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ORIGINAL RESEARCH ARTICLE

PROPAGATION LOSS DETERMINATION OF GSM SIGNAL STRENGTH IN SELECTED BUILDINGS IN ILORIN, NIGERIA

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ABSTRACT

GSM signal building penetration loss is a problem often encountered by subscribers inside a building. As a result of building penetration loss, poor reception and signal outages often occur in many indoor locations and this accounts for increased attenuation of received signal strength of a cellular network signal when a subscriber with a mobile phone moves from outdoor to indoor. The study assessed the GSM signal penetration loss in thatched, wooden, block, mud and zinc buildings. Three network providers named A, B and C was used for the experiment. A low budget but very effective equipment (Two Tecno Pouvoir 3 plus Android phone) was used as the measurement tool. It was loaded with Network Signal Info application developed by KAIBITS Software GmbH installed software and positioned inside and outside the building to record indoor and outdoor GSM signal strength respectively for the three service providers in Ilorin, Nigeria. The results were then analyzed in order to determine and compare the path loss introduced by each of the selected buildings. This process was repeated for all the selected buildings, and the measurement was carried out for 6 months. The findings revealed that the outdoor signal strength was higher than the indoor signal strength for all the selected buildings; it also revealed that penetration loss is likely to be a function of the material used in the construction of the buildings. Zinc building has the highest penetration loss of 12.0dBm and thatched building has the least penetration loss of 2.6dBm. Information from this research will assist in selection of building materials for good indoor cellular network signal reception. It will also assist cellular network service providers in the link budget preparation for environments where similar building materials are used.

1.0 Introduction

Today cellular services are used by millions of people worldwide in which African countries especially Nigerian is not left out, according to Akanni et al. (2020), Nigeria is a developing nation and the number of mobile communication and its applications is geometrically rising. For better cellular services, the environment in which the service is to be render must be taken into consideration when planning the link budget. One of the most important features of the propagation environment is propagation path loss, Path loss in an indoor reception may be due to many factors, such as reflection, refraction, diffraction, and Mobile Unit (Oni and Idachaba 2017). It has been observed that material used in buildings play significant role in an indoor path loss. The poverty level in Nigeria and most of the African countries lead to the choice of different materials used in the different building construction (Sholanke et al., 2015). The old style of buildings is still in existence at high proportion both in the rural and urban area and this tend to always make the user of wireless mobile phone to move outdoor in order to receive better service due to the degradation in the amount of signal received in indoor environment. According to Elechi and Otasowie (2016), the signal propagation losses due to building materials constitute about 31% of the total GSM signal loss. Buildings penetration loss leads to an increase in attenuation of the received signal observed when the mobile is moved from outside to inside of a building (Idim and Anyasi , 2014).

1.1 GSM Signal Propagation Approach

Forecasting and determining the magnitude of GSM signal strength in a particular environment involves studying and understanding radio communication primarily in that environment(Joseph et al., 2013).Radio wave communication especially in an indoor environment is subjected to some factors such as reflection, diffraction and scattering(Ahamed and Faruque .,2016). Reflection is said to have occurred when a propagating wave encounters a large man-made or naturally occurring object, which has dimensions that are large compared to the wavelength of the propagating wave. A Reflection may result in either decrease or increase in the level of signal power at the reception point (Neskovic et al., 2000).

Diffraction occurs when the radio wave encounter the obstacles with sharp irregular surfaces (edges/wedges) and has the dimension larger than the signal wavelength(Elechi Otasowi 2016).As a result of diffraction, signal wave bends over or around the edge of an obstruction thus resulting in weak signal at the receiving end (Heydariaan et al., 2018).

Scattering occurs when the propagation path contains objects like uneven walls, lamp posts and other small objects with irregular surfaces whose dimensions are small compared to the wavelength of the propagating signal. Of all the stated effects, scattering is the most difficult to predict (Neskovic et al., 2000).

