|  |  |
| --- | --- |
| **[RESEARCH ARTICLE]** |  |

**Buhari, Ridwan Adewale\*1 ,**

|  |  |
| --- | --- |
| 1Institution, Kwara State University, Kwara State, Nigeria  Email: [buhariradox@gmail.com](mailto:buhariradox@gmail.com)  Email: [adewalereadone@outlook.com](mailto:adewalereadone@outlook.com)  **Correspondence**  \*Muheeb Ahmed,P.M.B. 1530,23431, Malete, Kwara State, NG 241104  Email: [muheeb.ahmed@kwasu.edu.ng](mailto:muheeb.ahmed@kwasu.edu.ng)  **Funding Information**  Project Name  Grant/Award Number: XXXXXXXX | **Abstract**  **Various Construction materials cause significant losses when subjected to wireless signals along the path of propagation. A change in the signal strength, losses and user experience occur as a result of the complex composition of the materials. This paper is aimed to find out how 2G (1800MHz) signal is affected when subjected to an enclosure dimension (0.24mx0.20mx0.16m), made of 3 species of timber namely; *Chlorophoral excels (Iroko), Afzelia Africans (Apa) and Gosswei Lerodendrin balsamic ferum (Agba)*; a reflective glass and solid reinforced concrete. This paper study focused on, Received Signal Strength (RSS), Upload and Download speed (Mbps) and Jitter (ms). The steps taken involve finding the penetration loss from the RSS with their respective data representation and drawing fact from the represented data. The result of this work presented that, material C has 46.1% increase in indoor signal strength, material E has insignificant change in indoor signal strength, material D, B and A has 1.0% decrease, 10.2% increase and 16.4% increase respectively in indoor received signal strength.**  **The result from QOS parameter– Jitter(ms) are compared for both outdoor and indoor, this relatively showed that material B, C and E will provide improved experience to the user.**  **KEYWORDS**  ***Download speed, Jitter, Packet Loss, Penetration Loss, RSS, Upload speed.*** |

# Introduction

The need to visualize and measure the wireless signal parameters with the aid of efficient hardware device with software (mobile application) is important in every enterprise so as to determine what kind of activities to be done and the quality of service obtained from the network. It is very rampant in buildings whereby the mobile users tend to change position from one point to another in other to have a reliable wireless communication.

However, the density, coverage, signal power and other related metrics are factors which are needed to be known in various environmental conditions.

The quality of wireless signal is reduced when they are obstructed by different materials along the path of propagation. Several researchers have worked on radio waves propagation in building and statistical result were obtained from their measurement [[1](#And95)]- [[3](#Dur02)].

Wireless signals generated by RF (radio frequency) circuit or device are affected by various properties, which could be categorized in this report to be any of the following:

* **Intrinsic Properties**: This refers to the factors that affect the wireless signals internally within the sources where they are generated. This scenario is commonly affected by RF devices, such as: Router and RF Antenna operating within the following frequency band (900/1800MHz, 2100MHz, 2400 MHz). Examples of such include: short noise, thermal noise etc.
* **Extrinsic Properties**: This refers to the factors that tend to distort wireless signal externally relative to their environment immediately after they are directed away from the sources.

There is little awareness in the construction industry regarding the impact of wireless coverage when it is subjected to different construction materials. A change in building materials so as to meet the requirement for building regulation needs to be known, such that it can improve the efficiency of the signals. Some materials can help to improve the thermal conductivity properties of houses but can affect the transmission of wireless signals into and within houses. In the future, construction practice and materials may change particularly in response to improve signal transmission within them [[4](#Ric14)].Generally**,** most signals are affected by these factors depending on the characteristics of their propagating medium.

The loss experienced by radio waves when subjected to different materials depends on the frequency and angle of incidence of the waves as well as the materials properties. An approved recommendation by ITU-R (P.2014) defines the basic quantities related to the electrical properties of a building materials and penetration loss which describe the effect of the material structure, electrical properties and building loss measurement on radio propagation.[[4](#Ric14)].

Therefore, it is significant to distinguished different materials such as bricks, wood and glass when they are subjected to wireless signals.

The figure1 gives the physical model of the study, showing the Base Transceiver Station (BTS) having 2G Network, for wireless communication. The enclosure is subjected to the 2G (1800MHz) signal and predictive measurement is obtained for both indoor and outdoor scenarios.



**Figure 1. Illustration of Research Study.**

As a result, the environments where these signals are being propagated contribute immensely to how wireless signals behave.

Examples of such behavior include: Multipath, Reflection and Refraction, shadowing , attenuation etc.

Moreover, Radio signal are electromagnetic in nature, therefore, the signal becomes weaker as it further travels. This can be illustrated in the figure 2.

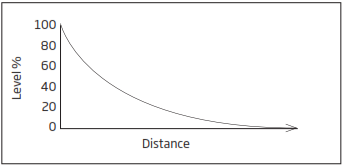


Figure 2. Evaluation of Radio Signal Strength and Distance. Source*:*[[5](#Rad16)].

The coverage of RF signal is further decreased by the impact caused by various household materials. They include: wood, brick, glass, metal, concrete and aluminum. The range if reductions in signal strength are indicated below for various materials [[5](#Rad16)]**.**The radio coverage can be illustrated as shown in table I.

