UNIABUJA Journal of Engineering and Technology
https://ujet.uniabuja.edu.ng/
ISSN: 2714-3236 (Online); 2714-3228 (Print)
Volume 2, Issue 2, 2025; 115-121

Development of a 4G Radio Frequency Signal Booster for Improved Mobile Communication Coverage

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Abstract
The construction of high rise building or the distance between mobile station and base station causes signal strength losses on mobile devices. This signal loss always led to wireless communication problems, therefore the need for a booster at the receiver. This article presents the development of a 4G Radio Frequency (RF) signal booster prototype aimed at improving indoor mobile network performance. The initial signal strength surveys for GLO and MTN networks between frequency bands of1800 MHz and 2100 MHz was first conducted with an Agilent FieldFox N9912A RF Analyzer. A 4G dual-component signal booster prototype was proposed, consisting of an indoor and outdoor antenna fabricated with aluminum elements and coaxial cable, coupled with a RF amplification module utilizing BFR93A transistors, ceramic capacitors, and resistors. This work compared the initial and the obtained signal strength from the proposed booster for GLO and MTN. The result shows an enhancement in the received signal strength measurement ranging from 2 dBm to 4 dBm approximately with a reduced uplink average gain of 1.2 dBm. This signal booster can be employed in mobile users to improve network qualities and coverage for better user service experience.

Keywords: *Antenna, 4G, Radio Frequency, Amplifier, signal strength.*

1.0 Introduction

Cellular wireless networks have greatly developed from First-Generation (1G) up to the Fifth-Generation (5G). Early 1G networks focused on voice calls and provided a foundation for the development of mobile telephony, while successive generations brought increasing data transmission speeds, capacity, and reliability (Hodara & Skaljo, 2021; Sil & Chatterjee, 2023). The transition from 2G to 3G introduced higher data rates that enabled new mobile applications such as internet access, gaming services, video calling, and broadband at higher speeds (Ariba *et al.*, 2025). Today's 4G and 5G networks deliver mind-boggling capacity, minuscule latency, and can support a multitude of connected devices (Imam-Fulani *et al.*, 2023; Mughees *et al.*, 2021; Turchet & Casari, 2023). Despite these advancements, the enduring issue of signal degradation persists in 4G network due to physical obstructions, weather, air and dense urban development (Liu *et al.*, 2024). These problems often result in inadequate connectivity, call disconnections, and diminished Quality of Service (QoS), particularly in areas distant from base stations (Adediran *et al.*, 2024). To solve this problem, a signal booster in the form of a repeater is required for signal amplification to user.

A signal booster is an electronic device that is used to increase the network signal with the aid of wired or wireless system. It acts as a signal booster and raise the real signal for further distance (Singh *et al.*, 2025). In Nigeria, the most common frequency bands of 1800 MHz and 2100 MHz for 4G services which are commonly used by network operators such as GLO and MTN are employed in this study. The choice of these frequency bands is based on the fact that they are widely used and unique propagation properties that affect range of coverage, signal penetration and overall network performance. Hence, it is important to know the performance of signal booster in these bands to optimize their design and implementation in telecommunication.

Recent research studies have addressed the problems arising due to long-term degradation in signal quality. For instance, Chibuzo and Omoniyi (2019) designed a booster system for enhanced weak-signal reception in offices, camps, recreational centers and automobile vehicles. The device worked by receiving weak wireless signals via an antenna, then boosting them inside the space with better signals. Unlike typical repeaters limited to certain networks, their design concentrated on broad accessibility regardless of terrain, height, or location. The practical significance lay in the extension of base station coverage to the neglected rural zones, thereby promoting better communication and economic activities. Although the concept demonstrated its adaptability, the study showed a lack of performance results regarding the level of gains

Received: 31-03-2026 / Accepted: 05-04-2026 / Published: 18-05-2026

https://doi.org/10.70118/ujet.2026.0302.11

and interference handling capabilities, thereby indicating limitations regarding the scalability of the booster system to accommodate high traffic areas.

