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Optimizing 4G LTE radio coverage areas with an outdoor extender booster

Optimisation des zones de couverture radio 4G LTE avec un booster d'extension extérieur

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Abstract

Nowadays with the multitude of networked mobile services, networked communications have become indispensable, wherever the cell phone is located （Dcs，2013）. However, in some areas, phone calls and internet services are poor and sometimes unavailable, especially for 4G LTE services. In practice, 4G LTE service is not yet stable in DR Congo, and some areas do not reach the 4G LTE signal. This is because the 4G signal is easily attenuated by surrounding conditions, such as the presence of tall buildings, trees and so on. To solve this problem, we have proposed a solution, to have a 4G Outdoor extension antenna that operates on the 825 MHz - 875 MHz frequency bands, with a good reflectance to provide additional 4G LTE signal coverage. The basis of this study is to increase the coverage of areas that do not receive the 4G LTE signal, and areas with very poor 4G radio conditions located at a great distance from the 4G base station to such an extent that every cell phone can receive signals without having any disturbance.

Keywords : 4G; LTE; Extender Outdoor; Radio coverage; Extension antenna

Résumé

Aujourd'hui, avec la multitude de services mobiles en réseau, les communications en réseau sont devenues indispensables, quel que soit l'endroit où se trouve le téléphone portable. （Dcs，2013） Toutefois, dans certaines régions, les appels téléphoniques et les services internet sont médiocres et parfois indisponibles, en particulier pour les services 4G LTE. Dans la pratique, le service 4G LTE n'est pas encore stable en RD Congo, et certaines zones n'atteignent pas le signal 4G LTE. Cela est dû au fait que le signal 4G est facilement atténué par les conditions environnantes, telles que la présence de bâtiments élevés, d'arbres, etc. Pour résoudre ce problème, nous avons proposé une solution, d'avoir une antenne d'extension 4G Outdoor qui fonctionne sur les bandes de fréquences 825 MHz - 875 MHz, avec un bon facteur de réflexion pour fournir une couverture supplémentaire du signal 4G LTE. La base de cette étude consiste à augmenter la couverture des zones qui ne reçoivent pas le signal 4G LTE, et les zones avec de très mauvaises conditions radio 4G situées à une grande distance de la station de base 4G, à tel point que chaque téléphone mobile peut recevoir des signaux sans avoir aucune perturbation.

Mots clés : 4G ; LTE ; Extender Outdoor ; Couverture radio ; Antenne d'extension

Introduction

In an increasingly connected world, where mobile communication has become an essential pillar of our daily lives, improving 4G radio coverage is of crucial importance （Ali，2006）. Connectivity challenges, such as underserved areas or weak signals, not only hamper productivity and quality of service, but also limit access to information and opportunities for many communities. To remedy these problems, the use of outdoor antennas represents a promising solution （Conception，2011）. These devices, designed for outdoor installation, offer a range of benefits in terms of extending coverage, improving signal quality and boosting connectivity in areas where it is lacking （Z. Zhang，2016）. This study looks at the various facets of improving 4G radio coverage using outdoor antennas, exploring their functionality, effective deployment and impact on mobile connectivity.

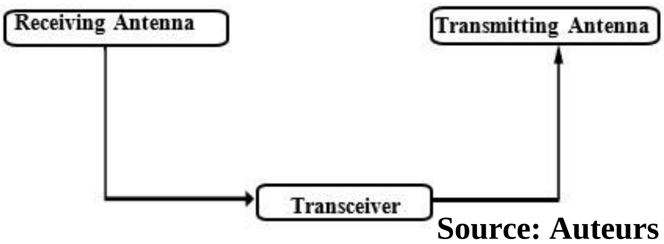
Improving 4G radio coverage represents a crucial challenge in today's telecommunications DRC zones （Abdelghani，2017）. Despite significant progress in the deployment of 4G networks, gaps persist, particularly in rural areas, densely populated areas or high-density buildings （Dioum，2014）. This issue raises several key questions: what are the main causes of gaps in 4G coverage? What technical, economic and regulatory challenges need to be overcome to improve coverage? What are the advantages and limitations of the various technical solutions available, such as the use of outdoor antennas, small cells, repeaters, or other emerging technologies? How can we guarantee an equitable approach to improving coverage, ensuring that all populations, whatever their geographical location or socio-economic status, can benefit from reliable, high-performance mobile connectivity? By addressing these questions, this issue seeks to explore ways of overcoming obstacles and developing effective strategies for extending 4G radio coverage, to meet the growing need for connectivity in our increasingly connected society.

