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Deployment of 5G Network for Efficient Spectrum Utilization in Alakahia, Rivers State.

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Abstract-*This work focused on the deployment of 5G network for efficient spectrum utilization in Alakahia,Obio/Akpor Local Government, Rivers State Nigeria. 5G is yet to be deployed for mobile communication in Nigeria, hence the need to investigate its deployment requirement and challenges. The choice of the region is influenced by its population density to accommodate greater capacity and high traffic demand of 5G network. The work demonstrates the ability of transmit base station to adequately sight the receiver stations in the designated area based on a non-standalone approach. MATLAB 2021 software was used to simulate antenna scenarios defined by different transmitters and receivers. From the results obtained, the region is strongly covered with the following measured parameters: Path loss due to foliage: 28.2381 dB, Signal strength at UPTH: -119.2969 dBm, Signal strength at Abuja Campus: -115.49 dBm, Signal strength at Choba Police Post: -140.8037 dBm, Signal strength at Delta Park: -101.7688 dBm, Signal strength at Choba Campus: -123.2512 dBm, Signal strength at ObiriIkwere: -143.3768 dBm.From the analysis of the result, the region shows that the area is strongly covered to promote low latency and good network capacity for 5G application using multiuser, higher band and speed of 100gbps as metrics of evaluation. This study will provide basic information on the infrastructural development while disclosing challenges and breakthroughs for imminent 5G deployment.*

Keywords;*5G Network, Cell towers, Latency, Network capacity, spectrum utilization.*

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I. INTRODUCTION

The goal of 5G and extended mobile connections is to consolidate multiple “Radio Access Technologies” (RATs) into such a single system that can manage network activities efficiently. Users will likely have access to a number of technologies that will improve the Quality of Experience (QoE) as a result of this interaction[1], [2]. Wireless connection restrictions in fourth generation (4G) networks are essentially similar to those that affect 5G and well beyond wireless networks. Despite some minor gains in previous generations, they are inadequate to satisfy the aim of 5G and beyond cellular connections. Owing to the currentcondition of mobile networks and the magnitude of future needs, wireless communication designers are being pushed to set significantly higher ambitions for 5G and beyond. Data rates for sluggish or stationary devices are now 1 GB/s, while mobile data rates are 100 Mb/s; however, the goal of 5G and far beyond wireless connections is to attain data speeds of 10 GB/s or more. As a result of these conditions, a considerable shift in the overall design of a mobile network is required to give a seamless experience for mobile users. More capacity, greater rate of data, reduced latency, enhanced connectivity for large number of subscribers, cheaper energy/price, and, most significantly, increased experience quality is faced by wireless network designers for 5G and beyond. Massive MIMO, device-to-device (D2D) networking, overall protocol reduction, multiple cellular design, virtual network function, temporal storage of content, and increased frequency scope has been investigated for a customary 5G and beyond cellular interconnectivity. In this paper therefore, system-level experimentations are used to analyse the deployment of Wireless 5G network for efficient spectrum utilization in Obio/Akpor, Rivers State. Fixed wireless access (FWA) over terrain utilizing 5G technology to provide internet to homes and businesses where landlines are unavailable or underperforming. A connection is established between user's fixed wireless terminal (FWT) and base station using FWA. Terrain and route loss elements like vegetation and weather have a substantial influence on link performance at the high frequencies necessary for 5G.

II. STATEMENT OF THE PROBLEM

To meet the increasing data demand of the fifth-generation mobile radio network knowing that communication network resources are limited is quite challenging. The few restrictions confronting the yet-to-be-deployed mobile network standard, such as network power usage,wireless coverage,spectrum type and network capacity, are important parameters to ensure efficiency and effectiveness in spectrum usage of the fifth-generation mobile radio network. To achieve optimum spectrum usage, this work is intended to investigate the 5G network rollout in Obio/ AkporLocal Government Rivers State, Nigeria as a case study.