(Adediran, 2023) conducted a comparative study on the field performance of GSM and CDMA networks in different settings. The results showed that GSM had better coverage due to the infrastructure, while CDMA had steady transmissions with the use of spread-spectrum technology. The distortion of the signal at crucial time and the interference of buildings was identified as a limiting factor in the study. The significance of boosters in avoiding the issue of congestion and environmental impact was also highlighted in the study, but did not give details on the booster system or the amplification technology. (Soim *et al.,* 2022) created an active booster system based on bi- quad and omnidirectional antennas to enhance 4G coverage. The design focused on minimizing the effects of signal attenuation as a result of environmental factors. The booster used adaptive designs, which dynamically could change the level of amplification as a balance between user demand and network load. The paper also highlighted the applicability of antenna diversity and active repeater architecture in solving practical coverage challenges. It was however only implemented in controlled laboratory conditions leaving the scalability to the field and did not address power consumption issue.

The topology of the power amplifier use for Doherty and Out phasing designs in 5G systems was proposed by (Bachi, 2022). Digital Pre-Distortion (DPD) was applied to mitigate distortion and widen the linear functioning range. While the study increased high-efficiency in the design, its focus remained on component-level innovation rather than whole booster systems, leaving integration difficulties for commercial 5G deployments unanswered. For easy selection of Wi-Fi signal repeaters by users, decision support system that uses composite performance index approach was employed by (Trianto *et al.,* 2023). The authors utilize composite performance index approach to solve issues in making decision with various options several benchmark by joining index to measure options. The results show that, the solution from composite performance index approach provided the same output as manual approach of signal boosting. (Carvalho *et al.,* 2025) deployed network controlled repeater in an urban environment to solve the problem of coverage in millimetre wave spectrum of 5G networks. The authors, survey the deployment alternatives and performance profits. The performance of various deployed network controlled repeater were analysed and compared. The results showed that, network controlled repeater is the best solution for solving coverage issues in 5G millimetre wave spectrum.

However, in an office environment network accessibility and connectivity is a key determinant problem that mobile user encounters because of the building materials such as reinforced concrete structures, metal frames and tinted glass that is power efficient introducing penetration losses and multipath fading effects. These effects are pronounced at 1800 MHz and 2100 MHz frequency band due to lower wavelength penetration ability leading to poor indoor coverage and signal quality uniformity. Hence, there is need to develop a circuit that will improve the signal strength thereby providing good Quality of Service (QoS) to mobile user. Therefore, this work developed a 4G Radio Frequency (RF) signal booster circuit that will work on 1800 MHz and 2100 MHz range for signal strength improvement in an office environment particularly for GLO and MTN network providers. The floor area of the office is about $16m^2(4m \times 4m)$ and the materials used in the construction is reinforced concrete with internal partition made of wood. This paper is structured as, section 2 discuss the material and methods utilized in the design of 4G RF signal booster proposed prototype. These shows the initial data collection, circuit design, component selection, proposed prototype development. Section 3 present the results and discussion. This section discusses the signal strength status before and after booster development. Finally, Section 4 concludes the paper.

2.0 Materials and Methods

The development of this device involves two steps. The first step is real-time measurement and data collection of the RF signal strength in the 4G band at a specific office setting while the second step is the design stage which involves circuit design, components selection, prototype development and testing.

2.1 Measurement and Data Collection

The Agilent FieldFox N9912A RF Spectrum Analyzer (AFN9912ARFSA) and Yagi antenna tools as shown in Figure 1 and 2 respectively are employed for measurement and data collection. The AFN9912ARFSA is a type of RF spectrum analyzer used for testing radio signals with frequency range that extends from 30 kHz to 6 GHz. It was employed to carry out field measurements and collect data across an office environment with a reinforced concrete with a dimension of $16m^2(4m \times 4m)$ in order to determine the Received Signal Strength (RSSI) and identify places with the weakest signal coverage. However, for proper electromagnetic waves detection and reception a Yagi antenna was used along with the spectrum analyzer because of it high gain and directional properties. Measurements and data collection was performed at 11:00 am and 3:00 pm respectively in order to record the load-induced change.