This article studies an outdoor 4G network amplification system. For this purpose, we will analyze the existing 4G coverage of three sample areas in Lubumbashi city: Katuba, Annexe, Lupoto with the four telecom operators in DRC: Airtel, Orange, Africell and Vodacom in order to identify the gaps. Based on the quality of the signal collected, we designed a system consisting of a receiving antenna, which collects a very weak signal, pre-amplifies it and sends it to the transceiver, which constitutes the second stage of signal amplification. The final stage is the power amplifier, which transmits the signal to end users without interference. This system is intelligent in that it can detect the optimum position at which the maximum signal strength from the operator's base station can be collected, and we've linked it to a mobile application for continuous remote monitoring.

In the rest of this article, we'll start by introducing the outdoor cellular signal amplifier, which is essential for boosting signal reception. Next, we'll present the components and links of a 4G base station. We'll then describe the equipment used and the methods employed to improve outdoor 4G radio coverage. We will then present the results obtained through our tests and analyses. Finally, based on these results, we will draw conclusions as to the effectiveness of this approach for improving 4G connectivity with an outdoor antenna.

1. Outdoor cellular extender signal booster

Figure 1 Outdoor cellular extender signal booster bloc schema



Source: Auteurs

An Outdoor-extender booster has some parameters which are the basics parameters for all antenna designing, those parameters, as shown below, influence the performance and the price of the antenna system （al.，2018）.

- Coverage range: depends on the power and gain of the transmitter, as well as the directionality. The coverage range can be limited to small spaces, medium spaces and large spaces
- Type of duplexing: the signal boosters can be FullDuplex (FD) or Half-Duplex (HD). FD Boosters can strengthen both uplink and downlink while HD boosters can only boost the uplink or downlink.
- Deployment of the antenna: Both the donor/receiving and transmitter antennas can be co-located on a single antenna or separated. The shared co-located antenna systems are compact and quick to install, but they are meticulously engineered to manage self-interference difficulties. Separate antenna systems are becoming increasingly popular, and usually have a directional donor antenna, mounted in the line of sight of the serving base transceiver station (BTS) and an isotropic transmitting antenna in the area of the users.

- Number of channels: There are single-channel cellular signal boosters that can only support one user at time, as well as multi-channel cellular signal boosters that can support many users at once.
- Functionality: Cellular signal boosters can operate at layer-1 and merely amplify-and-forward signals, while others are layer-2 devices that can decode-and-forward and compress-and-forward signals. Layer-1 repeaters are simple in design, but they can propagate noise in the system, whereas layer-2 repeaters are sophisticated and likely to contribute greater latency,

However, the signal can only be isolated and amplified （Abdelghani，2017）.

- Spatial stream: Single-input single-output cellular signal boosters have one donating antenna and one transmitting antenna, while multi-input multi-output cellular single boosters include many antennas on both ends.
- A wide variety of boosters are available on the market, table 1 shows some examples of boosters, their manufacturers, specifications, and prices.

