Characterization of Penetration Strength of GSM Signals (900 MHz) and their attenuation within some selected Buildings at the University of Ibadan

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Abstract. The diverse challenges been encountered by GSM subscribers within some locations at the University of Ibadan through their usual transits within and outside of buildings, before been able to receive uninterrupted flow of GSM communication due to signal fade and call drop, motivated the need to attempt to characterize signal strength penetration in buildings. This characterization would assist in determining the link budget required for a better Quality of Service (QoS) in this community. However, signal strength path measurement from GSM transmitter (i.e. base station) to the receiver is amongst the parameters required in estimating signal attenuation. Thus, in order to be able to estimate the magnitude of signal penetrations into buildings at the University of Ibadan, the factory fitted signal strength software installed on an android phone was utilized in obtaining the signal strengths of the four major GSM service providers (940MHz, 950MHz, 955MHz and 960MHz) operating in this vicinity. These measurements were taken for three weeks during the daily peak hours of communication (09Hr, 12Hr, 15Hr, and 18Hr) within every three minutes interval, at eight selected buildings (isolated and non-isolated) due to their closeness to GSM base stations. Analysis of data showed that the signal strengths at corridors of both isolated and non-isolated buildings are stronger than those indoors. Moreover, the signal attenuation used in depicting signal fade further showed that the attenuation increased at indoors more than corridors. This increment in indoor attenuations could be due to resistance against signals by the materials utilized in the construction of these buildings. In essence, the base station’s transmission power for this community should be increased by the various GSM network service providers in order to overcome attenuation problem. Likewise, the determined penetration attenuation allowance value of 15dB could be utilized in designing their link budget for a better QoS.

Keywords: Mitigating signal fade, GSM communication, Signal strength, Daily peak hours, Penetration attenuation

1. Introduction

A signal is an electromagnetic current used in conveying data from one device or network to another especially in communication, computing and networking. However, the strength of a signal can be reduced (i.e. attenuate) as it passes from one medium to another.

The attenuation of Global System for Mobile Communications (GSM) signal as it passes from the base station to various buildings had been reported to be caused by the iron column used in the construction of these buildings due to the fact that iron column re-transmit the signals received in a process called column radiation [1]. Moreover, attenuation also occurs in building materials such as roofs, walls and ceilings as a result of their permittivity [2]. Moreover, radio energy attenuates as it propagates and passes through solid obstacles including glass, wood, concrete, ceiling and other metal surfaces. In a similar way, due to attenuation signal call drops, fading and interference occurs as these radio waves are propagated from one point to another [3]. Additionally, several factors which are responsible for signal strength losses include diffraction, refraction and human activities [4] which also negatively affect their effective performance, both within and outside a building [5]. Also, multiple path losses are usually suffered by these signals as the distance between the transmitter and the receiver increases [6]. However, some researchers had suggested that signal penetration loss in a building decreases with frequency [7]. Thus, it is not an uncommon sight to see some of these GSM mobile subscribers moving from the inside of a building to its outside in order to be able to enjoy a smooth communication flow with minimal hindrances from attenuation [8]. In essence, this depicts that despite that the usage of GSM communication in Nigeria had made communication to be easier; however, some
discomforts are still associated with its usage [9]. Moreover, in a particular study on the penetration of signals into diverse materials using a narrowband measurement approach, empirical models were obtained for path loss propagation from measured radio data with 5.85GHz frequency [10]. Also, a work carried out at the University of Nigeria, Nsukka, showed that trees and buildings have significant effect on the path loss of signal strength [11]. Similarly, a statistical model was developed through the use of Log-Normal Distribution approach in studying the extra signal attenuation associated with path loss obtained during building penetration [12] in which emphasis was made on the signal losses at the various building floors, but nothing was reported on the penetration losses associated with the building walls and their roofs. Moreover, in another work, the ray tracing method with the simulation approach was utilized in obtaining the impact of diffraction and reflection on the received power [13]. However, in recent years some researchers had shown that the classical models utilized in the determination of path loss over-estimated its value when compared with that obtained in the actual specific measurements [14]. In a further study carried out on the signal strength penetration measurements in structures built by using glass, wood, concrete and bricks, it was attributed that the signal loss in such buildings actually depend on the particular type of materials utilized [15].

In this present work, the determination of signal penetration strength and its consequential losses due to attenuation at the various floors of some selected buildings at the University of Ibadan is aimed at, with the possible solutions in mitigating these losses also to be determined.

2. Materials and Methods

Signal strength penetration measurements were carried out within and around eight (8) selected buildings at the University of Ibadan, Ibadan using the signal strength software installed on Android Phones, Subscriber Identity Module (SIM) cards and stop watch. The GPS Locator was also used in determining the location of each of these buildings.