Table I Radio Coverage Reduction Loss. Source:[[5](#Rad16)].

|  |  |  |
| --- | --- | --- |
| **S/N** | **Materials** | **Range of Reduction of loss** |
| 1 | Wood, plaster, glass uncoated, without metal | 0 - 10 % |
| 2 | Brick, Press Board | 5 - 35 % |
| 3 | Ferro concrete | 10 - 90 % |
| 4 | Metal, aluminum lining | 15-95% |

To communicate wirelessly is the basic needs of the modern world owing to the fact that the population of mobile users has increased rapidly. In this situation, customers or end-users demand for good quality of service (QOS) and coverage. The penetration loss caused by different household construction materials, affect signal strength received by the end users. The penetration loss is significant while considering the overall losses in wireless communication [[6](#Rap03)].

The End-users usually experience network challenges whenever wireless signals are affected by either extrinsic or intrinsic properties. However, the intrinsic signal properties are caused by the hardware malfunction and failure, hence this is insignificant for reliable devices. Wireless signals usually suffer loss as a result of free space, which is dependent on distance.

The survey metrics in this project introduce the various parameters to be measured using optimum software and hardware device to detect and measure the metrics that are used as judging criteria to evaluate the Quality of Service (QOS) experience by the end user(s) for various household construction materials as wireless signal propagate through them.

It must be emphasized that, users experience on a particular network service which could either be Wi-Fi (2.4GHz), 2G(900/1800MHz), 3G(2100MHz) and 4G(2600MHz), differs based on their environment and the medium through which the wireless signal has travelled. The Radio Frequency (RF) signals are being used as wireless signals for propagation. The absorption rate of different household construction materials through which wireless signals travel differs from one another. However, additive sum of the effect of reflection and absorption are the major effect when signal propagate through different materials. This effect causes signal attenuation while other factors include: diffraction and Scattering [[6](#Rap03)].

The building materials considered in this project are non-magnetic and dielectric but behave like a lossy dielectric materials since they allow signal to penetrate through them.

The metrics of focus in this project are: Received Signal Strength (RSS) (dBm), downloadspeed(Mbps),

Upload Speed(Mbps), Penetration loss(dBm), Packet Loss and Jitter(ms).Therefore, this report presents the techniques required to evaluate the quality of service of wireless signal in different household construction materials.

The need to communicate wirelessly in an effective way without any delay in transmission and reception of data which is essential in today’s global world. Wireless communication requires the sending and receiving of signals without the use of any physical medium. As a result, wireless signals are susceptible to various challenges by penetrating through different materials before it gets to the user terminal. The unrealistic propagation of the wireless signal when it passes through various medium which is caused by multipath has made it penetrate through various construction materials having different characteristics which account to a significant penetration loss. The quality of service perceived by the end user is a function of various materials characteristics through which signals have travelled; hence performance on the network tends to slide down, as a result of the penetration loss through various construction materials. Evaluation of the losses encountered in various construction materials is essential to circumvent for the total losses in a building and also evaluate the quality of in-door signals.

1. **RELATED WORK**

The work in [[8](#Pro15)], presented the method used to determine the Global System for Mobile Communication (GSM)signal provided by 4 service provider- MTN, Airtel, Globacom and Etisalat in Port Harcourt. Focus was made on the penetration loss in 5 selected buildings, constructed with different materials such as (Mud house with thatched roof, mud house with rusted corrugated iron sheet, sandcrete building with rusted corrugated iron sheet, sandcrete building with unrusted iron sheet and building with alucoboard wall cladding. The measured data was obtained using a Techno Tablet installed with Radio Frequency Signal Tracker (RFST) software. The surveyed parameters were signal strength, and distance, from which the penetration losses were obtained. The average of the collected data was computed from which the measured data was taken twice a day in a month, which has an occurrence of sixty (60) values. The data were evaluated using Least Square Line Analysis to obtain the line that best fit the curve. The result obtained showed that the building with alucoboard wall cladding has the highest signal penetration loss while the sandcrete building/unrusted corrugated iron sheet roof has the lowest signal penetration loss.

The data obtained from the services provider were reliable and correlative, since they were taken twice a day in one month. However, the Signal to Noise Ratio (SNR) was not considered. This could be a bottle neck for wireless signal in the environment where external sources contribute majorly to signal distortion which could be referred to as extrinsic factor.

The work in [[9](#Fel11)] examined the penetration loss of doors and windows inside residence using Integrated Service Digital Network Broadcast-Terrestrial (ISDB-T) Television signal operating at 677MHz frequency. It demonstrated the signal parameters such as received power (Indoor and Outdoor), signal to noise ratio (SNR), field strength (δ) with the aid of spectrum analyzer which was connected to Ultrahigh frequency (UHF) antenna known as Rabbit Antenna, directly placed at the doors and windows made of different materials. This survey was conducted on sixteen (16) residences in an urban area in Philippines, that was 7km away from the National Broadcasting Network (NBN). The buildings were classified in accordance to their construction materials into four (4) classes: A, B, C and D. The indoor signal is measured and compared with the outdoor signal, the discrepancies was used as the penetration loss, as a result of the material characteristics which causes signal degradation. The result obtained from the average penetration loss for each houses was computed and compared using commutative distribution function(CDF) in a probability distribution curve which shows that Class A has the lowest APL(average penetration loss), while Class B and C have larger APL as a result of thicker wall with reinforced materials, Class D is of light materials. As a result, APL decreases from heavy to light materials.

More concerned was made on interference by using a desk set spectrum analyzer which aid visualization of operating signal in frequency and time domain. However, as a result of low power level in the device, it might not display accurate result of the surveyed data.

