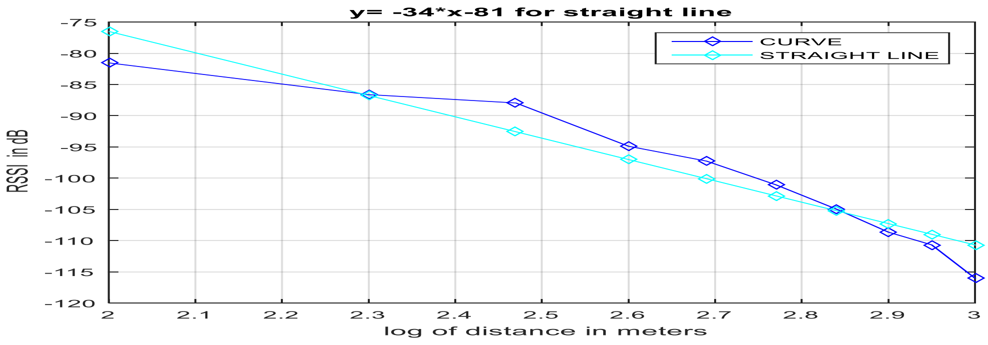

Figure 5: RSSI in dB verse log of distance in meter for Site 4

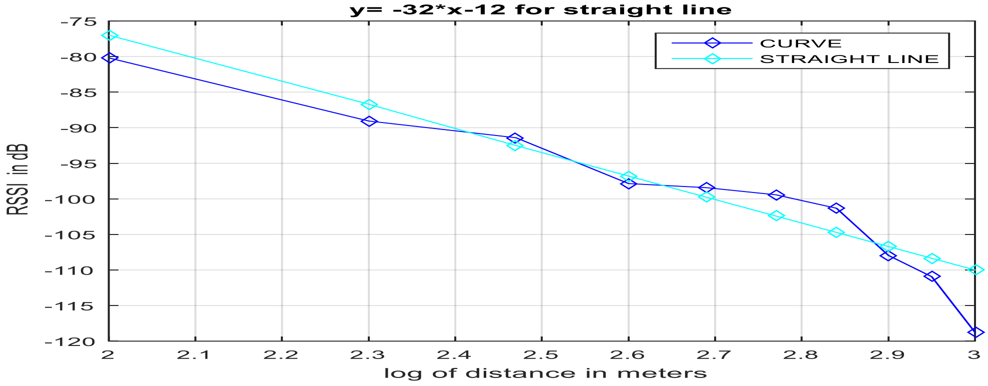

Figure 6: RSSI in dB verse log of distance in meter for Site 5

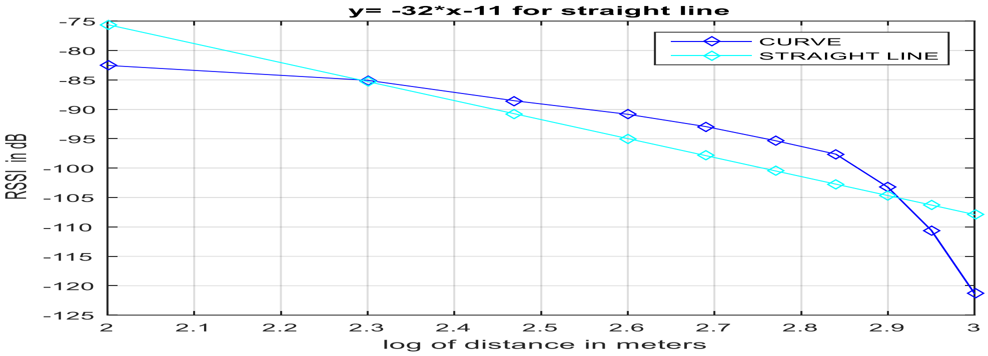

Figure 7: RSSI in dB verse log of distance in meter for Site 6

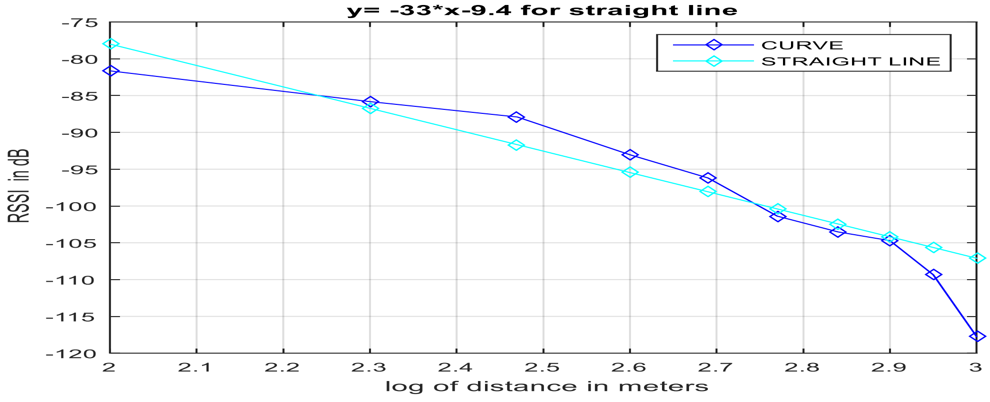

Figure 8: RSSI in dB verse log of distance in meter for Site 7

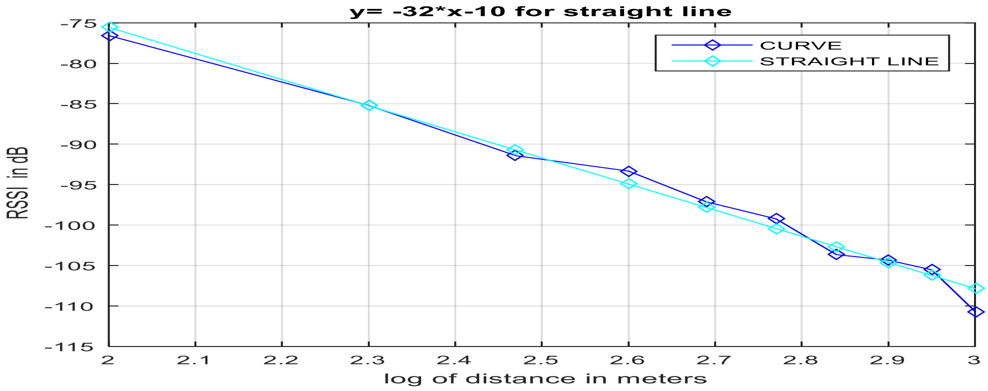