1.2 Propagation Loss

Propagation loss or path loss is the reduction in the power density of an electromagnetic wave as it propagates through space and is the major component in the analysis and design of the link budget of a telecommunication system(Idim and Ayansi 2014). The propagation loss is caused by many factors such as reflection, refraction, diffraction, free space loss, aperture medium coupling loss, terrain contours, environment such as rural, urban, vegetation and foliage (Idim and Anyasi 2014). A number of propagation models are available to predict path loss over different types of terrain. The models are generally classified into three namely; deterministic, statistical and empirical models (Sharma and Singh 2010).

1.3 Review of Related Works

A lot of researches on building penetration loss had been carried out in the past and there are still some on-going researches by authors in the field to address the issue. Turkmanj and de Toledo as cited in Svistunov and Mordachev(2016), carried out an investigation on propagation into and within buildings at 1800 MHz using buildings in the university of Liverpool environment; mean signal measurements were conducted in rooms and corridors of four different buildings and thereafter compared with street level outside. The average measured penetration loss at ground floor level was found to be 13 dB and rate of change of penetration loss with height was - 1.4 dB per floor. For floor levels higher than the sixth floor, it was found to be 0.4 dB per floor. The rate of change of the mean signal level for signals travelling within buildings was, on average, 8.3 dB per floor. The best coverage was obtained by locating the transmitter in a large room at the centre of the building. The path loss attenuation factor *n* that best modelled the within-building measurements was found to be *5.6*.

Idim and Anyasi and (2014) investigate the determination of building penetration loss of GSM signals in some selected buildings in Orhuwhorun, Delta State, Nigeria for concrete and blocks and found that the average penetration loss to be 10.62dBm, and 4.25dBm respectively. In addition, Elechi and Otasowie(2015) similar experimentin some selected buildings in Rivers state, Nigeria; using mud house with thatched roof, mud house/rusted corrugated iron sheet roof, sandcrete building/rusted corrugated iron sheet roof, sandcrete building/unrusted corrugated iron sheet roof and building with alucoboard wall cladding. The results showed that buildings with alucoboard wall cladding have the highest GSM signal penetration loss while the sandcrete building/unrushed corrugated iron sheet roof has the lowest GSM penetration signal loss. Furthermore such an investigation was conducted by Abiodun and Ukhurebor(2018)and their results reviewed that the average penetration loss for the tilled, concrete, mud and the wooden buildings are 13.0 dBm, 10.8 dBm, 9.57 dBm and 8.72 dBm respectively. It was observed that the tiled building with concrete tiled roof has the highest penetration loss in all the months considered, followed by the concrete wall building with corrugated galvanized iron roof, while the wooden wall building with rusted corrugated roof was having the lowest penetration loss.

This brief review of relevant research highlights the paucity of relevant studies in the local Nigerian system and African as a whole. It is evident from the reviewed of the existing works that none of the authors worked on GSM signal penetration loss introduced by full thatched building, also, the values of the signal strengths inside and outside the buildings were not measured simultaneously (not measured at the same time) and this may affect the accuracy of the measured values. This work aims at investigation of the GSM signals penetration loss introduced by full thatched building in addition to the one introduced by wooden, block, mud and zinc buildings. It also aims at providing a better methodology for accurate measurement values of the signal strength. This research work made used of two similar equipment (Two Tecno Pouvoir 3 plus Android phone) to measure the values of the signal strengths inside and outside the building simultaneously. In this way, the errors that would have occurred due to difference in the time will be eliminated.

2.0 MATERIALS AND METHOD

2.1 Buildings Description

The buildings selected for the experiment are located in Ilorin, the capital of Kwara State, Nigeria. It represents the prevalent types of buildings that can be found in most African countries, especially Nigeria. The buildings considered for the study are full thatched building made of grass for both wall and roof, wooden building constructed with planks; the roof of which was made with corrugated iron sheet having its floor cement plastered, block building constructed with cement blocks; the roof of which was made with corrugated iron sheets with the floor cement plastered, mud building constructed with mud; with the roof made of corrugated iron sheets, the floor was cement plastered, and zinc building constructed fully with zinc, and the roof made with corrugated iron sheet, the floor cement plastered too. Figures 1 to 5 show the photo of thatched, wooden, block, mud and zinc buildings, respectively.