The work in [[10](#Wil09)] analyzed and evaluated the performance of a radio signal in 4 different large buildings so as to give more understanding of what to expect from radio propagation environment in a worst case scenario. The method used by the author was to provide large set of data, which described attenuation variability of radio signals in various building types in the public safety frequency band. This was carried out in 4 different large building structures which are: Conventional Centre, High-Rise office building, Apartment building and Laboratory building. The operating frequency of the signal was 750MHz band, in which the measurement was done with three 3 different types of signal measuring devices. They include: Spectrum Analyzer Radio Mapping, Narrow band communication Receiver Radio Mapping and Broadband Synthetic-Pulse measurement; which was used to obtain the received signal strength (RSSL), Centre frequency and Root Mean Square (RMS) delay spread of signal power.

The result obtained showed that the present of short pulses in the time-domain waveform was as a result of multipath in a given environment. The RMS delay spread value was used to determine the time it will take the multipath reflection to decay below the threshold level. The median and standard deviation value were critically observed in most of the measurement in both spectrum analyzer and the receiving system. The result further illustrated that, the RMS delay spread value for the measurement made in the large open floor building were typically 2 to 5 times greater than the measurement obtained from the building with narrows corridors.

The use of the three set of measuring devices makes the result correct with little or no discrepancies. However, the RMS spread value was affected greatly by the direction of the antenna and the penetration loss. Therefore, radio signal analysis should not only be focus on the signal but also on the environment and material characteristics which could be classified as either lossy or lossless materials.

The authors in [[11](#Kat10)] presented a model metrics in relation to evaluate the Quality of Experience (QOE) and signal strength for future QOE optimization using a wireless Local Area Network(LAN) recognized as 802.11b/g in the IEEE standard. The evaluation was done with the aid of a software tool which comprises of QOE measurement so as to evaluate the end user and monitor the QOS (quality of services) parameter: Signal Strength. From the empirical study performed by the authors, using a mobile web browsing application which was tested on a Personal Digital Assistant (PDA), a result was obtained and evaluated using both the linear and exponential regression. The metrics of evaluation was focused on QOE parameters perceived by the user with the aid of a questionnaire which was scaled using the standardized Mean Opinion Score (MOS) such as, Excellent, Good, Fair, Poor and Bad. While the QOS parameters considered was the Signal Strength. The measurement was taken at 4 different location using wireless LAN in the test environment. The strength of the signal was demonstrated on histogram chart with their rating which indicated the MOS of for the user experience. The result demonstrated that, at location 2, having signal strength of -61dBm, has a higher MOS rating as compared to location 4, with signal strength of -83dBm. It can be deduced from the result that, the better the QOE, the better the QOS.

The author was able to give a correlative result between the QOS and QOE, based on user perception. However, due to the variation in human perception, more than one users experience should be perceived so as to obtain more reliable result.

In addition, the environment where the users opinion is perceived should be considered, so as to identify the possible bottle neck in wireless network.

The work in [[12](#Joh08)] examined the study of network neutrality principles which illustrated how packet data were being lost on traffic congestion causes by rapid increase of the additional users and high data rate application which is as a result of two distinct issues: discrimination and QOS. The approach used by the author was to categorized users activities on the network based on data rate, quality of service and economic value. The parameter of measurement involves the scaling of the data rate and quality of sensitivity of the activities on the network. The network activities were categorized according to their sensitivity level which could either be low or high and according to QOS parameters. From the result, it was shown that increase in data rate lead to an increase in sensitivity. The economic value for two different internet service provider (ISP) was compared, such that they were both use for the same network activities, the ISP with lowest sensitivity would have the lowest economic value and vice versa.

The work in [[13](#Pro16)] investigated on the Global Service for Mobile Communication (GSM) signal loss in a multi-storey building. The measurement was carried out in different building 0f 2,3,4 and 5 storey at Port Harcourt using the service obtained from 4 service provider which are: MTN, Globacom, Airtel and Etisalat to determine the signal strength with the aid of an RF Signal Tracker(RFST). The measurement was conducted outside and inside each floor of the building and the difference were computed using the standard deviation and the mean. The measured parameters include: signal strength (dBm), Local Area Code (LAC), Cell Identity (CID) and the distance from the transmitter. The result obtained illustrated that, the loss varies between 3.09 and 3.91, which was as a result of the effect caused by floor partition. The average path loss and the floor attenuation factor were determined as 3.53 and 21.22 respectively, while the standard deviation varied from 3.46 and 6.27. It was concluded that, the penetration losses were higher at the ground floor than the fifth floor; however, the fifth floor has the maximum floor attenuation factor.

The work in [[14](#Dil17)] examined the impact that 2.4GHz and 5GHz Wi-Fi (wireless Fidelity) has when subjected to different household construction materials across several distances. A Router of model Xfinity XB3, with a dual band 802.11ac Wi-Fi was used as the Radio Frequency (RF) source. It was housed in an enclosed box constructed from single material having dimension (10.5″X 3.3″ X 9.5″) .A software called inSSIDer 4 was used to obtain the data from the Laptop, so as to measure the signal strength received at both 2.4GHz and 5GHz while varying the distance. The inSSIDer aid the tracking of the following parameters: Signal Strength, Distance and Frequency Band, which was used to determine the output result. The results obtained were computed to plot two graphs (for 2.4GHz and 5GHz) of distance against signal strength. This shows the impact on the household materials which are: wooden -box, brick, sheet- metal, tile -ceramic, tile -porcelain, glass- tempered, dry -wall and cement –pavers which was indicated.

The author opined that signal strength of a particular material displayed in the graph for 2.4GHz did not go below -50dBm, irrespective of the far distance between the laptop and the enclosed router, while the 5GHz drastically fall in signal strength as the distance increases.