Table 1 : Common ETSI Specifications for Repeaters

Name of the Booster	Description	Price
weBoost Connect 4G	Perfect for mid-sized homes. Boosts cell signals up to 32x. Enhances 4G LTE and 3G signals for buildings up to 5,000 sq ft. Get fewer dropped calls, better voice quality, faster uploads and downloads.	***$ 549.99***
SureCall EZ 4G	Sets up in minutes - simple plug-and-play install. Boosts voice, text and 4G LTE signals for Reduces dropped & missed calls and supports multiple users simultaneously. Coverage area will vary based on existing signal at the window location	**$399.99**
Phonelex Cell Phone Signal Repeater Booster	Designed for band 13 Verizon 700 MHz 4G LTE 70 dB cellular band, Much faster high-speed 4G LTE internet. Perfect for fast uploads and downloads for streaming apps such as Google Chrome, Safari, YouTube, Netflix, Pandora, Spotify, and other data-heavy apps.	**$159.99**

ANNTL ENT GSM 850 MHz 3G	Frequency Range (MHz): 824-849; 869-894 Max Gain (dB): 65; Max output power (dBm): 15dBm; I /O Port: SMA-Female; Power Supply: input AC100~240V 50/60Hz, output DC 5V 0.35A	**$169.90**
Phone tone GSM 3G 850MHz	Frequency range: 824 ~ 849 MHz, 869 ~ 894 MHz Max Output Power: 22 dBm / Max Gain: 62 dB; I/O Port: N-Female on both ends FCC authentication certificated Verizon /T-Mobile.	**$299.90**
Lintratek	Lintratek is the best triband mobile signal booster available in Nigeria. It is compatible for improving voice calls, sms delivery and data speeds of all major Nigeria networks such as MTN, GLO, AIRTEL and 9MOBILE.	**$205.88**
Wilson Pro Plus	Wilson Pro 70 Plus is one of most popular, professional grade signal booster kits for large homes, offices and buildings., the Wilson Pro 70 Plus is able to receive a much stronger outside signal (+12 dBm) without overloading the amplifier, and then turn that strong signal into significantly more inside coverage (up to 20,000 sq. ft.)	**$1,199.99**
Cel-Fi GO X	The Cel-Fi GO X System is our top recommended signal booster for homes, offices, and other buildings where the existing outside signal is 2 bars or less. The GO X is a single carrier system, which allows the GO X to have up to 100 dB of gain Instead of being limited to only 70 dB of gain for multi-carrier systems.	**$999.99**

Source : https://www.amazon.fr/

1.1. From a performance point of view:

These boosters have performance characteristics that allow them to work in some low cell signal environments, but they cannot work when the signal is significantly weakened.

1.2. From a price point of view depending on the profitability of the environment where the network will be deployed:

Given their low price, these boosters can be installed in less profitable environments, without incurring much expense.

1.3. Limitations of existing cellular signal boosters

The Boosters, in table 1, are cheaper and can be used in less profitable environments, but have a limitation in the performance of the receiving antenna, as long as there is a signal available, not less than the sensitivity of the receiving antenna, However, in a situation where the signal is in deep decline, so that no signal is received by the outdoor antenna, the booster will not give a boost （P. Kavipriya， 2020）, hence the receiving antenna is the subject of this article.

2. The 4G Base Station (eNodeB)

Nowadays the most used equipment manufacturer in the Democratic Republic of Congo is HUAWEI. The 4G base station (eNodeB) from the manufacturer HUAWEI has the following specifications and prices:

Table 2 4G base station equipments price

Name of materiel	Quantity	Manufacturer	Price
BBU	1	HUAWEI	$3 000,00
RRU5909	3	HUAWEI	$1,500.00
Antennas LTE	3	HUAWEI	$450.00
Antennas Microwave	1	HUAWEI	$500.00
Total			**$5,450.00**