Figure 9: RSSI in dB verse log of distance in meter for Site 8

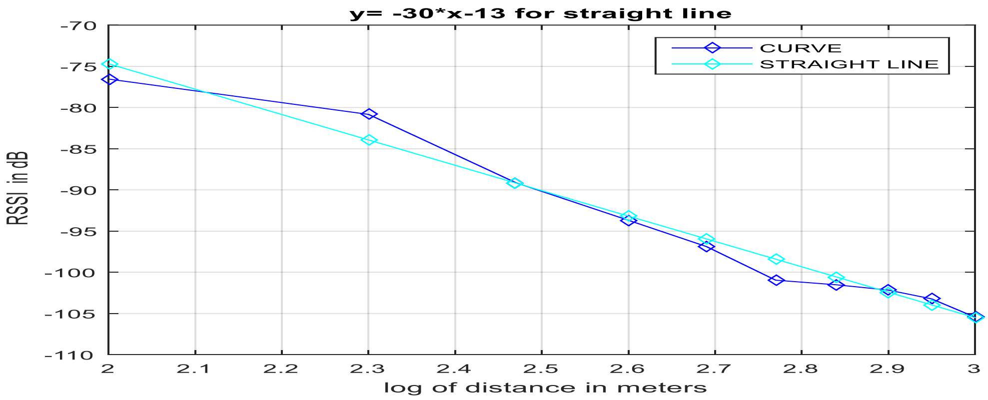

Figure 10: RSSI in dB verse log of distance in meter for Site 9

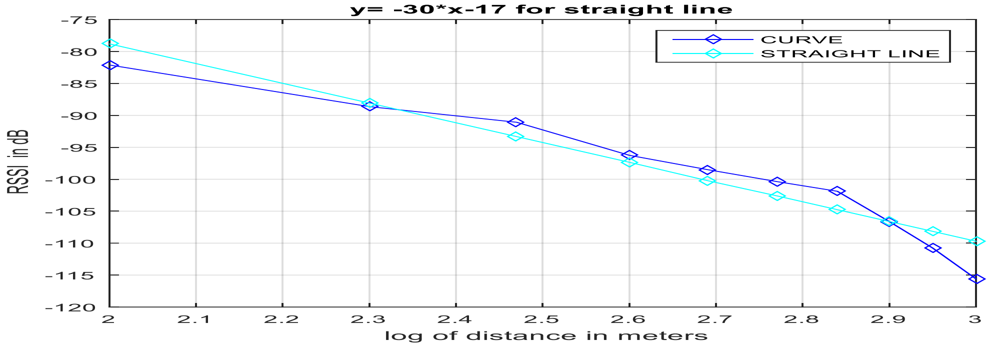

Figure 11: RSSI in dB verse log of distance in meter for Site 10

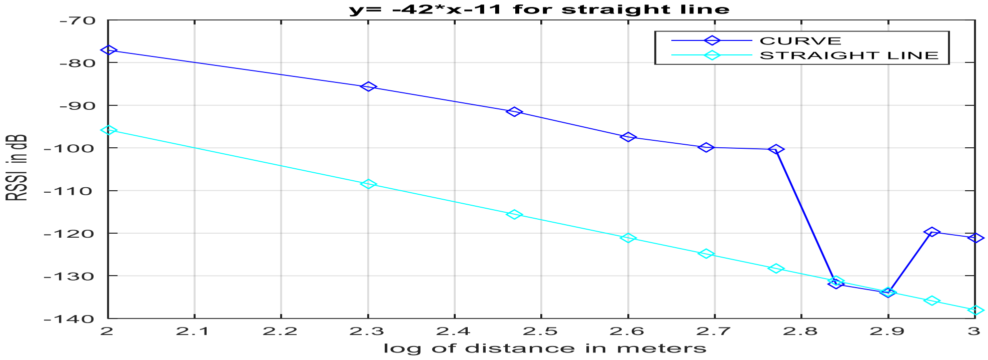

Figure 12: RSSI in dB verse log of distance in meter for Site 11

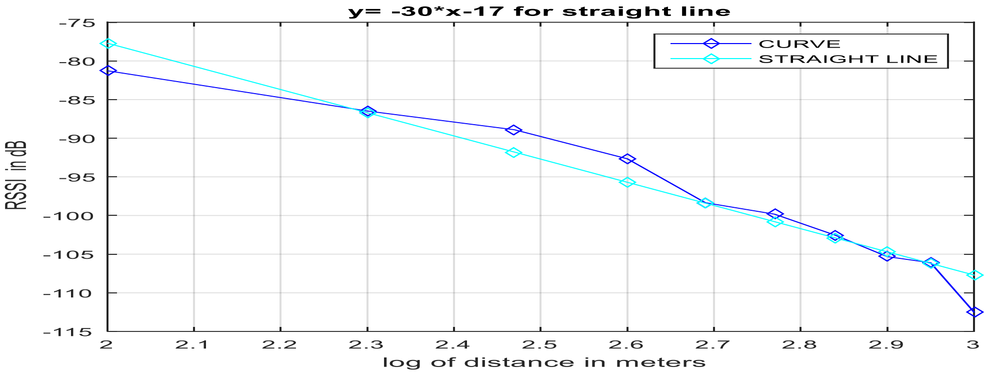

Figure 13: RSSI in dB verse log of distance in meter for Site 12