The work in [[15](#Idi14)] investigated on the penetration loss using two GSM (Global System for Mobile Communication) operator signals in Delta state, Nigeria. The GSM operator signals were used to investigate the measurement for a period of 6 month (January- June). The indoor and outdoor signal measurement in (dBm) in both concrete and block structures were obtained, using the Signal Tracker (Donut) installed on a Samsung Galaxy mobile phone. The software was able to capture signal strength, cell identity (CID), GPS parameter and distance. The measured parameters were used to compute the average outdoor and indoor signals; their differences were used to obtain the penetration loss. The penetration loss values were obtained for concrete and block building. The result showed that average loss of 10.62dbm and 4.25dBm were obtained for the concrete and block building respectively.

The authors opined that the signal degradation increase with an increase in penetration loss. In addition, the GSM signal is a function of the building types; the loss through a concrete building is higher than the loss through the block building.

The work in [[16](#VOA18)] investigated the GSM(Global System for Mobile Communication) signal strength level inside and outside the selected building by considering the available network(MTN, GLO and Airtel) in the location at Ogbomosho, Oyo State. The research area of focus was based on three locations with distinctively different but modern building material such as: Hollow Block, Solid Block and Precast Asbestos Block categorized as B1, B2 and B3 respectively. The study was carried out within 12 months, using the following equipment: Samsung Galaxy S6 Android Phone, Network Signal Info Pro (Kabiit Software), Network Operator SIM (subscriber Identity Module). The Network Signal Info Pro software helps to determine the RSSI (Received Signal Strength Indication), distance and associated location parameters from appropriate BTS (Base Transceiver Station) for various environments. The RSSI was obtained for both indoor and outdoor of the 3 buildings using the available network of 2400MHz band. The penetration Loss for the 3 operators was computed for B1, B2 and B3 and the mean value for the buildings were obtained. Comparison was made between the theoretical and measures pathloss for both indoor and outdoor. The result showed that, the measured pathloss was in agreement with the theoretical pathloss for the selected buildings, the building B1 with hollow structure has the lowest penetration loss while B3 has the highest penetration loss. The authors concluded that, the construction materials affect GSM signal level inside building which also depend on the reference point at which signal is measured.

The work in [[17](#Ahs13)] examined the effect on signal strength when being obstructed by building materials such as: Glass, Wood and Brick. The work was carried out with the aid of the following equipment: Acer Laptop and Cisco Aironet 1130 Access Point. The signal strength was obtained while the laptop distance was varied by 3 inches. The measure data was computed in both MS- Excel and sheet and a Scatter plot was computed from MATLAB. The signal strength and distance was obtained in (dB) and (m) respectively. Comparison was made between the practical result by plotting the signal strength against distance and the ITU- loss model for indoor environment. The result showed that, the increase in the glass thickens will yield an increase in loss, also the glass has the lowest loss of 5dB, while the wood has a 6dB loss and brick has a 17dB loss.

1. **METHODOLOGY**

This work was carried out at Kwara State University (KWASU) Campus, Malete and Ilorin region. The university campus consists of vegetation, students and sparsely located buildings and trees, while Ilorin region consist of condensed buildings with little vegetation. As a result the Kwara State University may be classified as a suburban. The surveyed data were obtained within these 2 site location as a result of unavailability and unreliability of Network service provided by the service provider. The services used for the field measurements of 2G signal were MTN NG and Airtel NG due to downtime.

1. **Description of Materials**

The focus of this research was based on 5 selected construction materials which are: 3 timber species, Concrete Slab, and a Glass-Reflective. The materials were categorized as; Material A, Material B, Material C, Material D and Material E. The description of the materials is shown in table II.

Table II Material Description.

|  |  |  |
| --- | --- | --- |
| **S/N** | **Material Name** | **Remark**  **Trade /Botanical Names** |
| 1. | Material A | *Apa- Afzelia Africans* |
| 2. | Material B | *Agba-Gosswei lerodendrin balsamic ferum* |
| 3 | Material C | *Iroko- Chlorophora excels* |
| 4. | Material D | Concrete |
| 5. | Material E | Reflective Glass |

1. **Software and Hardware Setup**

To achieve the aim of this work, an android smart phone, version 8.0.0(ABCDEF-180604V15) of model Infinix X-608 was used to measure the network parameters using RF signal tracker and Open Netttest soft ware. The RF signal tracker used by RF Engineers is capable of measuring the RSS(Received Signal Strength) with respect to its Geo Location for selected interval of 10s, while the Open Nettest which is co-financed by the European Union is capable of measuring the QOS parameters which include Jitter(ms), Upload and Download Speed(Mpbs), and Packet loss(%).The Open Nettest create a server which support IPV4 and IPV6 standard, which allow the network performance to be evaluated depending on the supported scheme.

1. **Description of Parameters Obtained**

The parameters used in this research are briefly defined below:

1. **Receive Signal Strength (RSS):**The Received Signal Strength (RSS) is a metric used by manufacturers to give users an indication of the signal strength their wireless device is receiving for a wireless network, measured in dBm [[7](#Sco11)].
2. **Upload speed**: This involves the interaction from the user terminal to the remote system (BTS) which is set-up for uploading data. It is measured in (Mbps)*.*
3. **Download Speed:** This involves the interaction from the user terminal to the remote system (BTS) which is set-up for downloading data. The opposite of the Upload Speed is done with the Download Speed. Its unit is measured in (Mbps)*.*
4. **Jitter:** This occurs as a result of packet loss. It is a measure of the delay in packet sent. It is pronounce in video conferencing and VOIP (voice over internet protocol).It is measured in (ms)
5. **Packet Loss:** This occurs when one or more transmitted packets fail to arrive at it destination node. It causes observable effect in every digital communication system. It is measured in (%)

**(1)**

1. **Determination of Penetration Loss(dBm)**

The penetration loss is a measure of the absorption of wireless signal when subjected to a material having specific absorption rate. It can be define as a loss in signal strength inside the material as compared to outside. This loss occurs in both lossy and lossless material as a result of material composition.

