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"Investigation of building Penetration Loss for GSM Signals into Selected Building Structures in Kaduna"

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***Abstract**: Radio propagation inside building is governed by mechanisms such as reflection, diffraction, and scattering from different objects. The field distribution inside building is therefore dependent on specific features of its internal structures. This research work investigated GSM signal variation in mud building/rusted corrugated iron sheet roof materials and compared the result obtained with other buildings built with different building materials. Handheld AAronia HF2025E spectrum analyzer was used to carry out the measurements. The frequency bands of five service providers; Airtel, MTN, Globacom, Etisalat, and Starcomm were used as the operating frequencies and handheld portable spectrum analyzer served as receiver which recorded the average signal strength level at each point of the measurement. Results obtained showed among the various combination of materials considered, mud building/rusted corrugated iron sheet roof presents higher signal losses of -59.08dBm, followed by mud building/ unrusted corrugated iron sheet roof had an average signal losses of -53.63dBm, the sandcrete building/rusted corrugated iron sheet roof presents signal losses of -50.32dBm, while sandcrete building/unrusted corrugated iron sheet roof had lower average signal losses of -45.37dBm.*

Keywords:** Building materials, Network service providers, Radio propagation, and Signal **strength.

I. Introduction

With the advent of microcellular, radio networks employed in third- generation 3G mobile communication systems, there is an increased interest in propagation models that are able to provide location-specific predictions of channel parameters such as local mean power, and delay spread [1]. Propagation research for mobile communications in urban microcells has hitherto been focused mainly on the modeling of reflection and diffraction from exterior walls and corners of buildings. These buildings are usually treated as an opaque at frequencies used for terrestrial mobile communications. Radio propagation inside buildings is governed by mechanisms such as reflection, diffraction, and scattering from various objects. The field distribution inside a building therefore dependent on specific features of its structure (e.g. Layout, construction materials [2].

Propagation in indoor environments have somewhat, more complex multipath structure than in outdoor environments which is largely due to the nature of the building structures used, the room layouts and the type of materials used in the construction of the building [3]. An important requirement for mobile radio systems is the provision of reliable services to the increasing number of users across outdoor to indoor interface. There are several factors that affect radio wave propagation which result in the degradation of signals; these factors include multipath fading effect, non line-of- sight, path loss, building penetration loss type of materials used in construction furniture in the rooms among others may be possible factors that caused variation in GSM signal strength received in these buildings under study [4][5].

Physical surroundings can be other possible factors that cause the variation, because within any building the signal strength may be affected since RF waves may enter the building directly from transmitting antenna (Line-of-sight). Once inside building the field encounters a wide array f objects which shield or reflects the RF signal or cause losses to it. Penetration losses are generally higher in urban environment [6]. Other factors that lead to variation of GSM signal strength the dimension of the windows area, direct incident wave arrival and the absorption of moisture (water) by building materials [7].the signal loss inside a factory building is quite different from the loss inside an office building due to the differences in the structure and the materials used [8].

1.1 Indoor Radio Propagation

The performance of the GSM signal strength depends heavily on the characteristic of the indoor radio channel. Excessive path loss within the home can prevent units from communicating with one another. The indoor mobile radio channel can be especially difficult to model because the channel varies significantly with the environment. The indoor layout of rooms, and the type of construction materials used. In order to understand the effects of these factors of electromagnetic wave propagation, it is necessary to recall the three basic mechanisms of electromagnetic wave propagation reflection, diffraction, and scattering [9].

Reflection occurs when a wave impacts as object having larger dimensions than the wavelength. During reflection, part of the wave may be transmitted into the object with which the wave has collided. The remainder of the way may be reflected back into the medium through which the wave was originally traveling. In an indoor environment, objects such as walls and floors cause reflection.

When the path between transmitter and receiver is obstructed by a surface with sharp irregularities, the transmitter waves undergo diffraction. Diffraction allows waves to bend around the obstacle even when there is no line-of- sight (LOS) path between the transmitter and receiver. Objects in an indoor environment which can cause diffraction include furniture and large appliances.

The third mechanism which contributes to electromagnetic wave propagation is scattering. Scattering occurs when the wave propagates through a medium in which there are a large number of objects such as small appliances cause scattering.

The combined effects of reflection, diffraction, and scattering cause multipath. Multipath results when the transmitted signal arrives at the receiver by more than one path. The multipath signal components combine at the receiver to form a distorted version of the transmitted waveform. The multipath components can combine constructively or destructively depending on phase variations of the component signals. The destructive combination of the multipath components can result in a severely attenuated received signal.