During measurements, the signal strength software was used in determining the signal strength, while the Subscriber Identity mode was used in identifying the particular network provider whose signal strength is to be measured, and the stop watch was utilized in carrying out the timing during measurement. Each of these measurements were taken at every interval of ten seconds for three minutes, at 09Hr, 12Hr, 15Hr, and 18Hr daily, for three weeks within the building (i.e. inside) and its outside (i.e. corridors). The daily hourly periods of measurements chosen were believed to be the GSM communication peak hours; a period in which customers usually make calls, surf the web and text messages mostly on a daily basis.

The choice of the buildings selected in this study is based on their closeness (i.e. not more than 50 meters away) to GSM transmitting base stations, whose antennas are directly beamed at an angle of 120° to such building. These buildings which are also at a height of not more than 20 meters were also categorized as either isolated (i.e. stand alone building) (6) or non-isolated (i.e. closeness or proximity to other buildings) (2). The selected isolated buildings are those of the Faculty of Science, Queen Idia Hall, Independence Hall, Animal Science Department, Veterinary Medicine Department and Veterinary Pathology Department, while those that are non-isolated are: Kenneth Dike library and Obafemi Awolowo Hall. The Third Generation (3G) broadband GSM network service providers’ transmitting frequency of 900MHz for four different GSM network service providers with frequencies 960MHz, 955MHz, 950MHz and 940MHz in Nigeria were those whose signal strengths were measured [16]. However, these signal strength measurements were taken on each floor of the buildings for all the frequencies of these considered GSM network service providers, and evaluated in order to be able to ascertain the accuracy of the signal attenuation at the various floor levels ($\gamma$) [17] for both corridors and indoors using the equation:

$$\gamma = H_t - H_f$$

Where,

$H_t$ is the signal strength at the terrace (i.e. the signal strength of the nearest base station), and

$H_f$ is the signal strength at the particular floor whose attenuation is to be determined.

Moreover, also utilized in the analysis carried out in this study were the mobile networks communication signal strength rating already categorized as: excellent (-45dBm to -59dBm), very good (-60dBm to -75dBm), good signal (-77dBm to -90dBm), fair signal (-91dBm to -100 dBm), poor signal (-101dBm to -110dBm) and no signal (less than -110dBm) [18].
3. Results and Discussions

3.1 Average signal strengths for the selected isolated three storey (i.e. three upper floors) buildings

Table 1 showed the results of the analysis of the average signal strengths (dBm) for the selected isolated three storey (i.e. three upper floors) buildings considered in this study.

3.1.1 GSM transmission at 960MHz frequency for the selected isolated three storey buildings. The signal strength level at the Faculty of Science building for the GSM provider transmitting at 960MHz frequency shows a good signal strength range of -79.24dBm to -84.15; and -79.24dBm and -89.66 dBm respectively, for both indoor and corridor. While, the signal strength level at the indoor and corridor of Queen Idia Hall building shows a fair signal strength of -89.28 dBm to -101.60; and -89.28dBm to -101.66 respectively, for both indoor and corridor. Also, the signal strength level at the indoor and corridor of Independence Hall building shows a very good signal strength of -55.29 dBm to -78.84; and -55.29 dBm to -73.20 respectively, for both indoor and corridor. Thus, it can be concluded that for this particular GSM provider transmitting at 960MHz the signal strength is strongest at Independence Hall (very good) when compared with that of Queen Idia Hall (fair) and Faculty of Science building, despite that it also had good signal strength at the Faculty of Science.

3.1.2 GSM transmission at 955MHz frequency for the selected isolated three storey buildings. For the GSM provider transmitting at 955MHz, the signal strength level at the indoor and corridor of the Faculty of Science building had a fair signal strength range of -87.55dBm to -93.41; and -87.55dBm to -89.81 dBm respectively, for both indoor and corridor. However, the signal strength level at the indoor and corridor of Queen Idia Hall building shows a very good signal strength of -57.28 dBm to -79.50; and -57.28dBm to -86.77 respectively, for both indoor and corridor. Also, in a similar way, the signal strength level at the indoor and corridor of Independence Hall building shows that the GSM provider transmitting at 955MHz had a very good signal strength range of -51.31 dBm to -76.96; and -51.31 dBm to -56.73 respectively, for both indoor and corridor. Thus, in a similar way to the GSM provider transmitting at 960MHz, it can be concluded that for this particular GSM provider transmitting at 955MHz, the signal strength at independence Hall (very good) is better than that of Queen Idia Hall and Faculty of Science building (fair), despite that Queen Idia Hall also had a very good signal strength.

3.1.3 GSM transmission at 950MHz frequency for the selected isolated three storey buildings. At the Faculty of Science building, the GSM provider transmitting at 950 MHz, the signal strength level at the indoor and corridor shows good signal strength range of -65.24dBm to -91.99; and -65.24dBm to -81.16 dBm respectively, for both indoor and corridor. The signal strength level at the indoor and corridor of Queen Idia Hall building shows a very good signal strength range of -63.25 dBm to -89.73; and -63.2dBm to -73.52 respectively, for both indoor and corridor. Similarly, the signal strength level at the indoor and corridor of Independence Hall building also shows a very good signal strength range of -51.31 dBm to -76.07; and -51.31 dBm to -68.78 respectively, for both indoor and corridor. Thus, in a similar way to both the GSM provider transmitting at 960MHz and that transmitting at 955 MHz, the signal strength at Hall independence Hall (very good) is better than that of Queen Idia Hall and Faculty of Science building (fair), despite that Queen Idia Hall also had a very good signal strength.