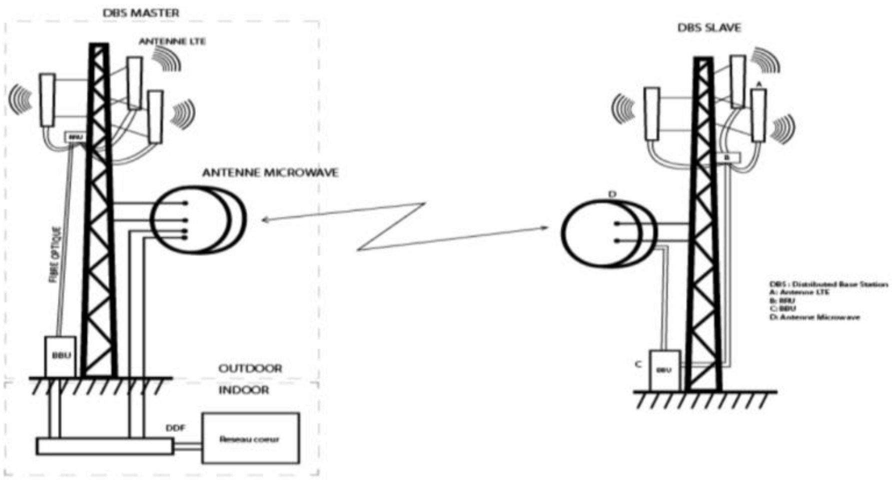
Source : https://www.alibaba.com/

Considering the price of monthly rental of masts or towers, as well as other expenses incurred monthly, this further increases the cost of 4G base station.

2.1. From a performance point of view:

The 4G base station hardware (BBU+RRU+LTE antennas + microwave antenna) is designed to work best in very weak cellular signal environments because the telecom operator can install a 4G base station in a very weak cellular signal environment such as very remote areas, and then link this 4G base station to the core network (EPC) through a terrestrial or satellite link.

Figure 2 eNodeB Link



Source: Internet

2.2. From the point of view of the price of the 4G base station in relation to the profitability of the area where the network will be deployed:

Figure 3 Mobile application IHM

The price of a 4G base station including the monthly rental of the tower where the 4G equipment (BBU+RRU+LTE antennas + microwave antenna) will be erected is expensive in relation to the monthly income of the area （al.， 2018）.

Source: Auteurs

2.3. 4G base station limitations

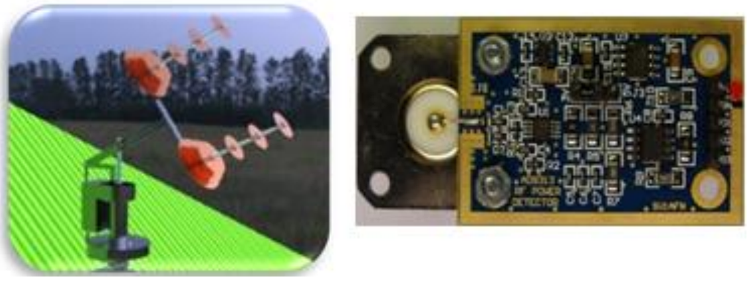
4G base station equipment has the performance to work best in very weak cellular signal environments but has a limit in terms of the cost of purchasing 4G equipment and monthly tower rental, so installing a 4G base station in a less profitable environment can result in monthly losses for the telecom operator, so cellular network signal booster stations in less profitable environments are a better cost solution for telecom operators （al.， 2018）.

3. Materials and methods

We have designed, simulated and implemented the 4G Outdoor-extender Booster, according the experience done, the materials used for the result are mentioned and explained in the following.

The antenna on Figure 2, whose main characteristics are directivity and spatial diversity, picks up the mobile network signal in areas far away from the 4G base station, strengthens it and then sends it to the 4G band pass filter and a demodulator.