Received: 31-03-2026 / Accepted: 05-04-2026 / Published: 18-05-2026

https://doi.org/10.70118/ujet.2026.0302.11

Figure 1: Agilent FieldFox N9912A RF Analyzer

Figure 2: Yagi Antenna

2.2 Design of 4G RF Signal Booster Circuit

The design of the circuit was carried out on proteus software as illustrated in Figure 3. The RF booster is made up of two essential parts: the antenna subsystem and the RF amplifier stage. The antenna subsystem receives weak signals from surrounding base stations, while the amplifier enhances these signals before retransmitting them.

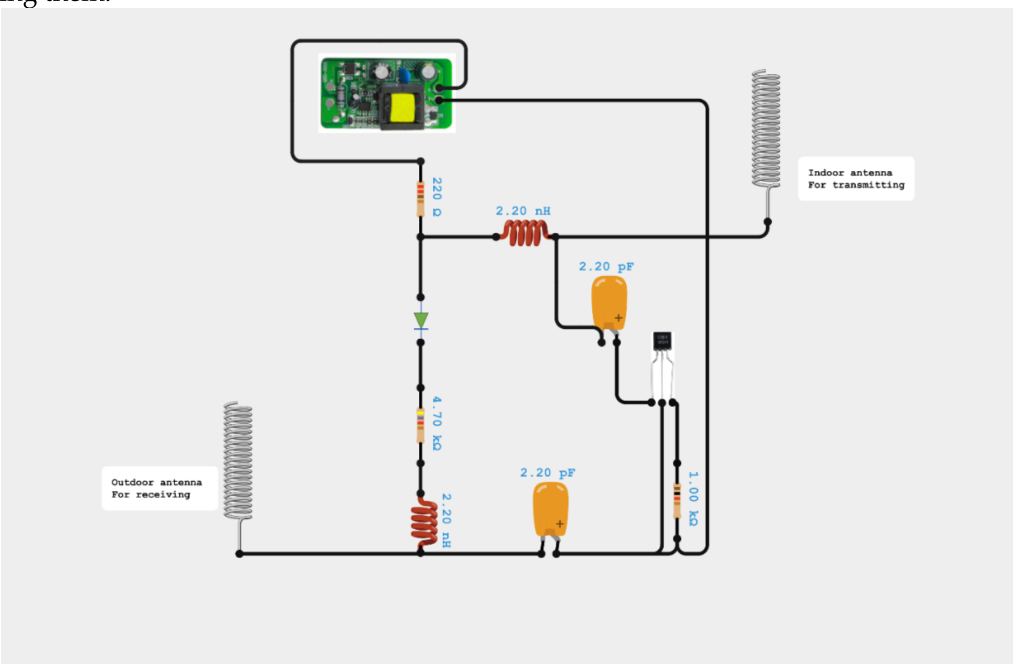

Figure 3: 4G Radio Frequency Signal Booster Circuit

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2.3 Components Selection
2.3.1 Signal Amplifier

Signal amplifier is the main electronic unit that amplifies poor 4G signal gotten form outside and increases it for indoor usage. The amplifier is a multi-band booster, amplifying multiple band simultaneously. The electronic unit consist of utilizing BFR93A transistors, ceramic capacitors, inductors and resistors, Low Noise Amplifier (LNA), power amplifier, Automatic Gain Control (AGC), and Filters. The BFR93A transistors is a Low Noise Amplifier (LNA) used to increase the incoming RF signal from the outside antenna with the introduction of minimal noise while the capacitors along with the inductors are generally employed as filters to ensure optimal power transmission and less signal loss. To enable circuit stability resistors with different resistance values such as 4.7 kΩ, 1 kΩ and 220 Ω were used.