3.1.4 GSM transmission at 940MHz frequency for the selected isolated three storey buildings. For the GSM provider transmitting at 940MHz, the signal strength level at the indoor and corridor of Faculty of Science building shows a very good signal strength range of -52.86 dBm to -73.20; and -52.86dBm to -60.30dBm respectively, for both indoor and corridor. However, the signal strength level at the indoor and corridor of Queen Idia Hall building shows a good signal strength range of -60.23 dBm to -97.87; and -60.23dBm to -91.40dBm respectively, for both indoor and corridor. But, the signal strength level at the indoor and corridor of Independence Hall building likewise shows a very good signal strength range of -68.99 dBm to -88.66; and -67.26 dBm to -74.11 respectively, for both indoor and corridor as that of the Faculty of Science building. Thus, in a similar way to the GSM provider transmitting at 960MHz, 955MHz and 950MHz, the signal strength at Hall independence Hall (very good) is better than that of Queen Idia Hall (good) and Faculty of Science building, despite that Faculty of Science building also had very good signal strength. Thus, amongst these isolated three storey (i.e. three upper floors) buildings studied, it was at Independence Hall that the strongest networks are obtained from all these network providers.

3.2 Average signal strengths for the selected isolated four storey (i.e. four upper floors) buildings.

Table 2 showed the average signal strength (dBm) level for Isolated Buildings at various floors up to the fourth floor level. However, these results followed the same trend as in Table 1, with the best signal strength measured at Veterinary Medicine Department Building, and the least in Veterinary Pathology Department Building.
3.3 Average signal strengths for the selected non-isolated fourth and sixth storey (i.e. four and sixth upper floors) buildings

In Table 3, the result of the average signal strength (dBm) level for non-isolated buildings at various floors up to the fourth and sixth level was presented with the better signal strength detected at the Obafemi Awolowo Hall than Kenneth Dike Library Building.

3.4 Signal attenuation for the selected isolated three storey (i.e. three upper floors) buildings

The average signal attenuation obtained from equation (1) for the various buildings considered in this study is as presented in Tables (4-6).

3.4.1 GSM transmission frequencies for the selected isolated three storey buildings

Table 4 showed the signal attenuation result obtained for the selected isolated three storey (i.e. three upper floors) buildings, in which there are more attenuations indoors than at corridors. This attenuation value was highest on the ground floor (indoor, 26.75dB) at the Faculty of Science with 950MHz frequency, while the least attenuation of 0.86dB was obtained at the corridor of the 3rd floor with the same frequency of 950MHz. This result is an indication that more call drop and signal fade is been experienced for this particular network indoors than at corridors in this Faculty. However, a similar trend was obtained at Queen Idia Hall where the highest attenuation of 37.64dB was obtained on the first floor (indoor) at 940MHz frequency, while the least attenuation of 1.18dB was obtained on the corridor of the 3rd floor at 960MHz frequency. Also, at Independence Hall the highest attenuation value was obtained at 28.74dBm (indoor) on the first floor at 950MHz frequency, while the least attenuation of 0.00dB was obtained on the same first floor at the corridor at 955MHz frequency.

3.4.2 GSM transmission frequencies for the selected isolated four storey buildings

Table 5 is the continuation of the signal attenuation result obtained for the selected isolated four storey (i.e. four upper floors) buildings, which showed that the obtained attenuation values at the Animal Science Department was highest at 27.74dB (indoor) on the ground floor at 950MHz, while the least attenuation of 0.99dB was obtained for the corridor on the 4th floor at 955MHz. Also, at Veterinary Medicine Department the highest attenuation of 35.27dB (indoor) was obtained on the ground floor at 950MHz, while the least attenuation of 1.00dB was obtained for the corridor on the 3rd floor at 940MHz. Moreover, at the Veterinary Pathology Department the highest attenuation of 29.98dB (indoor) was obtained on the ground floor at 950MHz, while the least attenuation of -4.26dB was obtained for the corridor on the ground floor at 955MHz. The obtained negative value of attenuation at Veterinary Pathology Department for this particular ground floor showed that not enough of the signal transmission from the terrace is getting to this particular floor of the building. This could be due to the presence of associated block attachments to the floor which increases the radiating column within the floor due to foliage effect on signal and its diffraction, amongst other factors. However, for both isolated and non-isolated buildings more attenuation is been experienced at the lower floors’ (i.e. ground and first floor) indoors, than the upper floors’ corridors, while there are lower attenuations at upper floors’ corridors (i.e. 3rd floors and above) than indoors at the upper floors.