The penetration loss is obtained using the penetration loss formula, which is defined as;

**(2)**

Alternatively;

**(3)**

Where is Penetration Loss in (dBm)

ABS is a measure of the absolute value.

is the Indoor Received Signal Strength in (dBm)

is the Outdoor Received Signal Strength in (dBm).

1. **Computation of the RSS(dBm) Mean Value**

The mean or average value of the collected data over 10 samples using the RF signal Tracker to measure the RSS (Received signal strength) in dBm can be expressed for the and for 10 sampled signal using the below expression

**(4)**

**(5)**

Alternatively using Matlab script;

**(6)**

**(7)**

Where is the total number of the sampled event.

1. **Theoretical Expression for Unit Conversion**

The standard referenced value of power (dBm) can be converted to Watt using the theoretical expression given below;

**(8)**

Where is the Received power by the smart phone antenna in W.

**(9)**

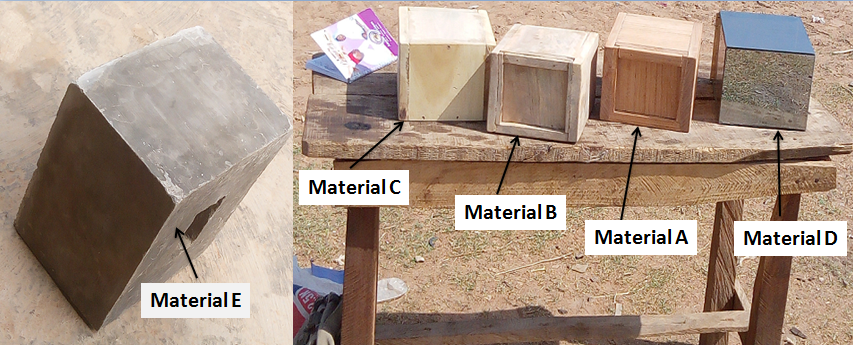
1. **Data Collection Procedure**

**Procedure I: Measurement for the RSS**

1. Using an android smart phone, version 8.0.0(ABCDEF-180604V15) of model Infinix X-608, having RF signal Tracker being installed on it accessing only 2G (1800MHz) signal.
2. The GPS receiver of the phone was turned on to give the geo location of the mobile phone.
3. The software user interface capable of giving the signal strength measurement was launched.
4. The graphical and accurate numerical values of the parameters were recorded for both indoor and outdoor.
5. Measurements were sampled for 100s at time interval of 10s and the average values were recorded.
6. The above procedures were repeated for material A, B, C, D and E.

**Procedure II: Measurement for the QOS (Quality of Service Parameter)**

1. Using an android smart phone, version 8.0.0(ABCDEF-180604V15) of model Infinix X-608 having Open Net Test software being installed on it accessing only 2G (1800MHz).
2. The GPS receiver of the phone was launched to give the geographical parameters of the mobile phone.
3. The software user interface capable of giving the QOS parameters was launched.
4. The graphical and accurate numerical values of the parameters were recorded for both indoor and outdoor scenarios**.**
5. The above procedures were repeated for material A, B, C, D and E.

****

**Figure 3. Snapshot of the Construction Materials Under Test**

1. **RESULT AND DISCUSSION**

For the Materials under test, the result obtained for both indoor and outdoor scenarios when subjected to 2G (1800MHz) are presented in figure 4 to figure 6. Similarly, the computational mean values for analysis are also presented in Table III to table XIV.

1. **Considering Material A**

Material A is termed as *Afzelia Africans (Apa).*This is one of the wood species commonly used in Nigeria as house hold construction materials. The indoor and outdoor measurement are shown in table III to table IV

**Table III Mean value of RSS for Material A**

|  |  |  |
| --- | --- | --- |
| **Material** | **2G**  **Indoor** | **2G**  **Outdoor** |
| **(dBm)** | **(dBm)** |
| **A** | -91.2 | -98.2 |
|  |  |  |

**Table IV QOS Parameter for Material A**

|  |  |
| --- | --- |
| **Material A**  **Indoor** | |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 39.5ms |
| **Download Speed** | 0.092Mbps |
| **Upload Speed** | 0.067Mbps |
| **Packet Loss** | 6.00% |
| **Material A Outdoor** | |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 21.6ms |
| **Download Speed** | 0.046Mbps |
| **Upload Speed** | 0.036Mbps |
| **Packet Loss** | 0.00% |

1. **Considering Material B**

Material B is termed as *Gosswei Lerodendrin balsamic ferum (Agba).* This is one of the wood species commonly used in Nigeria as house hold construction materials. The indoor and outdoor measurement are presented in table V and table VI

**Table V Mean value of RSS for Material B**

|  |  |  |
| --- | --- | --- |
| **Material** | **2G**  **Indoor** | **2G**  **Outdoor** |
| **(dBm)** | **(dBm)** |
| **B** | -98.8 | -103.2 |