III. REVIEW OF RELATED WORK

The first generation of mobile radio communication (1G) deployed frequency division multiple access technology principally for voice communication in the 800MHz range at a speed of 20MHz. The second generation (2G) used time division multiple access for voice and text messages. A variant of the 2G network; 2.5G and 2.75G was birthed while introducing general packet radio services (GPRS) though not well pronounced but were with more benefits to users without expanding the base station infrastructure. The third generation (3G) mobile radio used wide code division multiple access technology designed for voice, data and intelligent media applications. 4G witnessed the adoption of Orthogonal frequency division multiplexing (OFDM), Ultra-wide band radio (UWR) millimetre waves and smart antenna to achieve data rates of up to 20MB/s at 2 -8GHz frequency. 5G wireless systems aim at solving a variety of technical requirement that are unprecedented and difficult with other wireless application [3].

Figure 1: Showing the evolutionary trend of Wireless Technology

Various optimization solutions have been used to solve several challenging 5G network issues. Using optimization techniques, the goal is to discover a global ideal for network parameters that gives the best service quality.

The purpose of 5G networks is to provide a high degree of Quality of Service (QoS) to users, hence Resource Management (RM) becomes an important tool. Spectrum allocation, interference, power regulation, and user association are all included in the RM process. Due to the rapid increase in network demand, managing resources in 5G is a complex task. To address this issue, several works have been proposed. These include the works of[4]–[7][8]. Other meta-heuristics techniques include the works of are[9]–[11] with objectives to meet the service quality standard.[6]presented a performance study and optimization for a non-uniformly deployed mmWave cellular network, with the goal of optimizing the sum rate while maintaining QoS and power consumption limitations. Another significant issue with 5G is energy conservation. Its purpose is to reduce how much energy mobile communication networks utilize[12], [13], to determine which network configuration uses the least amount of energy. In cellular networks, coverage, capacity, and parameter planning are all important aspects of radio network design and dimensioning[14]. It is worth noting that both the number of mobile users and the demand for services is rapidly growing. The rise necessitates increased network capacity and coverage to maintain high service quality. [15]carried out a study on the uplink coverage and rate analysis of millimetre wave cellular network. [16]discussed antenna positioning problem of 5G networks known as antenna placement and localization which comprises of selecting the best locations to plant base stations from a list of candidatesite to optimize network coverage while lowering cost.

A. Speed

In most discussions regarding 5G, the term "speed" is frequently used to distinguish it from 4G. That seems reasonable, given that each successive cellular generation has been much quicker than the previous one. Even though 4G may currently reach speeds of up to 100 Mbps, actual performance is typically limited to 35 Mbps. With a theoretical peak speed of roughly 20 Gbps and current real-world rates ranging from 50 Mbps to 3 Gbps, 5G has the potential to be 100 times faster than 4G.

B.Latency

However, the time it takes for a packet of data to move between two points is known as latency. It's the latency that slows down any data transfer, regardless of how quick the connection is otherwise. 4G networks now have a latency of around 50 milliseconds, whereas 5G networks are predicted to have a latency of around 1 millisecond.

C. Network Coverage

Even after a decade of 4G, there are still some distant and rural places with poor 4G coverage throughout the world. Because 5G is still in its early stages, coverage is non-existent outside of a few big cities. It will take many years for 5G to reach a coverage level comparable to 4G, and it will be divided into three types (high-, medium-, and low-band 5G), each with its speed and bandwidth.

D. Bandwidth

5G's bandwidth, or capacity, is expected to be substantially higher than 4G's. This is partly due to 5G's significantly more effective utilization of available airwaves. 4G uses just a small portion of the available spectrum, from 600 MHz to 2.5 GHz, whereas 5G is split over three bands. Each band has its frequency range and speed, as well as diverse consumer, corporate, and industrial applications and use cases. That means 5G has a significantly larger capacity.