Figure 4 Antenna elements and RF Probe



Source : https://www.5gtechnologyworld.com/rf-coaxial-probes-and-probe-positioner-armed-with-unique-qualities/

Directivity concentrates the radiation energy in one direction, increases the gain of the antenna and pushes the radiation pattern far, the antenna is designed with reflecting, radiating and directing elements, and spatial diversity aggregates the carriers of antennas to increase the gain and bandwidth. （Yong Soo Cho, 2010）

The impedance at the antenna feed point is 50 ohms, the standing wave ratio is ≤ 1.5, the sensitivity is - 128 dBm, the polarization is circular, the frequency band is 850 MHz (telecom operators in DRC use this frequency band for 4G), the horizontal aperture angle is 450, vertical aperture is 450, the transmit power is 18 dBm and 90 dBi of Gain. （Uit-r, 2012）

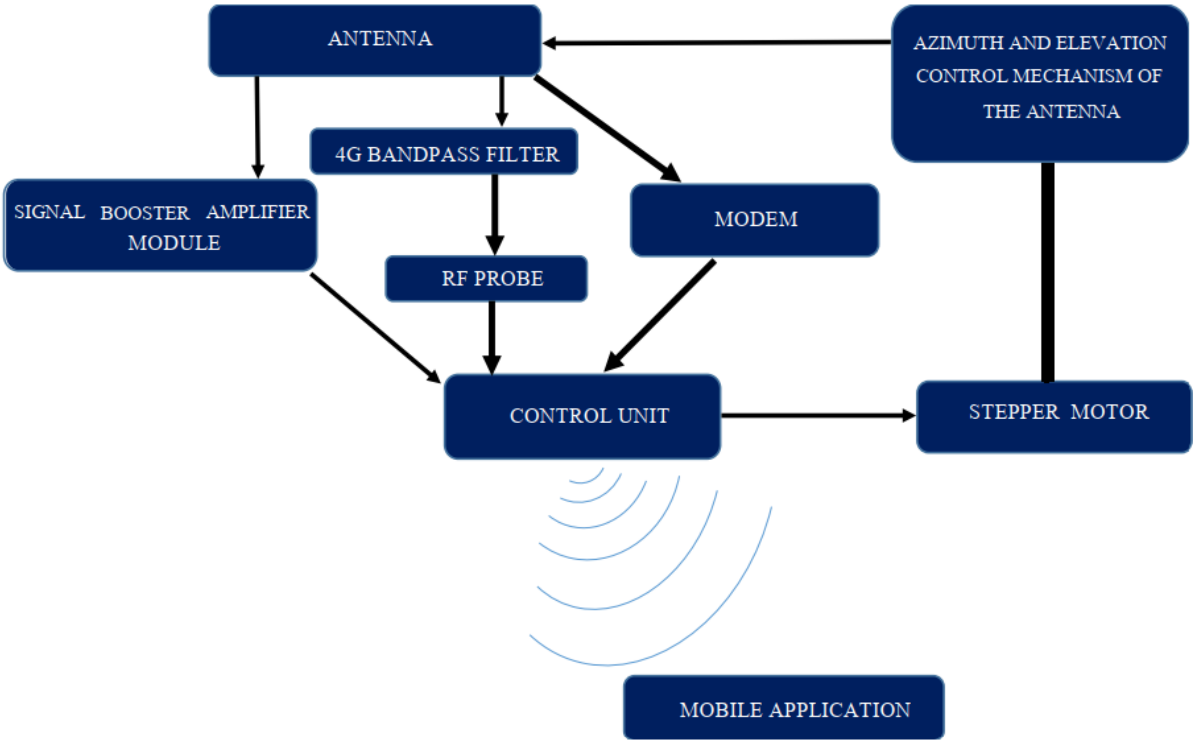
The 4G band pass filter sends the signal to the RF probe on Figure 4, based on the AD8313ARM circuit from Analog Devices, it is a complete RF Figure 3: mobile application power measurement head for a 50Ω system working from 100 to 2500MHz （1994）. It receives the radio signal at the input and outputs a voltage proportional to the signal strength on the other side, the voltage at the output of the probe will be evaluated by the control unit which is the Raspberry Pi 3 A+.