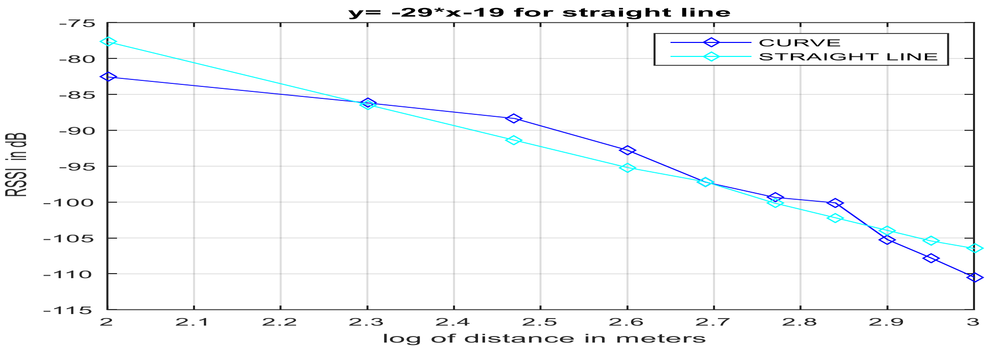

Figure 14: RSSI in dB verse log of distance in meter for Site 13

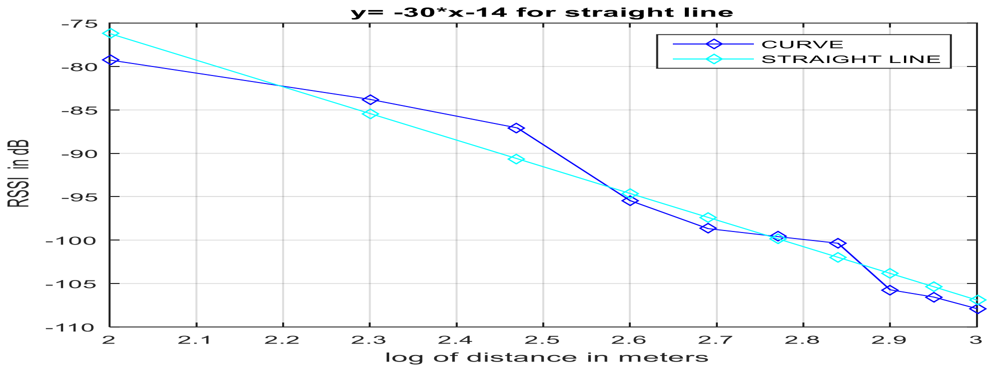

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Figure 15: RSSI in dB verse log of distance in meter for Site 14

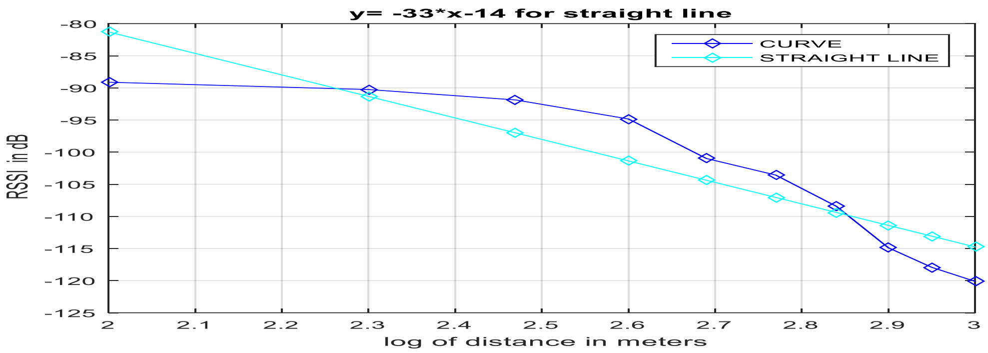

Figure 16: RSSI in dB verse log of distance in meter for Site 15

2.2. Determination of Exponent Path Loss

The values of the exponent path loss (n) and the intercept (I) for each site investigated are shown on the graphs. This is tabulated and presented in Table 3. The paper proposes that, the average exponent path loss of the investigated sites be used as the exponent path loss for Sapele metropolis. This is computed as follows: From the graphs of figures 2 to 16, the summation of exponent path loss is;

$$n = \frac{\sum_{i=n}^{N}(n)}{N} = 3.2$$
(1)

Where N is the number of sites, n is the Exponent path loss.