TABLE I: COMPARING THE DIFFERENCE BETWEEN 4G AND 5G NETWORKS

Parameter	4G	5G
Maximum transmission speed	1Gbps	20Gbps
User experience transmission speed	10Mbps	100-1,000 Mbps
Allowable maximum mobility speed	350km/h	500km/h
Latency	10ms	1ms
Maximum connecting Instrument	100,000/km^2	1,000,000 /km^2
Data processing capacity per the area	0.1 Mbps/m^2	10 Mbps/m^2
Power efficiency	1x	8,100 x

D. Beamforming in 5G Network

The three types of beamforming architectures utilized in 5G networks are digital beamforming (DBF), analog or radiofrequency beamforming (ABF), and hybrid beamforming architecture (HBF) [17]. The sections that follow go through these beamforming techniques in greater depth.

E. Digital Beamforming

At the baseband level, digital beamforming handles the complete array processing. It has a beamforming architecture that implies each antenna has a transceiver.

F. Analog Beamforming

The antenna array is powered by a transceiver in Analog Beamforming, and the transmitter and receiver array processing are done with RF components that can phase shift and possibly gain adjust itself. It's a type of beamforming that controls MIMO and beamforming at the radio frequency level.

G. Hybrid Beamforming

Controlling MIMO and beamforming necessitates splitting the RF and baseband so that one transceiver drives one set of antenna elements. The antenna array is driven by two to eight transceivers in a hybrid architecture.

H. Small Cells.

Because of the necessity to fulfill increased traffic demands as the number of users rises, as well as infrastructure densification, the introduction of 5G small cells into the 4G microcell network is a high-priority component of 5G communications (Le et al, 2015).

I. Massive Multiple in multiple out (MIMO)

Tremendous MIMO (also known as Large-Scale Antenna Systems, Very Large MIMO, and Hyper MIMO) is an intriguing notion that can solve the massive capacity demands of 5G wireless communication systems. Massive MIMO entails the use of a large number of antennas in the base station, to serve many users' devices adaptively and coherently with one or more antennas. The additional antennas increase throughput and energy efficiency by channeling signal energy transmission and reception into smaller areas of space. This is simple to do at millimeter-wave frequency since the high carrier frequency necessitates relatively compact antenna elements, allowing several antennas to be used at both the base station and the mobile station.

J. Antenna Technology

It's difficult to find antennas that can work in multiple frequencies at once, such as 450 MHz, 700 MHz, and 26 GHz. As a result, two separate antennas will very probably be required, each operating in a different frequency range. More antenna elements can be added in the restricted area at frequency greater than 24 GHz. Antenna technology with a larger number of particular antenna elements can achieve high beamforming gain. Beamforming systems with accurate pointing directions can compensate for increasing route loss in frequency ranges above 24 GHz. Phased array beamforming is used to boost the received signal power by applying beamforming gain. Higher antenna gains can be achieved by using narrower beams. Massive MIMO (multiple-input, multiple-output) technology would be used in 5G communication networks to compensate for higher frequency propagation loss and reduce interference. Terminals or user equipment should have antenna arrays built-in. Because the transmission wavelengths would be smaller, it should be possible in this case.

IV. RESEARCH METHODOLOGY

This research methodology describes the design of different phases of the work implementation, the selection of tools for development, bandwidth requirements, configuration, and the implementation milestones.

A. Research Design

In the initial phase of this work, a study was conducted where information was gathered about the existing 4G (network) coverage in Obio/Akpor, Rivers State, and the possible deployment of a 5G network for efficient spectrum utilization. The study was carried out based on appropriate tools which include; Mat Lab/Simulink 2021 software, Google Earth map, and Microsoft Visio software for the design case.

B. Development Approach

The deployment in this study is limited to a few municipals in Obio/Akpo Local Government. Table 2 showsthe geographical coordinates of variousreceiver sites. The geographic coordinates of six potential receiver base station locations acquired.