Through an API connection between the 4G modem and the memory and locates the position where the signal quality the control unit, the modem sends signal quality information to the and strength are simultaneously better, then reposition the control unit.

Via an impulse given from a mobile application on Figure 4, the control unit controls the 12V stepper motor with 67.54 °/s rotation speed, the motor drives the mechanical system (on Figure 8) which moves the antenna in elevation and azimuth.

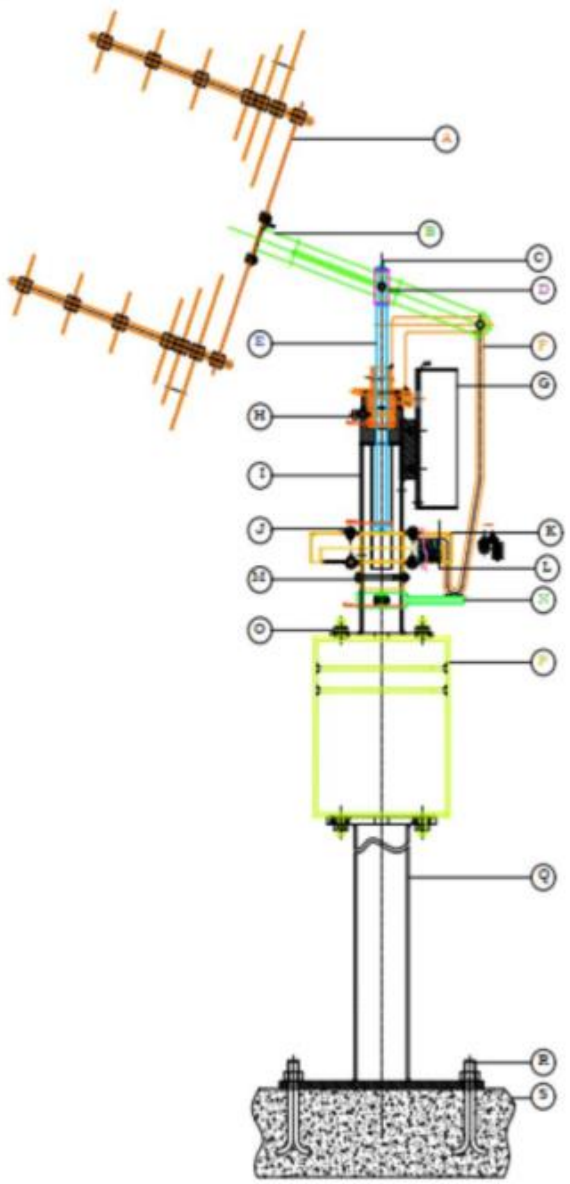
Antenna to this position. After this phase of searching for the position of the best quality signal, the antenna sends the 4G signal to the amplifier module which is on Figure 6, of 65dB of gain and 23 dBm of transmission power, this one amplifies the signal and propagates it in an area of a given size to such an extent that all the phones in the area can receive the signal without Depending on the mobile radio determination services, the having any disturbance.

Figure 5 amplifier module



While the antenna is rotating, through a computer program embedded in the control unit, the control unit records information about the signal strength and quality, and at the end of the antenna stroke, the control unit scans.

4. Results



Benchmark	*Designation*
A	Antennas elements
B	Articulated arm to support the antennas
C	Pin
D	Rotational guide ring for the antenna support arm
E	Elevation guide screw for antennas
F	Antenna azimuth guidance system
G	Motor housing
H	Azimuth guidance system translation locking screw
I	Machine frames
J	Assembly bolt M6
K	Brush mechanism protection system
L	Spring housing part
M	Assembly bolt M6
N	Rotational guide collar of the antenna azimuth guidance system
O	Stud M10
P	On-board antenna component package
Q	Machine stand or foot
R	M16 anchor bolt
S	Wall or concrete embedding

The result is based on the runs we made in areas with poor and less good radio conditions, which are located at a given distance from the 4G base station.