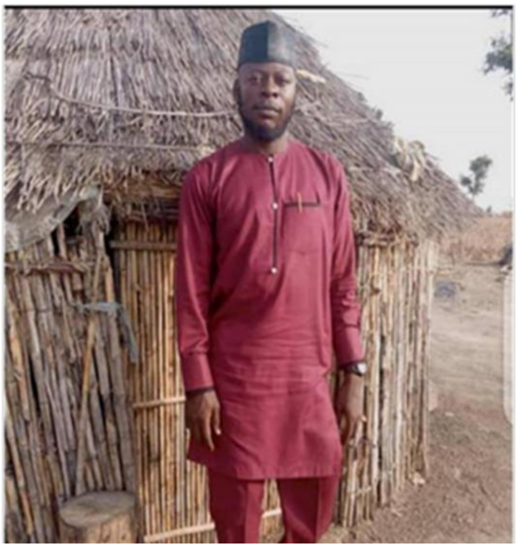


Figure 1: Thatched building

Figure2: Wooden building

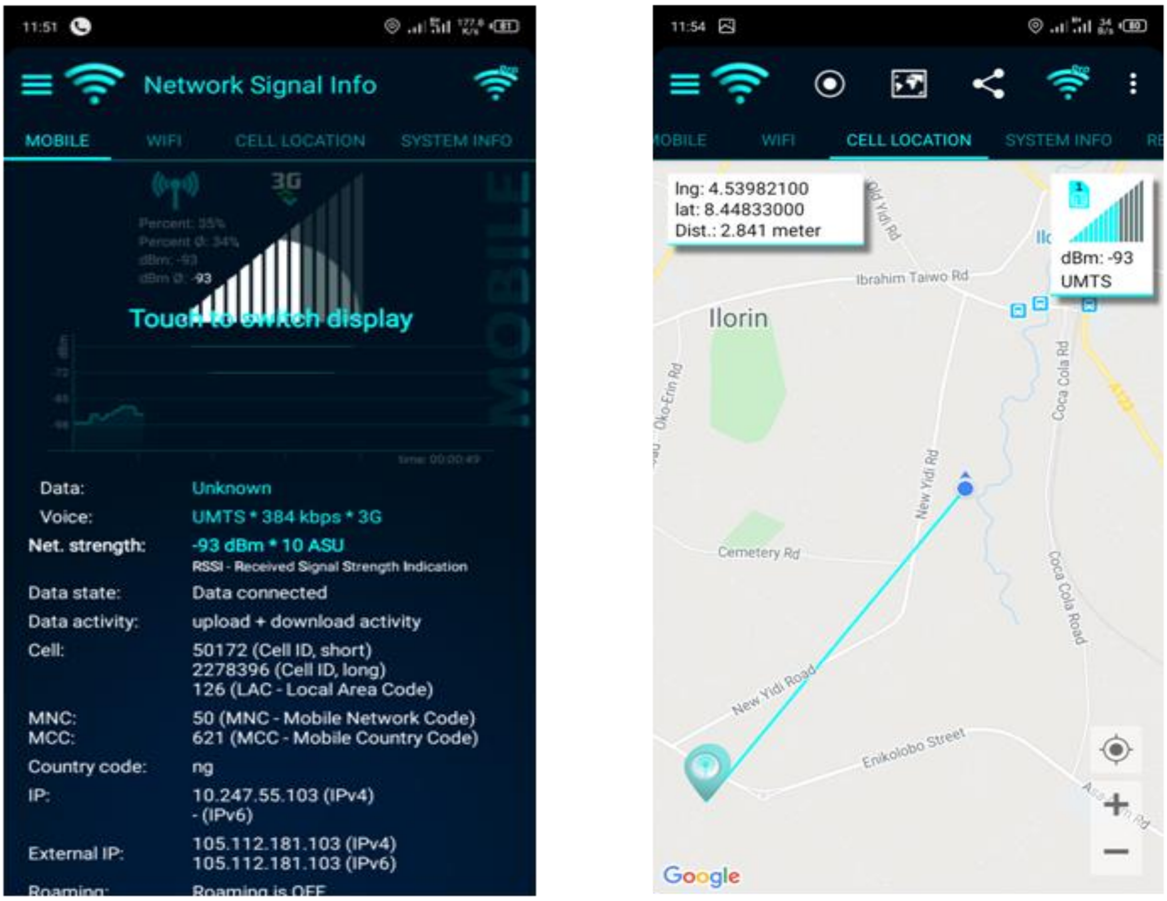
Figure 3: Block building

Figure 4: Mud building

Figure 5: Zinc building

2.2 Measurement Tools and Procedure

A Tecno Pouvoir 3 plus Android phone, with Network Signal Info application installed; was used as the measurement tool to record the received signal strength inside and outside each of the five selected buildings. The Network Signal Info application was developed by KAIBITS Software GmbH was used. Figure 6(a) shows the screenshot of the measured received signal strength obtained with the Tecno Pouvoir 3 while Figure 6(b) shows the screenshot of the GPS location of the cell phone as connected to a base station



(a) (b)

Figure 6: The screenshot of the Network Signal Info Application

Three network providers named A, B and C were used for this experiment. The test equipment loaded with the test software were positioned inside and outside the building to record indoor and outdoor GSM signal strength respectively for the three service providers. This process was repeated for all the selected buildings. The measurement was carried out for 6 months.

3.0 Data Analysis

The Penetration and the Average penetration loss are calculated using Equations(1) and (2) respectively.

$$P_{Loss} = S_o - S_i \tag{1}$$

$$AverageP_{Loss} = \frac{TotalP_{Loss}}{n} \tag{2}$$

$where: S_o = Outdoor\ Signal\ Stength\ (dBm)$

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S_i = Indoor Signal Strength (dBm)

$P_{Loss} = PenetrationLoss\ (dBm)$

$n = numberofsamples$

4.0 Results and Discussion

The experimental results of the measured outdoor signal strength and indoor signal strength from the base stations of the three selected GSM network operators named A, B and C at various selected buildings of different types in Ilorin metropolis were recorded. With the aid of statistical "Ad-in" feature in Microsoft EXCEL the measured signal strengths were used to calculate the average penetration loss introduced by the different building types on the service rendered by each of network providers.