**Table VI QOS Parameter for Material B**

|  |  |
| --- | --- |
| **Material B Outdoor** | |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 21.6ms |
| **Download Speed** | 0.046Mbps |
| **Upload Speed** | 0.036Mbps |
| **Packet Loss** | 0.00% |
| **Material B Indoor** |  |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 11.9ms |
| **Download Speed** | 0.13Mbps |
| **Upload Speed** | 0.076Mbps |
| **Packet Loss** | 0.00% |

1. **Considering Material C**

Material C is termed as *Chlorophoral excels (Iroko).* This is also one of the wood species commonly used in Nigeria as house hold construction materials. The indoor and outdoor measurement are illustrated in table VII and table VIII

**Table VII Mean value of RSS for Material C**

|  |  |  |
| --- | --- | --- |
| **Material** | **2G**  **Indoor** | **2G**  **Outdoor** |
| **(dBm)** | **(dBm)** |
| **C** | -82 | -101.8 |
|  |  |  |

**Table VIII QOS Parameter for Material C**

|  |  |
| --- | --- |
| **2G Network Outdoor** | |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 21.6ms |
| **Download Speed** | 0.046Mbps |
|  |  |

|  |  |
| --- | --- |
| **Material C Indoor** | |
| **QOS Parameter** | **Measured Value** |
| **Jitter** | 16.8ms |
| **Download Speed** | 0.0060Mbps |
| **Upload Speed** | 0.053Mbps |
| **Packet Loss** | 0.00% |

1. **Considering Material D**

Material D is termed as concrete. This is being used in building and construction work and also in house hold construction materials. The indoor and outdoor measurement are shown in table IX and table X.

**Table IX Mean value of RSS for Material D**

|  |  |  |
| --- | --- | --- |
| **Material** | **2G**  **Indoor** | **2G**  **Outdoor** |
| **(dBm)** | **(dBm)** |
| **D** | -102.7 | -102.6 |

**Table X QOS Parameter for Material D**

|  |  |
| --- | --- |
| **QOS Parameter** | **Measured Value Outdoor** |
| **Jitter** | 21.6ms |
| **Download Speed** | 0.046Mbps |
| **Upload Speed** | 0.036Mbps |
| **Packet Loss** | 0.00% |
| **QOS Parameter** | **Measured Value Indoor** |
| **Jitter** | 55.9ms |
| **Download Speed** | 0.039Mbps |
| **Upload Speed** | 0.0093Mbps |
| **Packet Loss** | 37.00% |

1. **Considering Material E**

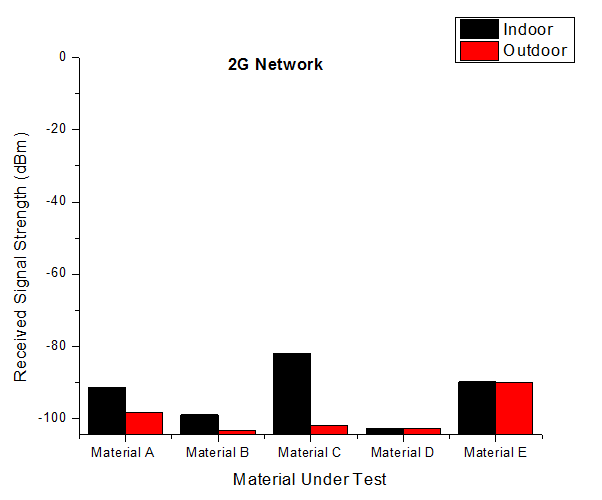
Material E is termed as Reflective Glass. This type of glass can allow low or no penetration as a result of the coatings. The indoor and outdoor measurement are illustrated in table XI and table XII

**Table XI Mean Value of RSS for Material E**

|  |  |  |
| --- | --- | --- |
| **Material** | **2G**  **Indoor** | **Outdoor** |
| **(dBm)** | **(dBm)** |
| **E** | -89.8 | -89.9 |

**Table XII QOS Parameter for Material E**

|  |  |
| --- | --- |
| **QOS Parameter** | **Measured Value Outdoor** |
| **Jitter** | 21.6ms |
| **Download Speed** | 0.046Mbps |
| **Upload Speed** | 0.036Mbps |
| **Packet Loss** | 0.00% |
|  |  |
| **QOS Parameter** | **Measured Value Indoor** |
| **Jitter** | 26.6ms |
| **Download Speed** | 0.14Mbps |
| **Upload Speed** | 0.086Mbps |
| **Packet Loss** | 7.00% |



**Figure 4. Mean Value of the Materials indoor and outdoor Signal Strength**

1. **Average Value of the Penetration Loss**

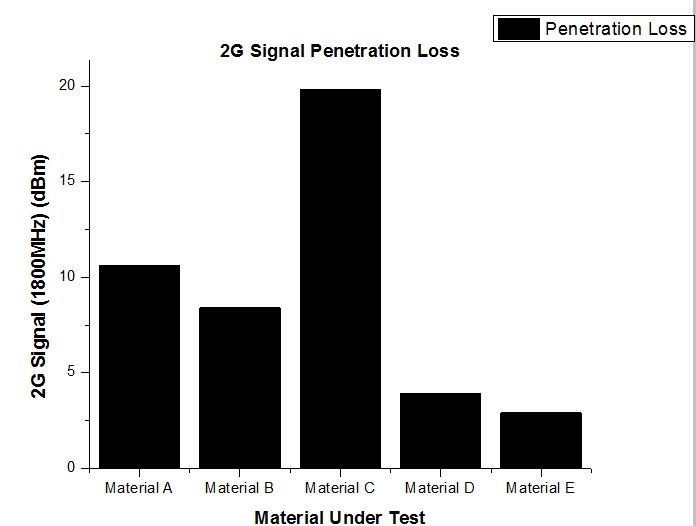
The mean value of the penetration loss also referred to as absorption loss as a result of the material characteristics is presented in table XIII. The average penetration Loss can be computed using equation (2) and equation (3) for the 5 selected materials.