2.3.2 H-Connectors

The "H" shape is employed to hold one side of the main conductor and the other connect a branch line. This is helpful for adding to or changing the pathways of signals in structured cabling or outdoor installations. It is made of conductive metals like copper, which makes sure that the electrical connection is stable with minimal signal loss. A crimping tool is used to install it so that it stays in place. After crimping, the connector is insulated to keep moisture and interference out.

2.3.3 Input and Output Antenna

Antennas are employed for transmitting and receiving of signals. The output antenna is responsible for picking up weak signals from the surrounding area. This signal is then fed into the booster circuit. The coil in the input antenna helps in tuning and impedance matching, ensuring optimal signal capture. It also features tuning elements to prevent loss and preserve signal intensity. Both coils are commonly built as loop kinds. Proper alignment and positioning of these coils are critical for optimal booster effectiveness. Other components selected are Coaxial cable, LED and 5V DC power supply.

2.4 Proposed Prototype Development and Testing

At this stage all hardware components are assembled using the circuit diagram from Portus software as a guide. For easy connection and testing, the components were initially assembled temporarily on breadboard. After, proper functioning the circuit on breadboard was transferred to the Vero board. Figure 4 shows the proposed prototype consisting of 4G signal booster circuit comprising of RF amplifier circuit utilizing BFR93A transistors, ceramic capacitors, inductors and resistors, input and output antenna all housed in an enclosure with a DC power supply. Before assembling, the components were thoroughly tested for proper functionality. The amplifier circuit was placed in between the outdoor and indoor antenna for efficient signal transmission via a low-loss coaxial cable. Field measurement testing was carried out for both GLO and MTN mobile provider.

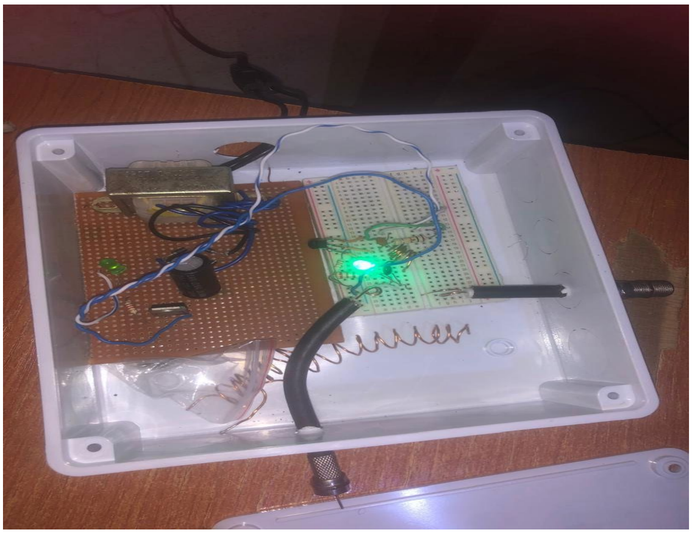

Figure 4: Prototype of 4G radio frequency signal booster system

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3.0 Results and Discussion

The proposed circuit was tested for both GLO and MTN networks at 1800 MHz and 2100 MHz frequency band during two different load period. The performance of the proposed signal booster was evaluated based on measured signal strength before and after boosting at different load period. The signal strength status before and after boosting of different network provider during 11 am and 3 pm load period is depicted in Table 1 and Table 2 respectively.