Table 1 shows the GSM signal penetration loss for Thatched Building. The monthly average measured outdoor signal strengths, S_O (dBm), indoor signal strengths, S_i (dBm) and penetration loss P_{Loss} (dBm) for a period of six months for each of the operator were tabulated. Also, the average penetration loss P_{Loss} (dBm) over a period of six months for each of the operator were tabulated. It was observed that the outdoor signal strength (dBm) received is higher than the indoor signal strengths (dBm) received for all the network providers. It was also observed that the average penetration loss of all the network providers over a period of six months was approximately 2.6 dBm.

Table 2 shows the GSM Signal penetration loss for Wooden Building. It follows the same trend as in Table 1. It was observed that the wooden building has higher penetration loss compared to that of thatched building. It was also observed that the average penetration loss of all the network providers over a period of six months was approximately 3.3 dBm.

Table 3 shows the GSM Signal Penetration Loss for Block Building. It follows the same trend as in Table 1and 2. It was observed that the block building has higher penetration loss compared to that of thatched and wooden buildings. It was also observed that the average penetration loss of all the network providers over a period of six months was approximately 6.3 dBm.

Table 4 shows the GSM Signal Penetration Loss for Mud Building. It follows the same trend as in Table 1, 2 and 3. It was observed that the Mud building has higher penetration loss compared to that of thatched, wooden, and block buildings. It was also observed that the average penetration loss of all the network providers over a period of six months was approximately 8.3 dBm.