3.4.3 GSM transmission frequencies for the selected non-isolated storey buildings up to the sixth floor

Table 6 showed the signal attenuation result obtained for the selected non-isolated fourth to the sixth storey (i.e. four upper floors) buildings which showed that at Kenneth Dike Library highest attenuation value of 33.99dB (indoor) was obtained on the first floor at 955MHz, while the least attenuation of 0.06dB was obtained for the corridor on the ground floor at 940MHz. Moreover, at the Obafemi Awolowo Hall the highest attenuation of 34.77dB (indoor) was obtained on the ground floor at 950MHz, while the least attenuation of 0.78dB was obtained for the corridor on the 5th floor at 955MHz. However, it could not be determined which had the higher attenuation between isolated and non-isolated buildings because of the lower sample representations utilised in this work for both types of buildings.

3.5 Average signal attenuation (dB) for all the GSM networks considered.

Table 7 showed the average signal attenuation values obtained for the entire GSM network (900MHz) providers considered, and that there is more attenuation indoors than at corridors. Also, an average signal attenuation value of 14.09dB was obtained for the indoors, while a value of 9.78dB was obtained for the corridors. Thus, based on this value obtained it would be suggested that the GSM providers’ transmission power should be increased to about 15dB and this value could be used as the penetration attenuation allowance in designing the link budget for the base stations’ values at these locations within the University of Ibadan.
Table 1: Average Signal strength (dBm) level for Isolated Buildings at various floors up to the third floor level

| Faculty of Science Building | Frequency | Floor | Indoor | Corridor |
|----------------------------|-----------|-------|--------|----------|
|                            | 960 MHz   | terrace | -79.24 | -79.24 |
|                            |           | 3rd    | -82.55 | -81.31 |
|                            |           | 2nd    | -83.29 | -84.61 |
|                            |           | 1st    | -84.15 | -86.74 |
|                            |           | Ground | -81.38 | -89.66 |
|                            | 955 MHz   | Terrace | -87.55 | -87.55 |
|                            |           | 3rd    | -88.65 | -88.41 |
|                            |           | 2nd    | -89.12 | -89.46 |
|                            |           | 1st    | -91.64 | -89.79 |
|                            |           | Ground | -93.41 | -89.81 |
|                            | 950 MHz   | Terrace | -65.24 | -65.24 |
|                            |           | 3rd    | -69.55 | -69.55 |
|                            |           | 2nd    | -70.69 | -71.21 |
|                            |           | 1st    | -74.97 | -79.09 |
|                            |           | Ground | -91.99 | -81.16 |
|                            | 940 MHz   | Terrace | -52.86 | -52.86 |
|                            |           | 3rd    | -54.55 | -56.95 |
|                            |           | 2nd    | -63.91 | -53.74 |
|                            |           | 1st    | -71.21 | -56.06 |
|                            |           | Ground | -73.2  | -60.38 |

| Queen Idia Hall Building | Frequency | Floor | Indoor | Corridor |
|--------------------------|-----------|-------|--------|----------|
|                          | 960 MHz   | terrace | -89.28 | -89.28 |
|                          |           | 3rd    | -89.95 | -90.46 |
|                          |           | 2nd    | -100.19 | -100.97 |
|                          |           | 1st    | -101.60 | -101.60 |
|                          |           | Ground | -95.90 | -91.17 |
|                          | 955 MHz   | Terrace | -57.28 | -57.28 |
|                          |           | 3rd    | -69.44 | -61.70 |
|                          |           | 2nd    | -80.28 | -73.53 |
|                          |           | 1st    | -78.18 | -74.75 |
|                          |           | Ground | -79.50 | -86.77 |
|                          | 950 MHz   | Terrace | -63.25 | -63.25 |
|                          |           | 3rd    | -76.21 | -67.90 |
|                          |           | 2nd    | -85.91 | -71.76 |
|                          |           | 1st    | -96.11 | -96.11 |
|                          |           | Ground | -89.73 | -73.52 |
|                          | 940 MHz   | Terrace | -60.23 | -60.23 |
|                          |           | 3rd    | -74.34 | -68.69 |
|                          |           | 2nd    | -81.20 | -74.84 |
|                          |           | 1st    | -97.87 | -91.40 |
|                          |           | Ground | -87.14 | -73.77 |