Path Loss is usually expressed in decibel (dB). In its simplest form, path loss can be calculated using the formula;

$$P(dBm) = 10n\log(d) + I_{AVG}$$
(2)

Where, P is the path loss propagation characteristic in decibel, n is the exponent path loss, d is the distance between the transmitter and receiver, usually measured in meters, and I_{AVG} is intercept, a constant which accounts for system losses.

Taking the premise that the path loss propagation characteristic (P) for the city studies conforms to the pattern of equation 2, then;

$$P(dBm) = 32\log(d) + 12.6$$
(3)

3. Results and Discussion

3.1 Results Presentation

The results of the fifteen graphs above shows the exponents path loss and the intercepts was obtained for each environment as indicated in table 3 below.

Table 3: Showing each Sites with Exponents Path loss and Intercepts

S/N	Sites	Exponents Path Loss	Intercepts
Site 1	Sapele power station	3.5	4.5
Site 2	Christ Embassy church	3.3	7.7
Site 3	Glory of zion church of Christ ministry	3.0	18.8
Site 4	Okirigwhre motor park	3.4	8.1
Site 5	Obule maternity and Hospital	3.2	12.0
Site 6	Mascap Hospital	3.2	11.0
Site 7	Rhema medical centre	3.3	9.4
Site 8	St. Martins catholic church	3.2	10.9
Site 9	St. Patrick catholic church	3.0	13.1
Site 10	Okotie Eboh Grammar School	3.0	17.0
Site 11	Our Lady of Apostle nursery school	4.2	11.3
Site 12	St. Hanna new Jerusalem ministry	3.0	17.7
Site 13	Okparavero memorial hospital	2.9	19.2
Site 14	Central hospital sapele	3.0	14.8
Site 15	Sapele central mosque	3.3	14.4
	AVERAGE	**3.2**	**12.6**

3.2 Discussion of Results

From the analysis conducted: the value of the exponent path loss and the path loss characteristics of Sapele City are presented in Table 3.

The joint analysis of path loss and its spatial variability across diverse settings, as depicted in Figures 2 to 16, respectively, yields the following observations:

In terms of location variability, Environment 13 (Ikwewu Sapele Road) exhibited the highest variance, followed by Environment 3 (Catholic Mission Road), and then Environment 12 (Awolowo Road), with peak variations of 19.2 dB, 18.8 dB, and 17.7 dB, respectively. Conversely, Environment 1 (New Ogorode Road), Environment 2 (Omuvwie Road), and Environment 4 (Jesse Sapele Road) displayed the least location variability, with peak variations of 4.5 dB, 7.7 dB, and 8.8 dB, respectively.

In terms of exponents path loss, Environment 11 (Reclamation Road) exhibited the highest exponent path loss at 4.2, followed by Environment 1 (New Ogorode Road) and Environment 4 (Jesse Sapele Road), both with a exponents path loss of 3.5, and Environment 4 with a exponents path loss of 3.4 dB. Environments 2, 7, and 15 shared the same exponents path loss at 3.3 dB. Environments 3, 9, 10, 12, and 14 shared the lowest exponents path loss of 3.0 dB, indicating similarities in human-made structures, multiple paths fading, and environmental topology.

We can therefore state that the exponents path loss of the city is between 3.0 and 4.2. The average value of path loss constant for Sapele is 3.2, this indicated that Urban area cellular radio system must be use in this environment for effective communication to be established with average intercept of 12.6

4. CONCLUSION

The exponent path loss, a crucial factor in mobile telecommunications planning, was measured in Sapele to assess the area's signal quality. The study revealed a exponent path loss of 3.2, indicating subpar signal quality. This parameter is essential for planning and analysing mobile communication in Sapele. The determined path loss exponent and characteristics are recommended for use until further research is conducted. Additional studies in other Nigerian cities are also recommended. A potential extension to this research is developing a propagation model for 1800MHz and 2700MHz signals in urban, suburban, and open areas. The empirical model's results can be used to compare measured values and existing radio propagation models.

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