Table 5 shows the GSM Signal Penetration Loss for Zinc Building. It follows the same trend as in Table 1, 2, 3.and 4. It was observed that the Zinc building has higher penetration loss compared to that of thatched, wooden, block and mud buildings. It was also observed that the average penetration loss of all the network providers over a period of six months was approximately12 dBm.

Table 1: GSM Signal Penetration Loss for Thatched Building

		OPERATOR A			OPERATOR B			OPERATOR C		
S/N	Month	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_o (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)
1	January	-78	-80	2	-66	-70	4	-71	-72	1
2	February	-78	-81	3	-67	-69	2	-69	-72	3
3	March	-81	-84	3	-67	-69	2	-70	-72	2
4	April	-79	-81	2	-65	-68	3	-70	-73	3
5	May	-78	-82	4	-67	-71	4	-71	-75	4
6	June	-80	-81	1	-68	-69	1	-70	-73	3
Average P_{Loss} (dBm)				2.5			2.7			2.7

Table 2: GSM Signal Penetration Loss for Wooden Building

		OPERATOR A			OPERATOR B			OPERATOR C		
S/N	Month	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_o (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)
1	January	-81	-83	2	-81	-83	2	-59	-63	4
2	February	-79	-85	6	-79	-85	4	-59	-61	2
3	March	-81	-85	4	-81	-86	5	-56	-61	5
4	April	-81	-84	3	-81	-85	4	-57	-60	3
5	May	-81	-84	3	-81	-84	3	-57	-60	3
6	June	-80	-83	3	-80	-82	3	-59	-63	4
Average P_{Loss} (dBm)				3.5			3.3			3.5

Table 3: GSM Signal Penetration Loss for Block Building

		OPERATOR A			OPERATOR B			OPERATOR C		
S/N	Month	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_o (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)
1	January	-63	-71	8	-57	-63	6	-63	-70	7
2	February	-65	-71	6	-57	-63	6	-63	-70	7
3	March	-67	-71	4	-57	-63	6	-65	-71	6
4	April	-65	-71	6	-57	-63	6	-63	-69	6
5	May	-65	-71	6	-57	-65	8	-63	-70	7
6	June	-63	-71	8	-57	-63	6	-65	-69	4
Average P_{Loss} (dBm)				6.3			6.3			6.2

Table 4: GSM Signal Penetration Loss for Mud Building

		OPERATOR A			OPERATOR B			OPERATOR C		
S/N	Month	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_o (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)
1	January	-81	-91	10	-85	-93	8	-73	-85	12
2	February	-81	-88	7	-85	-91	7	-75	-85	10
3	March	-81	-89	8	-83	-93	10	-79	-85	6
4	April	-81	-89	8	-83	-91	8	-75	-85	10
5	May	-81	-90	9	-83	-91	8	-79	-85	6
6	June	-81	-89	8	-85	-94	9	-79	-85	6
Average P_{Loss} (dBm)				8.3			8.3			8.3

Table 5: GSM Signal Penetration Loss for Zinc Building

		OPERATOR A			OPERATOR B			OPERATOR C		
S/N	Month	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_o (dBm)	S_i (dBm)	P_{Loss} (dBm)	S_O (dBm)	S_i (dBm)	P_{Loss} (dBm)
1	January	-79	-91	12	-79	-89	10	-79	-93	14
2	February	-79	-93	14	-79	-93	14	-79	-93	14
3	March	-79	-91	12	-81	-93	12	-79	-89	10
4	April	-83	-95	12	-81	-92	11	-79	-89	10
5	May	-83	-93	10	-81	-93	12	-79	-89	10
6	June	-89	-91	12	-81	-93	12	-79	-93	14
Average P_{Loss} (dBm)				12			11.8			12

Figure 7 shows the bar chart of the average penetration loss of each of the building type for each of the network provider obtained with the aid of statistical “Ad-in” feature in Microsoft EXCEL as tabulated in Table 1 through Table 5. The bar chart easily revealed the average penetration loss of each building type for each of the network provider and it can be seen that the thatched building has the lowest average penetration loss, followed by the wooden while the zinc has the highest average penetration loss.