| Independence Hall building | Frequency | Floor | Indoor | Corridor |
|----------------------------|-----------|-------|--------|----------|
|                           | 960 MHz   | terrace | -55.29 | -55.29 |
|                           |           | 3rd    | -70.65 | -58.27 |
|                           |           | 2nd    | -71.21 | -73.2  |
|                           |           | 1st    | -78.84 | -56.4  |
|                           |           | Ground | -71.65 | -64.02 |
|                           | 955 MHz   | Terrace | -51.31 | -51.31 |
|                           |           | 3rd    | -62.69 | -52.31 |
|                           |           | 2nd    | -66.89 | -56.73 |
|                           |           | 1st    | -64.25 | -51.31 |
|                           |           | Ground | -76.96 | -51.31 |
|                           | 950 MHz   | Terrace | -51.31 | -51.31 |
|                           |           | 3rd    | -65.35 | -59.27 |
|                           |           | 2nd    | -69.11 | -75.52 |
|                           |           | 1st    | -80.05 | -63.81 |
|                           |           | Ground | -76.07 | -68.78 |
|                           | 940 MHz   | Terrace | -68.99 | -68.99 |
|                           |           | 3rd    | -78.80 | -72.02 |
|                           |           | 2nd    | -83.50 | -74.11 |
|                           |           | 1st    | -85.36 | -69.59 |
|                           |           | Ground | -88.66 | -67.26 |
## Table 2: Average Signal strength (dBm) level for Isolated Buildings at various floors up to the fourth floor level

| Animal Science Department Building | Veterinary Medicine Department Building | Veterinary Pathology Department Building |
|------------------------------------|-----------------------------------------|------------------------------------------|
| Frequency                          | Frequency                               | Frequency                                |
| 960 MHz                            | 960 MHz                                 | 960 MHz                                  |
| 955 MHz                            | 955 MHz                                 | 955 MHz                                  |
| 950 MHz                            | 950 MHz                                 | 950 MHz                                  |
| 940 MHz                            | 940 MHz                                 | 940 MHz                                  |

| Floor | Indoor   | Corridor  | Floor | Indoor   | Corridor  | Floor | Indoor   | Corridor  |
|-------|----------|-----------|-------|----------|-----------|-------|----------|-----------|
| 4th   | -82.12   | -82.12    | 4th   | -83.15   | -83.15    | 4th   | -77.51   | -77.51    |
| 3rd   | -86.25   | -83.72    | 3rd   | -92.64   | -84.26    | 3rd   | -89.67   | -70.10    |
| 2nd   | -85.36   | -83.42    | 2nd   | -95.7    | -91.35    | 2nd   | -95.87   | -93.18    |
| 1st   | -91.88   | -85.47    | 1st   | -98.96   | -97.69    | 2nd   | -100.76  | -93.40    |
| Ground| -97.69   | -93.9     | Ground| -92.6    | -91.82    | 1st   | -103.29  | -93.40    |
|       |          |           |       |          |           |       |          |           |
| 4th   | -75.19   | -75.19    | 4th   | -57.28   | -57.28    | 4th   | -89.36   | -89.36    |
| 3rd   | -85.47   | -76.18    | 3rd   | -66.77   | -58.39    | 3rd   | -89.61   | -93.58    |
| 2nd   | -91.11   | -82.93    | 2nd   | -67.28   | -58.50    | 2nd   | -91.24   | -85.14    |
| 1st   | -79.39   | -69.11    | 1st   | -69.83   | -65.48    | 1st   | -105.10  | -109.30   |
| Ground| -88.79   | -80.5     | Ground| -73.09   | -71.82    | 1st   | -107.30  | -109.30   |
|       | -96.58   | -91.95    |       | -66.73   | -65.95    |       |          | -85.10    |
|       |          |           |       |          |           |       |          |           |
| 4th   | -65.79   | -53.85    | 4th   | -77.8    | -72.38    | 4th   | -61.26   | -61.26    |
| 3rd   | -67.12   | -60.38    | 3rd   | -73.21   | -64.46    | 3rd   | -63.03   | -81.38    |
| 2nd   | -67.23   | -61.26    | 2nd   | -86.44   | -77.47    | 2nd   | -83.08   | -84.48    |
| 1st   | -77.24   | -57.61    | 1st   | -88.51   | -78.14    | 1st   | -84.69   | -89.31    |
| Ground| -78.78   | -71.21    | Ground| -89.12   | -79.14    | 1st   | -89.61   | -93.58    |
|       | -91.24   | -85.14    |       |          |           |       |          |           |
| 4th   | -51.31   | -51.31    | 4th   | -53.85   | -53.85    | 4th   | -91.24   | -85.14    |
| 3rd   | -65.79   | -53.85    | 3rd   | -77.8    | -72.38    | 3rd   | -63.03   | -81.38    |
| 2nd   | -67.12   | -60.38    | 2nd   | -73.21   | -64.46    | 2nd   | -83.08   | -84.48    |
| 1st   | -65.79   | -53.85    | 1st   | -88.51   | -78.14    | 1st   | -89.61   | -93.58    |
| Ground| -78.78   | -71.21    | Ground| -89.12   | -79.14    | Ground| -91.24   | -85.14    |
|       | -91.24   | -85.14    |       |          |           |       |          |           |