Table 1: Status of signal strength before and after boosting during the 11 am load period

Network Provider	Frequency	Direction	Initial signal before boosting (dBm)	Obtained signal after boosting (dBm)
GLO	1800 MHz	Downlink	-72.10	-69.82
GLO	2100 MHz	Downlink	-70.94	-68.34
GLO	1800 MHz	Uplink	-70.56	-68.45
GLO	2100 MHz	Uplink	-71.23	-69.16
MTN	1800 MHz	Downlink	-77.12	-73.11
MTN	2100 MHz	Downlink	-71.67	-67.58
MTN	1800 MHz	Uplink	-71.12	-68.74
MTN	2100 MHz	Uplink	-72.45	-69.20

Table 2. Status of signal strength before and after boosting during the 3 pm load period

Network Provider	Frequency	Direction	Initial signal before boosting (dBm)	Obtained signal after boosting (dBm)
GLO	1800 MHz	Downlink	-70.89	-69.82
GLO	2100 MHz	Downlink	-71.45	-68.34
GLO	1800 MHz	Uplink	-67.89	-68.45
GLO	2100 MHz	Uplink	-70.12	-69.16
MTN	1800 MHz	Downlink	-74.78	-73.11
MTN	2100 MHz	Downlink	-70.12	-67.58
MTN	1800 MHz	Uplink	-68.67	-68.74
MTN	2100 MHz	Uplink	-69.89	-69.20

Figure 5 present the comparison chart before and after signal boosting during 11 am load period. The chart shows that, GLO and MTN network provider gave an approximately average gain of 2.27 dBm and 3.43 dBm respectively and an approximate standard deviation of 0.24 dBm and 0.83 dBm respectively. The results demonstrated an enhancement and stable performance in signal strength for both network providers, indicating the efficiency of the developed 4G signal booster.

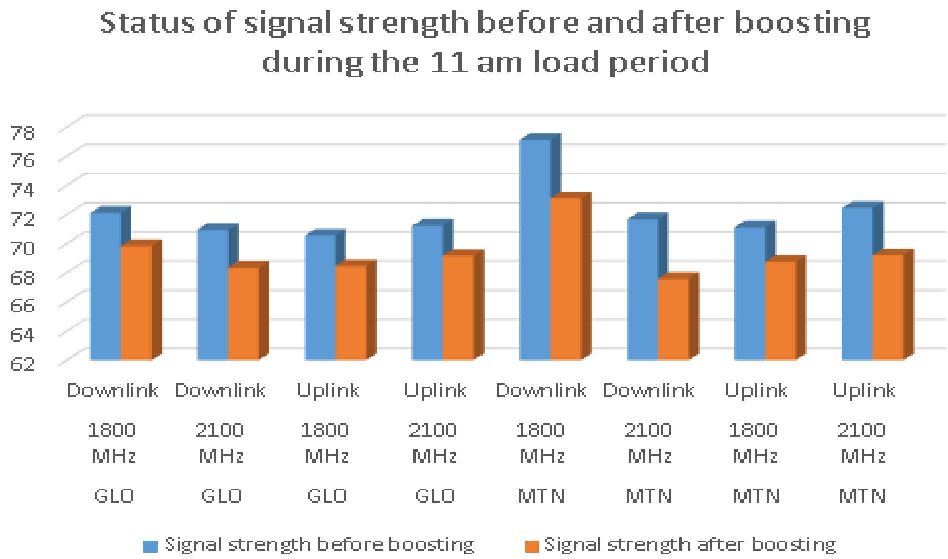

Figure 5: Comparison chart before and after signal boosting during 11 am load period.

Figure 6 present the comparison chart before and after signal boosting during 3 pm load period. The chart shows that, GLO network provider presented an approximate average gain of 1.15 dBm and standard deviation of 1.54 dBm while MTN demonstrated improved higher average gain of 1.21 dBm and standard deviation of 1.13 dBm after signal boosting. The results demonstrated high performance instability for both

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network providers thereby limiting the reliability of the system mainly due to uplink signal degradation and instability in the average and standard deviation gains.

Although Figure 5 and 6 illustrate that there was improvement in the downlink signal received during the different load period, however, there was gain fluctuation in the uplink path during 3 pm load period which is due to more network load, noise and interference restricting system performance when the conditions are congested, therefore, optimization of the system is required. The increased traffic pressure on networks means more users will be sharing fewer resources, thereby increasing the interference and decrease SINR. The amplified noise is caused by internal thermal noise produced by BFR93A transistors as a result of the intrinsic charge carrier motion in the device and reduce signal strength due to external interference caused by neighbouring base stations, co-channel users, and other electronic devices that are operating at 1800 MHz and 2100 MHz bands. However, even with this limitation, the developed 4G signal booster improve signal strength especially in the downlink when compared with uplink providing a better user satisfaction in wireless networks.