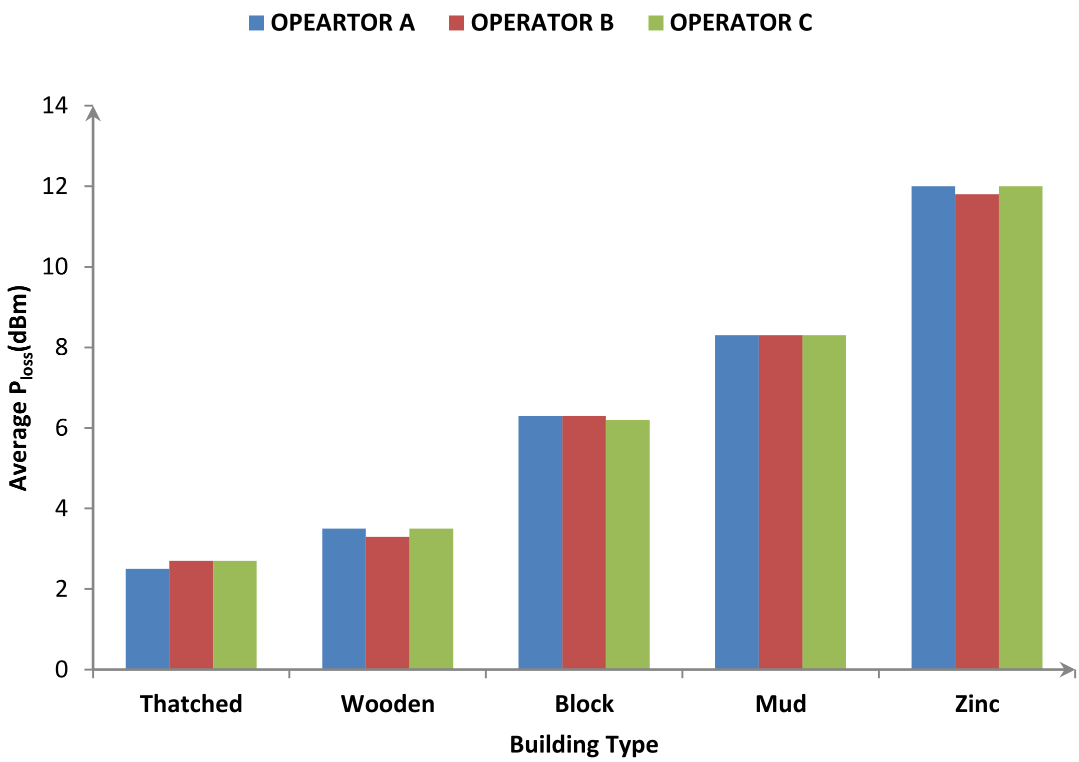

Figure 7: Average Penetration Loss P_{Loss} over a Period of Six months

4.0 Conclusion

In this paper, measurements on outdoor signal strengths and indoor signal were used to determine the penetration loss on GSM signal strength caused by different types of buildings. Building penetration loss which is one of the major parameter in the determination of received signal strength inside a building in telecommunication systems design has been evaluated for the selected building made of different materials. The results obtained shows that the outdoor signal strength was higher than the indoor signal strength for all the selected buildings; it also revealed that penetration loss is likely to be a function of the material (mud, brick, zinc and thatched) used in the construction of buildings. Zinc building has the highest penetration loss of 12.0dBm and thatched building has the least penetration loss of 2.6dBm.Also the block and mud building penetration loss is almost in conformity with that of existing research work (Idim et al., 2014).

From the study, it is concluded that for good indoor cellular network signal reception, selection of building materials should always be taken into consideration. It is recommended that the GSM service providers should take into consideration when preparing the link budget the types of materials used in building structure in that environment.

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