Four runs were made in four environments: 7.10 km from the 4G base station, 9.01 km, 12.60 km and 14.04 Km.

- 7.10 km: commune of Katuba 3, is a commune with a poor 4G radio condition.
- 9.01 km: the Annex commune of Lubumbashi, is a commune with poor 4G radio conditions, sometime the 4G radio conditions are less than a mobile phone sensibility as shown for some telecom operator in table 4,6, 8 and 10.

- 12.06 km (village of Lupoto) and 14.04 Km (village of Mimbulu), those villages both have almost the some 4G radio conditions, a very poor 4G radio conditions, sometime the 4G radio conditions are less than a mobile phone sensibility as shown for some telecom operator in table 4,6, 8 and 10.

We have 2 algorithms which locate the position of best signal strength in the area:

- The first algorithm is one where, when the signal quality is degraded, the search is initiated by the user with a pulse from a wireless mobile application. (Assisted mode)
- The second algorithm is one where, when the signal quality is degraded, the search is started automatically without the user's intervention by an impulse from a wireless mobile application. (Unassisted mode)

4.1. Seated mode :

The user initiates the signal search through a mobile application that sends a wireless command to the microcontroller. The microcontroller receives the command and checks the stored time value.

If the value of the stored time is 0: **runSearchSignal()**

Otherwise (T different from 0): the microcontroller controls relay 2 for the time **t**

launchSearchSignal()

launchSearchSignal()

The microcontroller controls relay 1 for a period T,

Every millisecond it retrieves the value at the analogue input and the corresponding time **t**

It then compares the first analogue value with the second, retaining the larger value between the two and its corresponding time, and so on with the third, fourth, fifth and so on. At the end of the stroke (stroke for time T), the microcontroller controls relay 2 for a period T-t.

With:

- **T**: total time needed to control the antenna during the total stroke i.e. from low to high point,
- **t**: time stored in the memory,

Relay 1: Operates the motor in the up direction,
relay 2: operates the motor in the downward direction.

4.2. Non-assisted mode:

Here the microcontroller is not assisted by the user, it starts the search itself. The microcontroller listens to the value at the analogue input every millisecond and compares the value at the analogue input with a predefined threshold.

If the value at the analogue input is below the threshold, (the microcontroller starts the process of searching for the best quality signal): The microcontroller checks the value of the stored time.

If the value of the stored time is 0: **runSearchSignal()**
Otherwise (T different from 0) : the microcontroller controls relay 2 for the time **t**
launchSearchSignal()
launchSearchSignal()
The microcontroller controls relay 1 for a period T,
Every millisecond it retrieves the value at the analogue input and the corresponding time **t**
It then compares the first analogue value with the second, retaining the larger value between the two and its corresponding time, and so on with the third, fourth, fifth and so on.
At the end of the stroke (stroke for time T), the microcontroller controls relay 2 for a period T-t.

4.2.1. Test carried out in the commune of Katuba 3 (Lubumbashi- Democratic Republic of Congo)

This test was carried out at the same location of the attempt that led to our study, precisely at 7.10 km from the 4G base station.

- **A screenshot of Google Earth software:** which measures and shows the distance.

Figure 6 Google Earth

- **A test the phone's connectivity to the 4G network**

At reception we measured the signal level with the RHODE & SCHWARTZ spectrum analyzer and a smartphone, the smartphone shows the signal level it has received by entering the options in the **Settings** application**:** "**Settings - System - About Phone - Status - SIM Card Status.’’**

Table 3 results of the descent

	AIRTEL	ORANGE	AFRICELL	VODACOM
Before installing 4G Outdoor extender	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Celtel Intensité du signal -107 dBm 3 asu Type de réseau mobile EDGE État du service Service en cours	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Orange Intensité du signal -102 dBm 8 asu Type de réseau mobile HSPA État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Vodacom Intensité du signal -99 dBm 7 asu Type de réseau mobile GPRS État du service Service en cours