1.2 Calculation of penetration loss

For a given building, the average building penetration loss may be computed using equation (1) [10].

APL (dBm) = Mean S_{out} (dBm) –Mean S_{in} (dBm) where

APL (dBm) is the average penetration loss in dBm, Mean S_{out} is mean signal level outside the building in dBm and Mean S_{in} is mean signal level inside building in dBm.

II. Method/ Material

To measure the indoor, GSM signal strength variation in building at the frequencies of 900MHz and 1800MHz, measurements were conducted with a spectrum analyzer as a receiver. The operational frequencies of GSM network service providers were used for these measurements. The measurements were conducted in five selected areas in Kaduna Metropolis; Anguwan Kanawa, Hayen- Danmani, Anguwan Muazu, Kabala Costain, and Mararaban Jos. An AAronia HF2025E (700MHz-2GHz) spectrum analyzer was used to carry out the measurements. The frequency bands of five service providers; Airtel downlink (955-960MHz), MTN downlink (950-955MHz), Globacom downlink (945-950HMz), Etisalat downlink (890-895MHz), and Starcomm downlink (1883-1888MHz) were used as the operating frequencies, ad handheld portable spectrum analyzer, served as the receiver which recorded the averaged signal strength level at each point of the measurement. The measurements were performed in indoor environments; the indoor measurements were conducted in four different building types; mud building/rusted corrugated iron sheet roof, mud building/unrusted corrugated iron sheet roof, sandcrete building/ rusted corrugated iron sheet roof and sandcrete building/ unrusted corrugated iron sheet roof.

The measurements were conducted to investigate the variation of GSM signal strength received within the building types mentioned in this research. The data collected through measurements and the results were presented for each of the respective area considered.

III. Result Generated through field measurement at various areas in Kaduna

Table 1: Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Anguwan Kanawa Area

Network provider	Mud building / rusted corrugated iron sheet roof	Mud building/ unrusted corrugated iron sheet roof	Sandcrete building / rusted corrugated iron sheet roof	Sandcrete building / unrusted corrugated iron sheet roof
Airtel	-54.11	-52.99	-52.84	-47.03
MTN	-48.07	-46.54	-45.25	-42.34
Glo	-53.41	-49.44	-47.98	-44.97
Etisalat	-69.23	-53.65	-47.67	-41.62
Starcomm	-70.757	-67.70	-69.70	-61.94

Table 2: Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Hayen- Danmani

Network provider	Mud building / rusted corrugated iron sheet roof	Mud building/ unrusted corrugated iron sheet roof	Sandcrete building / rusted corrugated iron sheet roof	Sandcrete building /unrusted corrugated iron sheet roof
Airtel	-58.34	-50.41	-47.23	-45.55
MTN	-51.00	-49.92	-42.66	-41.47
Glo	-58.55	-57.69	-52.01	-50.05
Etisalat	-57.44	-54.21	-48.91	-43.02
Starcomm	-63.69	-62.40	-63.10	-53.83

Table 3: Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Anguwan Muazu Area.

Network provider	Mud building / rusted corrugated iron sheet roof	Mud building/ unrusted corrugated iron sheet roof	Sandcrete building / rusted corrugated iron sheet roof	Sandcrete building / unrusted corrugated iron sheet roof
Airtel	-52.70	-51.53	-50.36	-51.53
MTN	-53.72	-52.02	-49.42	-39.17
Glo	-55.89	-50.65	-43.39	-40.21
Etisalat	-69.47	-56.41	-46.47	-41.07
Starcomm	-66.44	-62.84	-58.98	-57.11

Table 4: Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Anguwan Kabala Costain Area

Network provider	Mud building / rusted corrugated iron sheet roof	Mud building/ unrusted corrugated iron sheet roof	Sandcrete building / rusted corrugated iron sheet roof	Sandcrete building / unrusted corrugated iron sheet roof
Airtel	-54.37	-50.04	-47.33	-40.72
MTN	-56.10	-52.42	-47.57	-37.87
Glo	-58.94	-51.33	-48.08	-39.21
Etisalat	-59.66	-54.33	-50.28	-40.89
Starcomm	-64.86	-62.00	-51.66	-48.29

Table 5: Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types at Mararaban Jos Area

Network provider	Mud building / rusted corrugated iron sheet roof	Mud building/ unrusted corrugated iron sheet roof	Sandcrete building / rusted corrugated iron sheet roof	Sandcrete building / unrusted corrugated iron sheet roof
Airtel	-54.37	-50.04	-47.33	-40.72
MTN	-56.10	-52.42	-47.57	-37.87
Glo	-58.94	-51.33	-48.08	-39.21
Etisalat	-59.66	-54.33	-50.28	-40.89
Starcomm	-64.86	-62.00	-51.66	-48.29