Frequency: MHz
Floor: Indoor or Corridor
### Table 3: Average Signal strength (dBm) level for Non-Isolated Buildings at various floors up to the fourth and sixth level

| Frequency | Floor     | Indoor | Corridor | Kenneth Dike Library Building | Floor     | Indoor | Corridor | Obafemi Awolowo Hall Building |
|-----------|-----------|--------|----------|-------------------------------|-----------|--------|----------|-------------------------------|
| 960MHz    | Terrace   | -71.21 | -71.21   | 960MHz                        | Terrace   | -67.23 | -67.23   |                               |
|           | 6th       | -       | -        | 6th                           | 6th       | -73.2  | -69.44   |                               |
|           | 5th       | -       | -        | 5th                           | 5th       | -73.31 | -76.96   |                               |
|           | 4th       | -73.53  | -73.20   | 4th                           | 4th       | -84.14 | -72.2    |                               |
|           | 3rd       | -92.88  | -77.40   | 3rd                           | 3rd       | -76.63 | -76.18   |                               |
|           | 2nd       | -93.1   | -83.04   | 2nd                           | 2nd       | -88.87 | -74.31   |                               |
|           | 1st       | -93.11  | -71.31   | 1st                           | 1st       | -77.62 | -74.08   |                               |
|           | Ground    | -87.24  | -72.21   | Ground                        | Ground    | -98.22 | -75.85   |                               |
| 955MHz    | Terrace   | -57.83  | -57.83   | 955MHz                        | Terrace   | -63.25 | -63.35   |                               |
|           | 6th       | -       | -        | 6th                           | 6th       | -70.44 | -76.96   |                               |
|           | 5th       | -       | -        | 5th                           | 5th       | -77.18 | -64.13   |                               |
|           | 4th       | -92.77  | -79.39   | 4th                           | 4th       | -76.41 | -65.02   |                               |
|           | 3rd       | -97.62  | -93.19   | 3rd                           | 3rd       | -83.92 | -73.97   |                               |
|           | 2nd       | -88.57  | -79.83   | 2nd                           | 2nd       | -79.94 | -79.94   |                               |
|           | 1st       | -91.82  | -74.89   | 1st                           | 1st       | -74.64 | -70.66   |                               |
|           | Ground    | -91.41  | -80.46   | Ground                        | Ground    | -90.96 | -80.49   |                               |
| 950MHz    | Terrace   | -65.24  | -65.24   | 950MHz                        | Terrace   | -51.31 | -51.31   |                               |
|           | 6th       | -       | -        | 6th                           | 6th       | -82.54 | -72.73   |                               |
|           | 5th       | -       | -        | 5th                           | 5th       | -78.36 | -79.75   |                               |
|           | 4th       | -77.29  | -68.84   | 4th                           | 4th       | -75.31 | -63.57   |                               |
|           | 3rd       | -81.16  | -77.18   | 3rd                           | 3rd       | -69.56 | -68.78   |                               |
|           | 2nd       | -84.37  | -79.17   | 2nd                           | 2nd       | -76.08 | -84.86   |                               |
|           | 1st       | -76.67  | -81.16   | 1st                           | 1st       | -80.97 | -87.9    |                               |
|           | Ground    | -84.05  | -86.6    | Ground                        | Ground    | -86.08 | -79.75   |                               |
| 940MHz    | Terrace   | -79.97  | -79.97   | 940MHz                        | Terrace   | -51.31 | -51.31   |                               |
|           | 6th       | -       | -        | 6th                           | 6th       | -70.99 | -81.71   |                               |
|           | 5th       | -       | -        | 5th                           | 5th       | -74.97 | -53.85   |                               |
|           | 4th       | -81.2   | -80.14   | 4th                           | 4th       | -75.74 | -71.21   |                               |
|           | 3rd       | -88.76  | -86.62   | 3rd                           | 3rd       | -76.41 | -66.12   |                               |
|           | 2nd       | -89.11  | -88.11   | 2nd                           | 2nd       | -82.82 | -71.87   |                               |
|           | 1st       | -82.7   | -80.49   | 1st                           | 1st       | -76.07 | -74.31   |                               |
|           | Ground    | -79.99  | -80.03   | Ground                        | Ground    | -80.61 | -78.06   |                               |
Table 4: Signal attenuation (dB) for Isolated Buildings at various floors up to the third level