TABLE II: GEOGRAPHICAL COORDINATES OF RECEIVER SITES (OBIO AKPOR LGA)

Location	Northings	Eastings	Base station type
Alakahia	6.925	4.881	Transmitter
	6.918	4.885	Receiver
	6.921	4.893	Transmitter
	6.933	4.89	Receiver
	6.927	4.897	Transmitter
	6.935	4.884	Receiver

TABLE III: POPULATION AND SIZE OF THE OBIO AKPOR RIVERS STATE[18]

Name	Population Census 1991-11-26	Population Census 2006-03-21	Population Projection 2016-03-21
Rivers	3,187,844	5,198,716	7,303,900
Obio/Akpor	263,017	462,350	649,600

C.The 5G Antenna Used

On the site of deployment, the antenna acts as the BS (Base Station) which is the central connection point for the wireless signals. Gain is 18dBi, the connection is a multi-type option, VSWR is 2:1, Bandwidth is broadband, Impedance is 50 ohms, and H-plane is used. E-plane, Omni-directional Beamwidth = 100 degrees, polarization = vertical, mounting = double-sided tape, and mechanical properties, such as reception apparatus cover = polyurethane, are all examples of mechanical properties. Temperature range: -20°C to +60°C for operation, and 30°C to +75°C for storage.

D. Link Budget

On the downlink and uplink sides, link budget computation seeks to estimate thehighest value of Allowable Path Loss (MAPL), or the weak signal received between the mobile antennas and mobile station antenna

TABLE IV: STANDARD GSM BASE STATION TRANSMISSION PARAMETERS

Height, Ht	10m
Frequency of Transmission Fc	3.5Ghz
Radiate Power, Pr	1 watt
Transmitting Antenna gain (Gt)	2dBi
Effective Isotropic Radiate Power (EIRP)	5dBm
Maximum Receive Power (Rm)	3dBm

D. Methods of Data Collection

The data used in this work is a Primary Source, gathered from anonymous base station engineering and technical department of a mobile network provider, to collate information on 4G network coverage to help in 5G network deployment for efficient spectrum utilization. The information also involved personal oral interviews.

E. Simulation Procedures Using MATLAB

MATLAB Simulink software will be used together with google earth map to deploy the 5G network in the selected region. The reason for selecting Obio/Akpo is because it is a densely populated area, it's not a Riverine area hence, easy to capture the geographical coordinates of the town within the available resources and time-space. The regions selected will be mapped using google earth map and cited with the designed antenna and base stations.

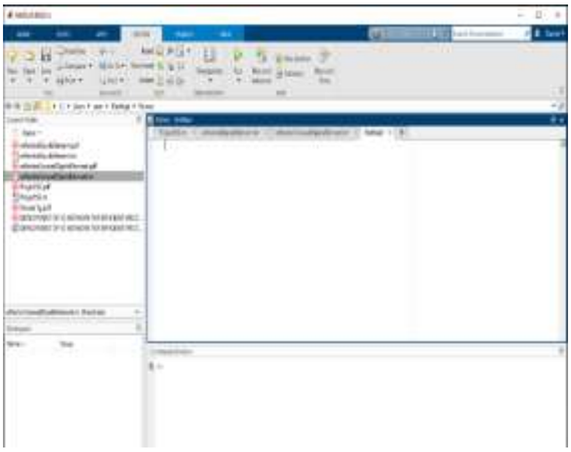

Figure 2: MATLAB IDE used for Simulation of the Work

F. Create Base Station Transmitter Sites

It is fundamental to create a transmitter site in Obio/Akpor, Rivers State to transmit the 5G radio signal to the receivers in Rivers State. The transmitter location is designed to represent a 3.5 GHz base station with a 1Watt transmitter power.

G. Create Receiver Sites

Receiver sites are created to receive 5G signals from the transmitter and plot the locations on a map. Each reception site corresponds to the location of a user's fixed wireless terminal. The combination of the receiver sites and the transmitter make up the Base Transceiver Station (BTS) site on the deployment location.

H. Endure Link Visibility in Line-of-Sight

A diagram of the base stations and receivers' line-of-sight propagation pathways were created. The computation of line-of-sight takes into account the terrain of the region but ignores other obstacles, revealing a limited line-of-sight to receiver locations.

I. Create MIMO Antenna Array Base Station

An 8-by-12 antenna array with crossed dipole antenna elements is created to produce a highly directional beam. The radiation pattern on the map is plotted using the default antenna orientation, with the antenna array physically oriented east.