**Table XIII Average Penetration Loss for the Materials**

|  |  |
| --- | --- |
| **Material**  **Under Test** | **2G Signal**  **P\_Loss(dBm)** |
| **A** | 10.6 |
| **B** | 8.4 |
| **C** | 19.8 |
| **D** | 3.9 |
| **E** | 2.9 |

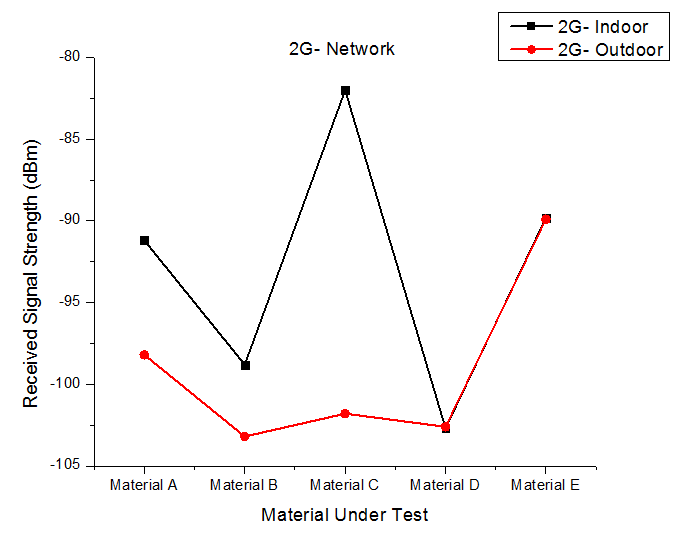
**Table XIV Change in Signal Strength Level**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Material** | **2G**  **Indoor** | **Outdoor** | **RSS**  **Indoor** | **Outdoor** | **Percentage Change** | **Remark** |
| (dBm) | (dBm) | (mW) | (mW) | (%) |  |
| A | -91.2 | -98.2 | 979.2 | 977.6 | 16.4 | Increase |
| B | -98.8 | -103.2 | 977.5 | 976.5 | 10.2 | Increase |
| C | -82 | -101.8 | 981.3 | 976.8 | 46.1 | Increase |
| D | -102.7 | -102.6 | 976.6 | 976.7 | 1.0 | Decrease |
| E | -89.8 | -89.9 | 979.5 | 979.5 | 0 | No change |

****

**Figure 5. Materials Penetration Loss**

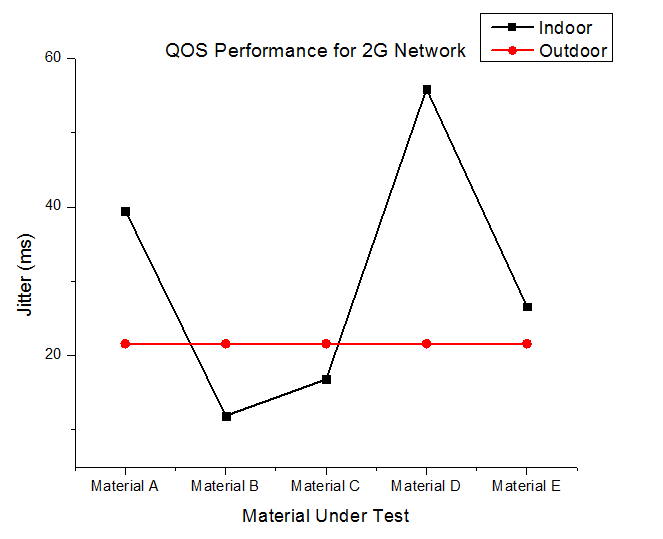
The average value for the RSS which was measured within and outside the materials when subjected to 2G signal is illustrated in figure 6.



**Figure 6. Indoor and Outdoor RSS Variation**

The quality of service parameters were obtained from open Net Test in the application Interface, which presented in table III to table XII which described the quality of experience perceived by the users when subjected to different materials for the indoor and outdoor scenario.

As a result, Jitter is being considered since it gives substantial variation for both the indoor and outdoor scenario. The Jitter variation in the selected materials for 2G signal is demonstrated in figure 7.



**Figure 7. Jitter Variation in Materials**

1. **CONCLUSION**

In conclusion, the results obtained from the surveyed data with the aid of RF signal Tracker and Open NetTest software using Infinix X608 mobile phone showed that, the construction materials have significant impact on 2G signal in terms of Received Signal Strength and Quality of Service. The result of the penetration loss, indoor and outdoor signal strength are compared in table XIII and table XIV, this revealed that, all the 5 selected materials namely; Material A,B,C,D and E have significant effects on signals .

The result from the penetration loss confirms that Material C has the highest penetration loss of 19.8dBm while Material E has the lowest penetration loss of 2.9dBm. This attests to the facts from the reviewed works that the type of construction materials affect 2G signal.

Material C has 46.1% increase in indoor signal strength, material E has insignificant change in indoor signal strength, material D, B and A has 1.0% decrease, 10.2% increase and 16.4% increase respectively in indoor received signal strength.

The result from QOS parameter (Jitter) are compared for both outdoor and indoor, this conclusively showed that Material B, C and E will provide improved experience to the user, as a result of their spread.