| Frequency | Faculty of Science Building | Queen Idia Hall Building | Independence Hall building |
|-----------|-----------------------------|---------------------------|---------------------------|
| **960 MHz** |                             |                           |                           |
| Floor     | Indoor | Corridor | Floor | Indoor | Corridor | Floor | Indoor | Corridor |
| 3rd       | 3.31   | 2.07     | 3rd   | 0.67   | 1.18     | 3rd   | 15.36  | 2.98     |
| 2nd       | 4.05   | 5.37     | 2nd   | 10.91  | 11.69    | 2nd   | 15.92  | 17.91    |
| 1st       | 4.91   | 7.50     | 1st   | 12.32  | 12.32    | 1st   | 23.55  | 1.11     |
| Ground    | 2.14   | 10.42    | Ground| 6.62   | 1.89     | Ground| 16.36  | 8.73     |
| **955 MHz** |                             |                           |                           |
| Floor     | Indoor | Corridor | Floor | Indoor | Corridor | Floor | Indoor | Corridor |
| 3rd       | 1.10   | 0.86     | 3rd   | 12.16  | 4.42     | 3rd   | 11.38  | 1.00     |
| 2nd       | 1.57   | 1.91     | 2nd   | 23.00  | 16.25    | 2nd   | 15.58  | 5.42     |
| 1st       | 4.09   | 2.24     | 1st   | 20.90  | 17.47    | 1st   | 12.94  | 0.00     |
| Ground    | 5.86   | 2.26     | Ground| 22.22  | 29.49    | Ground| 25.65  | 0.00     |
| **950 MHz** |                             |                           |                           |
| Floor     | Indoor | Corridor | Floor | Indoor | Corridor | Floor | Indoor | Corridor |
| 3rd       | 4.31   | 4.31     | 3rd   | 12.96  | 4.65     | 3rd   | 14.04  | 7.96     |
| 2nd       | 5.45   | 5.97     | 2nd   | 22.66  | 8.51     | 2nd   | 17.80  | 24.21    |
| 1st       | 9.73   | 13.85    | 1st   | 32.86  | 32.86    | 1st   | 28.74  | 12.50    |
| Ground    | 26.75  | 15.92    | Ground| 26.48  | 10.27    | Ground| 24.76  | 17.47    |
| **940 MHz** |                             |                           |                           |
| Floor     | Indoor | Corridor | Floor | Indoor | Corridor | Floor | Indoor | Corridor |
| 3rd       | 1.69   | 4.09     | 3rd   | 14.11  | 8.46     | 3rd   | 9.81   | 3.03     |
| 2nd       | 11.05  | 0.88     | 2nd   | 20.97  | 14.61    | 2nd   | 14.51  | 5.12     |
| 1st       | 18.35  | 3.20     | 1st   | 37.64  | 31.17    | 1st   | 16.37  | 0.60     |
| Ground    | 20.34  | 7.52     | Ground| 27.51  | 13.54    | Ground| 19.67  | -1.73    |
Table 5: Signal attenuation (dB) for Isolated Buildings at various floors up to the fourth level

| Animal Science Department Building | Veterinary Medicine Department Building | Veterinary Pathology Department Building |
|------------------------------------|----------------------------------------|------------------------------------------|
| Frequency | Floor | Indoor | Corridor | Frequency | Floor | Indoor | Corridor | Frequency | Floor | Indoor | Corridor |
| 960 MHz | 4th | 4.13 | 1.60 | 4th | 9.49 | 1.11 | 4th | 12.16 | 7.41 |
| | 3rd | 3.24 | 1.30 | 3rd | 10.00 | 1.22 | 3rd | 18.39 | 15.89 |
| | 2nd | 4.28 | 1.25 | 2nd | 12.55 | 8.20 | 2nd | 23.25 | 16.34 |
| | 1st | 9.76 | 3.35 | 1st | 15.81 | 14.54 | 1st | 25.78 | 15.89 |
| | Ground | 15.57 | 11.78 | | | | | | |
| 955 MHz | 4th | 10.28 | 0.99 | 4th | 9.49 | 1.11 | 4th | 0.25 | 4.22 |
| | 3rd | 15.92 | 7.74 | 3rd | 10.00 | 1.22 | 3rd | 1.88 | -4.22 |
| | 2nd | 4.20 | -6.08 | 2nd | 12.55 | 8.20 | 2nd | 15.74 | 19.94 |
| | 1st | 13.60 | 5.31 | 1st | 15.81 | 14.54 | 1st | 17.94 | 17.64 |
| | Ground | 21.39 | 16.76 | | | | | Ground | 19.94 | -4.26 |
| 950 MHz | 4th | 14.48 | 2.54 | 4th | 23.95 | 18.53 | 4th | 1.77 | 20.12 |
| | 3rd | 15.81 | 9.07 | 3rd | 19.36 | 10.61 | 3rd | 19.57 | 23.22 |
| | 2nd | 15.92 | 9.95 | 2nd | 32.59 | 23.62 | 2nd | 23.43 | 28.05 |
| | 1st | 25.93 | 6.30 | 1st | 34.66 | 24.29 | 1st | 28.35 | 32.32 |
| | Ground | 27.47 | 19.90 | | | | | Ground | 29.98 | 23.88 |
| 940 MHz | 4th | 4.42 | 1.44 | 4th | 13.05 | 17.58 | 4th | 9.49 | 1.11 |
| | 3rd | 7.30 | 2.05 | 3rd | 8.84 | 1.00 | 3rd | 10.00 | 1.22 |
| | 2nd | 9.95 | 5.08 | 2nd | 14.04 | 4.86 | 2nd | 12.55 | 8.20 |
| | 1st | 17.80 | 13.93 | 1st | 15.15 | 18.13 | 1st | 15.81 | 14.54 |
| | Ground | 21.45 | 14.71 | | | | | Ground | 9.45 | 8.67 |
Table 6: Signal attenuation (dB) for Non-Isolated Buildings at various floors up to the fourth and sixth level