J. Create MIMO Antenna Array Receiver Site

A reflector-backed vertical dipole antenna element can be used to make a 3-by-3 rectangle array. The radiation pattern on the map at each receiver site is plotted by pointing the antenna to the BS.

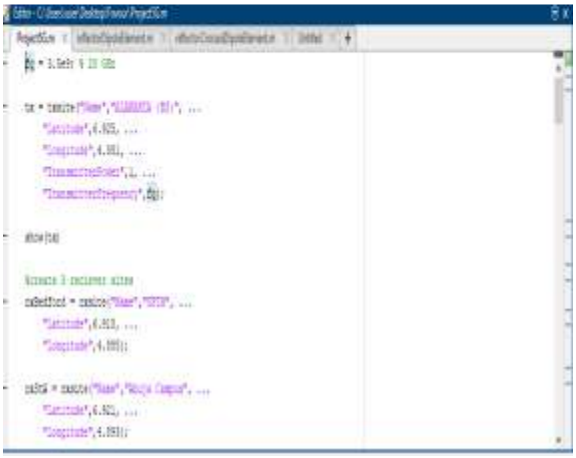

Figure 3. Defining transmitter and receiver antenna location

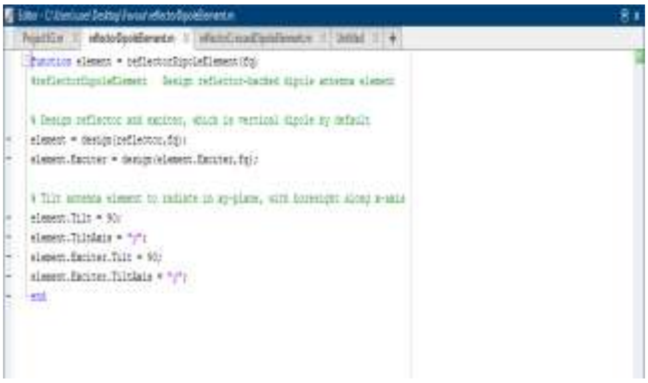

Figure 4. Defining the reflector dipole moment of 5G Antenna

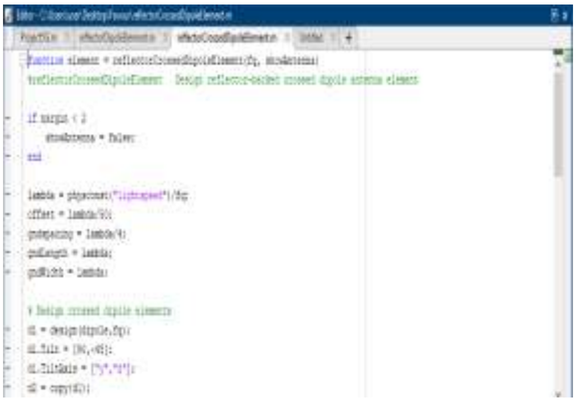

Figure 6. Defining the reflector cross dipole moment of 5G Antenna

Beam forming is applied to Determine Signal Strength in Free Space. The received signal strength for each receiver site is calculated using the free space propagation model.

The total propagation loss (dBi), of a wireless signal propagating through a vegetation-covered area can be calculated as

$$PlTl\ (dB) = PlFSP(dB) + PlFoilage \qquad (1)$$

The propagation loss due to free space is known as PlFSP, and PlFoilage is the propagation loss owing to foliage. The PlFSP is now as follows:

$$PlFSP\ (dB) = 32.5 + 20\ x \log(f) + 20\ x \log(d) \qquad (2)$$

In equation 2 above, **d** signifies the distance between links in kilometers and **f** specifies the frequency in megahertz (MHz). In this study, the foliage propagation loss is calculated using the "Weissberger model". The foliage propagation loss (in decibels) as described in the model is PlWeis(dB).