It is opined that, calculating the material penetration loss account for attenuation of signal strength. Therefore, Penetration Loss is a function of the material composition.

In addition, it is observed that, while taking the readings during the day, penetration loss tends to increase, since it is the rush or busy hour, human and other materials has some level of absorption, hence they may cause destructive interference.

**ACKNOWLEDGEMENTS**

The Authors appreciate the effort of everyone involved in making this paper a success.

**CONFLICT OF INTEREST**

The author declares no potential conflict of interest.

**REFERENCES**

|  |  |
| --- | --- |
| [1] | Andersen, J.B., Rappaport, T.S. and Yoshida, S., Propagation Measurement and Model for Wireless Communication Channel, 1995. |
| [2] | Anderson C.R., Rappaport, T.S., Bae, K., Verstak, A., Ramakrishnan, N., Tranter, W. H., Shaffer, C.A. and Watson, L. T., "In-buiding wideband Multipath characteristics at 2.5GHz and 60GHz," in *IEEE Conference*, vol. 5, 2010, pp. 97-101. |
| [3] | Durgin, G., Rappaport, T.S. and Hu, H., Radio Path Loss and Penetration Loss Measurement in and aroung Homes and Trees at 5.85GHz, 2002, Group:1-4. |
| [4] | Richard , Rudd; Ken, Craig; Martin , Gantey; Richard, Hartless;, "Building Materials and Propagation," Department of Signal Science, OFCOM, U.K, Document 2014. [Online]. <http://www.zerocarbonhub.org/current-roject/performance-gap> |
| [5] | Radio System Installation and Signal Penetration, 2016. |
| [6] | T.S. Rappaport, *Wireless Communications:Principle and Practice*, 2nd ed. Singapore: Pearson Education PTE Limited, 2003. |
| [7] | Armitage Scott, "Guide to surveying building for Wireless Network," *JISC* , July 2011, Published on Jisc community (https://community.jisc.ac.uk). [Online]. [http://www.community.jisc.ac.uk/library/advisory-services/guide-surveying-buildings-wireless- networking](http://www.community.jisc.ac.uk/library/advisory-services/guide-surveying-buildings-wireless-%20networking) |
| [8] | Elechi Promise and O. Otasowle P., "Determination of GSM Signal Penetration Loss in Some Selected Buildings in River State,Nigeria," *Nigerian Journal of Technology(NIJOTECH)*, vol. 34, no. 3, pp. 609-615, 2015. [Online]. <www.nijotech.com> |
| [9] | Felicito, S. Caluyo; Jeniffer, C. Dela Cruz;, "Penetration Loss of Doors and Windows Inside Residence Using ISDB-T Digita Terrestrial Television Signal at 667MHz," in *Preceedings of the World Congress on Engineering and Computer Science(WCECS*, vol. II, San Francisco, 2011, PHD Research Work. |
| [10] | William, F Young; Kate, A Remley; John, Ladbury; Christopher, L Holloway; Chriss, Grosvenor; Galen, Koepke; Dennis, Camell; Sander, Floris; Wouter, Numan; Andrea, Garuti;, "Measurement to Support Public Safety Communication: Attenuation and Variability of 750MHz Radio Wave SIgnals in Four Large Building Structures," U.S Department of Commerce, National Institute of Staandard and Technology, Washington, NIST Technical Note 20402-0001, 2009. [Online]. <www.gpo.gov> |
| [11] | Katerien, De Moor; Wout , Joseph; Istvan, Ketyko; Emmeric , Tanghe; Tom, Deryckere; Luc, martens; Lieven, De Marez;, "Linking Users Subjective QOE(Quality of Experience) Evaluation to Signal Strength in an IEEE 802.11b/g wireless LAN Environment," *EURASIP Journal*, vol. 2010, pp. 1-12, February 2010. |
| [12] | Kruse John, "Network Neutrality and Quality and Service(QOS)," , Germany, January 2008, pp. 25-26. |
| [13] | Promise, Elechi; Otasowie, P O;, "Investigation of GSM Signal Loss in Multi- Storey Building," in *International Conferemce and Exhibition on ICT & Telecommunication*, Benin, 2016, p. 65. [Online]. <https://www.researchgate.net/publication/310832222> |
| [14] | Frank Dillon, "2.4GHz and 5GHz Wi-Fi Signal Strength Through Household Construction Materials," Department of Computer Engineering, University of Maryland, U.S, Research 2017. |
| [15] | Idim, A I; Anyasi, F. I.;, "Determination of Building Penetration Loss of GSM Signal Using Selected Building in Orhuwhorun, Delta State, Nigeria as a case Study," *Jornal of Electronics and Communication Engineering*, vol. 9, no. 5, pp. 1-5, Octomber 2014. [Online]. <www.iosrjournals.org> |
| [16] | V., O. Akpaida; S., I. Uzairue; A., I.s Idim; F., I. Anyasi;, "Determination of an Outdoor Pathloss Model and Signal Penetration Level in Some Selected Modern Residential and Office Appartment in Ogbomosho Oyo State, Nigeria," *Journal of Engineering Research and Reports*, vol. 2, no. 1, pp. 1-25, May 2018. [Online]. <www.sciencedomain.org/review-history/24784> |
| [17] | Ahsan , Sohail; Zeeshan, Ahmad; Iftikhar, Ali;, "Analysis and Measurement of Wi-Fi Signals in Indoor Environment," *International Journal of Advances in Engineering & Technology(IJAET)*, vol. VI, no. 2, pp. 678-687, May 2013. |