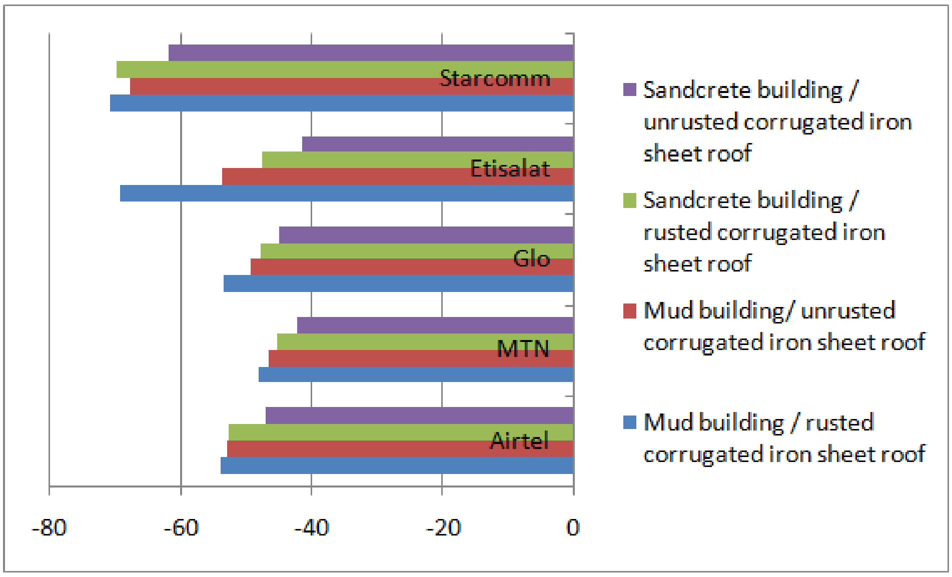

Figure:1 Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Anguwan Kanawa

Figure:2 Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Hayen-Danmani.

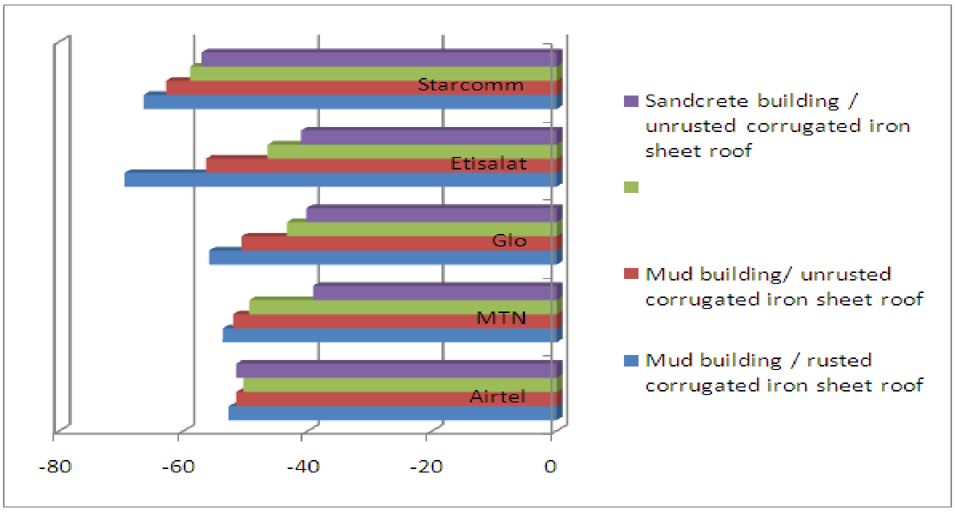

Figure:3 Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Anguwan Muazu.