K. Simultaneous Transmission

Create a single beam that can transmit to all receiving locations at the same time, rather than guiding the base station antenna beam to each receiver site independently. A single beam generates radiation lobes that are directed toward the three-receiver sites. The signal strength at each receiver site decreases with simultaneous broadcast but still gets to meet the receiver sensitivity.

L. Add Path Loss Impairments

Because of the greenery and weather, the signal is attenuated even further. Weissberger's model is used to assess signal intensity owing to weather and the propagation models such as gas and rain used to estimate signal loss caused by foliage. Weissberger's model can be written as seen in equation 3 below:

$$Pl = \begin{cases} 0.45f^{0.284}\left(d_f\right) & for \quad 0 \leq d_f \leq 14m \\ 1.33f^{0.284}(df)^{0.588} & for\ 14 \leq d_f \leq 400m \end{cases} \quad (3)$$

d_f = the foliage depth in meters along the line-of-sight

f = the frequency in GHz is denoted by

Hence,Compare Performance in the Different 5G Frequency Bands. To achieve more favourable path loss and the requisite signal strength, make a design of the MU-MIMO system for the frequency range within the frequency band of 2.8 GHz to 60 GHz

V. RESULTS

Figure 7 shows a goggle map of Alakahia Obi/Akpo LGA.

Figure 8, shows a 5G base station transmitter deployed in Alakahia area of Obio/Akpo Local government of Obio/Akpor, Rivers State Nigeria on a geographical location of latitude 6.925 East and longitude 4.881 North.

Figure 9 shows a no line-of-sight connection between the receivers and the transmitter

Figure 10 shows the line-of-sight contact between the transmitter base station and the receiver.

Figure11 shows the transmitter base station beamforming pattern within the Alakahia environment.

Figure 12 shows the Beamforming at the Receiver Station

Figure 13 shows the beam radiation pattern from the transmitter covering the Alakahia environment

Figure 7: Google map of Alakahia, Obio/Akpo LGA

Figure 8: Deployment of a Single 5G Transmitter Base Station in Alakahia

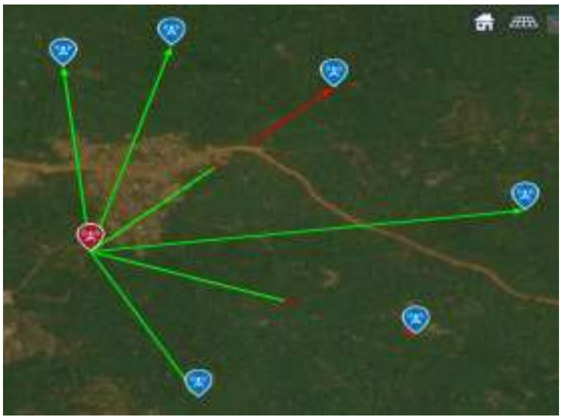

Figure 9: No line-of-sight contact on some transmitters base station and the receiver

Figure 10: Line-of-sight contact among transmitter base station and the receiver after antenna parameter adjustment.