| Frequency (MHz) | Floor | Indoor | Corridor | Frequency (MHz) | Floor | Indoor | Corridor |
|-----------------|-------|--------|----------|----------------|-------|--------|----------|
| **Kenneth Dike Library** |       |        |          | **Obafemi Awolowo Hall** |       |        |          |
| 960 MHz         | 6th   | -      | -        | 6th           | 5.97  | 2.21   |          |
|                 | 5th   | -      | -        | 5th           | 6.08  | 9.73   |          |
|                 | 4th   | 2.32   | 1.99     | 4th           | 16.91 | 4.97   |          |
|                 | 3rd   | 21.67  | 6.19     | 3rd           | 9.40  | 8.95   |          |
|                 | 2nd   | 21.89  | 11.83    | 2nd           | 21.64 | 7.08   |          |
|                 | 1st   | 21.90  | 0.10     | 1st           | 10.39 | 6.85   |          |
|                 | Ground | 16.03  | 1.00     | Ground        | 30.99 | 8.62   |          |
| 955 MHz         | 6th   | -      | -        | 6th           | 7.19  | 13.61  |          |
|                 | 5th   | -      | -        | 5th           | 13.93 | 0.78   |          |
|                 | 4th   | 34.94  | 21.56    | 4th           | 13.16 | 1.67   |          |
|                 | 3rd   | 39.79  | 36.07    | 3rd           | 20.67 | 10.62  |          |
|                 | 2nd   | 30.74  | 22.00    | 2nd           | 16.69 | 16.59  |          |
|                 | 1st   | 33.99  | 17.06    | 1st           | 11.39 | 7.31   |          |
|                 | Ground | 33.58  | 22.63    | Ground        | 27.71 | 17.14  |          |
| 950 MHz         | 6th   | -      | -        | 6th           | 31.23 | 21.42  |          |
|                 | 5th   | -      | -        | 5th           | 27.05 | 28.44  |          |
|                 | 4th   | 12.05  | 3.60     | 4th           | 24.00 | 12.26  |          |
|                 | 3rd   | 15.92  | 11.94    | 3rd           | 18.25 | 17.47  |          |
|                 | 2nd   | 19.13  | 13.93    | 2nd           | 24.77 | 33.55  |          |
|                 | 1st   | 11.43  | 15.92    | 1st           | 29.66 | 36.59  |          |
|                 | Ground | 18.81  | 21.36    | Ground        | 34.77 | 28.44  |          |
| 940 MHz         | 6th   | -      | -        | 6th           | 19.68 | 30.40  |          |
|                 | 5th   | -      | -        | 5th           | 23.66 | 2.54   |          |
|                 | 4th   | 1.23   | 0.17     | 4th           | 24.43 | 19.90  |          |
|                 | 3rd   | 8.79   | 6.65     | 3rd           | 25.10 | 14.81  |          |
|                 | 2nd   | 9.14   | 8.14     | 2nd           | 31.51 | 20.56  |          |
|                 | 1st   | 2.73   | 0.52     | 1st           | 24.76 | 23.00  |          |
|                 | Ground | 0.02   | 0.06     | Ground        | 29.30 | 26.75  |          |
Table 7: Average Signal attenuation (dB) for all GSM networks considered

| CONSIDERD BUILDINGS             | INDOOR ATTENUATION VALUE (dB) | CORRIDOR ATTENUATION VALUE (dB) |
|---------------------------------|-------------------------------|---------------------------------|
| Faculty of Science              | 7.77                          | 5.37                            |
| Queen Idia Hall                 | 18.44                         | 13.44                           |
| Independence Hall               | 16.69                         | 6.40                            |
| Animal Science Department       | 13.79                         | 7.13                            |
| Veterinary Medicine Department  | 16.81                         | 11.71                           |
| Veterinary Pathology Department | 20.28                         | 17.92                           |
| Kenneth Dike Library            | 9.47                          | 7.53                            |
| Obafemi Awolowo Hall            | 9.42                          | 8.70                            |
| **MEAN**                        | **14.09**                     | **9.78**                        |

4. Conclusion

The analysis of signal strength measurements carried out on the four major GSM network service providers operating within the University of Ibadan showed that it was at the Independence Hall buildings that the best network service provisions were been enjoyed mostly, amongst all the other buildings considered. Also, the ranking of the transmitting frequencies in their decreasing order of signal strength performance are: 940MHz, 950MHz, 955MHz and 960MHz. However, the average signal attenuation values of 14.06dB and 9.78dB obtained for the entire GSM network (900MHz) considered at indoors and corridors respectively, showed that attenuation occurred at indoors more than at corridors. This may be due to the iron columns utilized in the building constructions which are responsible for the occurrence of secondary transmitted signals in isolated buildings. Thus, with this high indoor attenuation penetration value of 14.06dB, a link budget design is required along the base station path, with an allowance attenuation of about 15dB in order to ensure a better quality of service at these locations, for an enhanced data, video streaming and internet services.

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