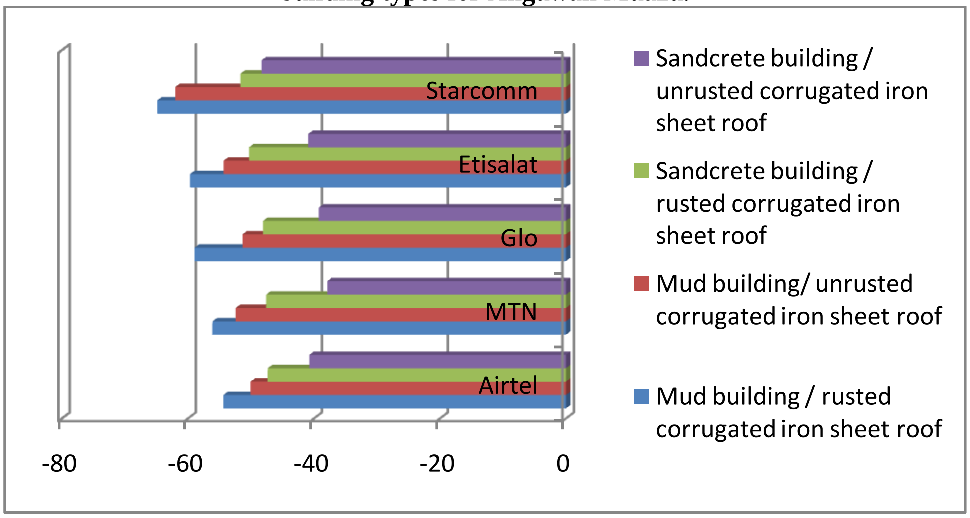

Figure: 4 Comparison of signal strength variation in mud building/rusted corrugated iron sheet and other building types for kabala costain.

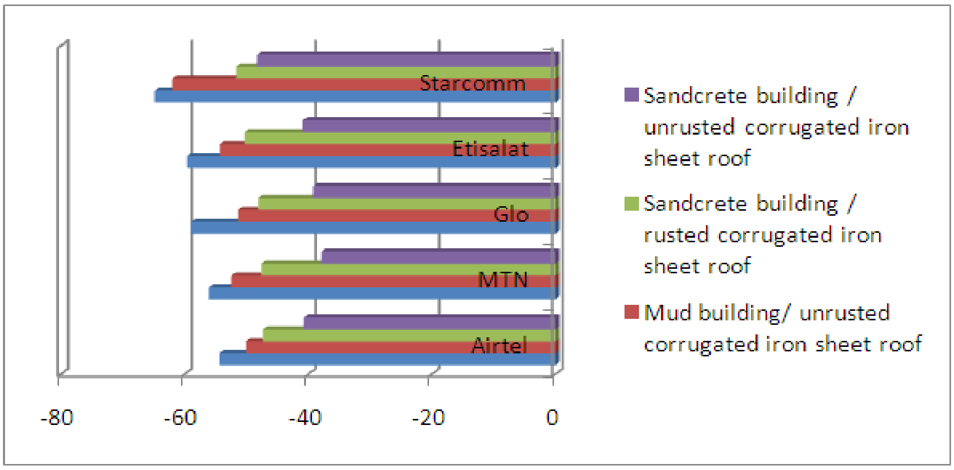

Figure: 5 Comparison of signal strength variation in mud/rusted corrugated iron sheet roof and other building types for Mararaban Jos.

3.1 Discussion of Results

The results obtained are shown in Tables 1-5 and figure 1-5. They showed the average received signal strength in different parts of Kaduna metropolis covered by GSM network service providers (i.e Airtel, MTN, Globacom, Etisalat and Starcomm) respectively.

At Anguwan Kanawa area, mud building/rusted corrugated iron sheet roof presents average signal strength of -59.08dBm which has the highest signal attenuation loss for all the network service providers considered. Similarly at Hayen-Danmani area result obtained shows that mud building/rusted corrugated iron sheet roof indicate average signal strength of -57.80dBm. Furthermore at Anguwan Muazu area also the same mud building/rusted corrugated iron sheet roof accounted for average signal strength of -59.68dBm. At Kabala Costain area result indicate that mud building/rusted corrugated iron sheet roof presents average signal strength of -58.79dBm. However, at Mararaban Jos area mud building/ rusted corrugated iron sheet roof presents average signal strength of -54.74dBm.

"The factors identified earlier in the introduction of this research may be responsible for the variation of GSM signal strength received in these buildings.

IV. Conclusion

In conclusion results obtained showed that mud building/ rusted corrugated iron sheet roof accounted for the higher signal loss of -59.08dBm; this is follow by mud building/unrusted corrugated iron sheet roof which has an average signal loss of -53.63dBm. The sandcrete building/rusted corrugated iron sheet roof presents average signal loss of -50.32dBm and sandcrete building/ unrusted corrugated iron sheet roof presents the lower signal loss of -45.37dBm, which the strongest among the results obtained.

The result of this research work can be apply in future planning of GSM signal strength inside building and therefore the RF Engineers of these network providers should take into consideration the variation and should be included in their Link budget when planning for network.

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