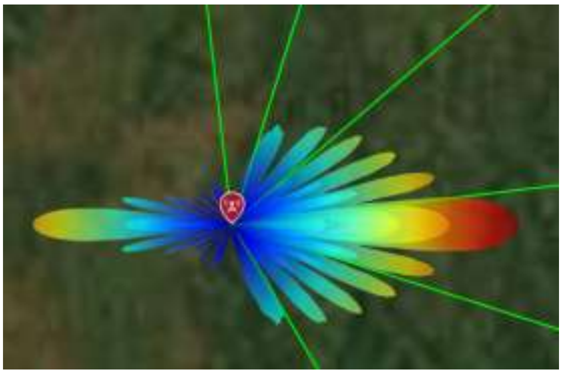

Figure 11: The Transmitter Base Station Beamforming Pattern

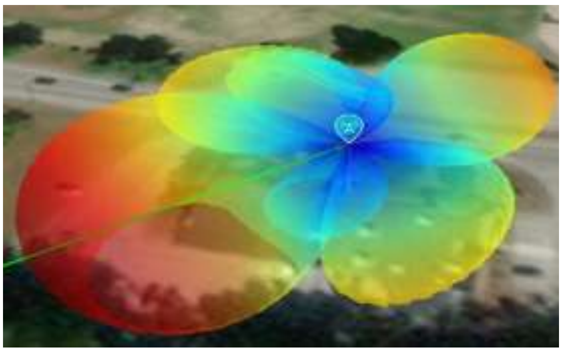

Figure 12 Beamforming at the Receiver Station

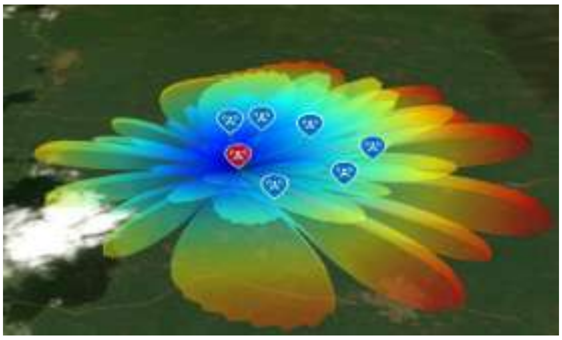

Figure 13: Beamforming of the Transmitter Stationand all the 6 Receiver Stations

The deployment of 5G base station in Alakahia on a geographical location of latitude 6.925 East and longitude 4.881 North was achieved. In the design of the transmitter, the MATLAB code with subroutine was implemented. The transmit frequency was set at 3.5 gigahertz and the transmit power of 1 watt was chosen. The initial deployment height was 10 meters and had zero surface elevation.

In Figure 10, with the appropriate antenna height adjustment of 15 meters in all the receiving stations, the line of sight was maintained in all the receivers deployed.

Figure 10 shows a line-of-sight connection and the beam formed by the transmitter base station, the 1-watt power transmitter created a beam that is well enough to cover Alakahia and its immediate environment. According to measurement obtained from google earth map, each of these receivers' sites are about 250 meters away from the transmitter station. It can be observed from the beamformed that the transmitter will be able to cover a distance that is 5 times away from the transmitter perfectly well.

Figure 12 shows one of the deployed 6 fixed 5G receivers within the Alakahia environment responding perfectly well to the direction of signal arrival from the transmitter. It can be observed that the receiver station created a beam focus in the direction of the desired incoming signal.

Figure 13 shows the beam radiation pattern from the transmitter covering the Alakahia environment. From the locations of the receiver which is 250m from the transmitter

The observation means that the region is strongly covered with the following parameter measured: Path loss caused by foliage: 28.2381 dB, Signal strength at UPTH: -119.2969 dBm, Signal strength at Abuja Campus: -115.49 dBm, Signal strength at Choba Police Post: -140.8037 dBm, Signal strength at Delta Park: -101.7688 dBm, Signal strength at Choba Campus: -123.2512 dBm, Signal strength at Obirikwere: -143.3768 dBm,Path loss due to foliage: 28.2381 dB.

VI. CONCLUSION

This work describes the deployment of a 5G network applied for mobile communication for efficient spectrum utilization in Obio/ Akpor, Rivers State. It demonstrated the ability of the transmitting base station to sight the receiver stations in chosen area. MATLAB 2021 software simulation text-based codes were used to design the antenna scenarios defined by different transmitters and receivers. The observation shows that the region is strongly covered with the following parameter measured: Path loss due to foliage: 28.2381 dB, Signal strength at UPTH: -119.2969 dBm, Signal strength at Abuja Campus: -115.49 dBm, Signal strength at Choba Police Post: -140.8037 dBm, Signal strength at Delta Park: -101.7688 dBm, Signal Strength at Choba Campus: -123.2512 dBm, Signal strength at Obirikwere: -143.3768 dBm, Path loss due to foliage: 28.2381 dB.In this work, it was also seen that at a lower carrier frequency of 3.5GHz, the antenna of 1 watt transmit power covers a longer range of 2Km and hence, saves more money due to fewer base station deployments than the use of transmit carrier frequency of 60Ghz which covers a shorter range.

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