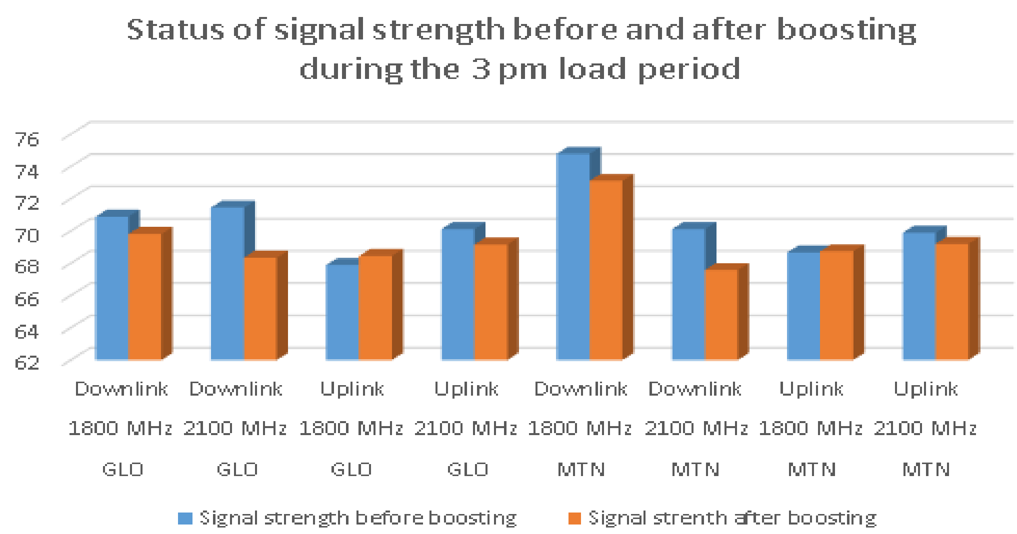

Figure 6: Comparison chart before and after signal boosting during 3 pm load period

4.0 Conclusion

This study focused on the design of a 4G RF signal booster prototype aimed at improving network coverage in indoor environments. The work first collected the initial signal strength for GLO and MTN network provider at 1800 MHz and 2100 MHz bands. A 4G signal booster circuit was design and developed, consisting of RF amplifier circuit utilizing BFR93A transistors, ceramic capacitors, inductors and resistors, input and output antenna all housed in an enclosure with a DC power supply. The developed prototype was tested and the receive signal strength data collected. The data obtained before and after construction was compared. The results show that, the developed 4G signal booster appears to have a strong potential in enhancing wireless signal power, especially in the downlink and low signal conditions. There is improved in downlink signal strength because the base station is the source of the signals and the weak downlink signals received at the booster input are relatively stable and can be successfully amplified to enhance the office coverage. Conversely, uplink is a transmission made by mobile devices which are necessarily power-constrained by battery and regulatory constraints. The signal sent to the booster by the user equipment is therefore usually much feeble and prone to noise and interference. As the booster increases the uplink signal, it also increases noise which may reduce the quality of the effective signal at the base station receiver. Nonetheless, better calibration of the system and optimization of uplink gain are necessary to achieve the same high-level of reliable performance under various conditions of operation.

However, in future, 4G signal booster circuit that supports the integration of both current 4G and the newly deployed 5G frequency band could be designed and implemented. In addition, an adaptive power control and gain control could also be employed to improve the performance of the signal booster under varying load and environmental conditions. Furthermore, the work can be extended to larger areas thereby improve broadband accessible in underserved regions.

Received: 31-03-2026 / Accepted: 05-04-2026 / Published: 18-05-2026

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