After installing 4G Outdoor extender

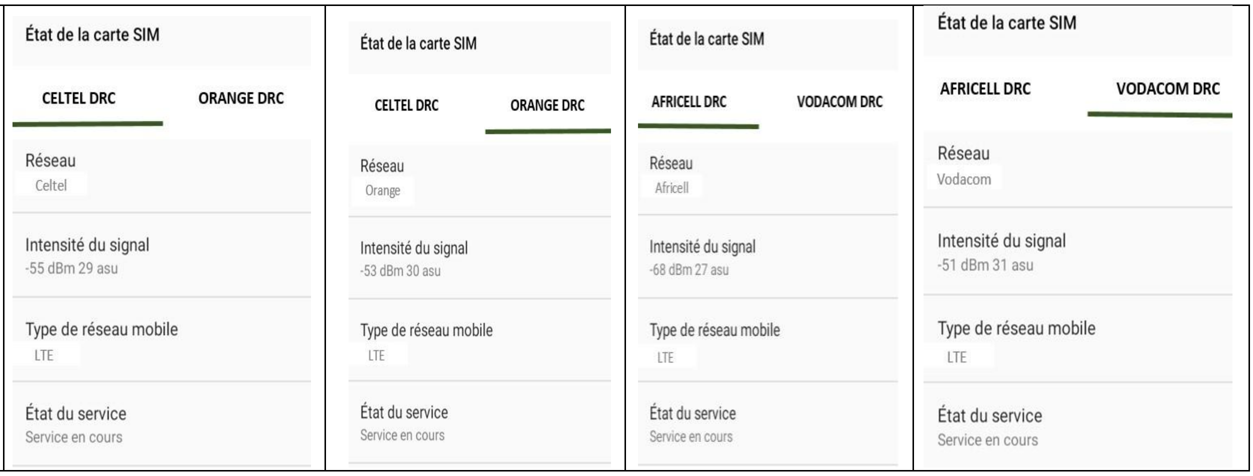


Table 4 Results of the descent

	Airtel	Orange	Africell	Vodacom
Before installing 4G Outdoor-extender booster	-107dBm	-102dBm	0mW	-99dBm
After installing 4G Outdoor extender booster	-55dBm	-53dBm	-68dBm	-51dBm

On reception of the 4G signal booster antenna the amplitude measured at the central frequency of the 4G band is - 60 dBm.

4.2.2. Test conducted in the Annex commune (Lubumbashi- Democratic Republic of Congo)

This test was carried out at a distance of 9.01 km between the 4G base station and the Outdoor-extender booster station.

❖ **A screenshot of Google Earth software**

Figure 7 Google Earth

❖ **Test the phone's connectivity to the 4G network**

At reception we measured the signal level with the RHODE & SCHWARTZ spectrum analyzer and a smartphone, the smartphone shows the signal level it has received by entering the options in the Settings application**:** "**Settings - System - About Phone - Status - SIM Card Status".**

Table 5 results of the descent

	AIRTEL	ORANGE	AFRICELL	VODACOM
Before installing 4G Outdoor extender	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Orange Intensité du signal -105 dBm 4 asu Type de réseau mobile GPRS État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Vodacom Intensité du signal -101 dBm 6 asu Type de réseau mobile EDGE État du service Service en cours
After installing 4G Outdoor extender	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Celtel Intensité du signal -61 dBm 26 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Orange Intensité du signal -55 dBm 29 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Africell Intensité du signal -75 dBm 14 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Vodacom Intensité du signal -59 dBm 27 asu Type de réseau mobile LTE État du service Service en cours

Table 6 results of the descent.

	Airtel	Orange	Africell	Vodacom
Before installing 4G Outdoorextender antenna	0 mW	-105dBm	0 mW	-101dBm
After installing 4G Outdoorextender antenna	-61dBm	-55dBm	-75dBm	-59dBm

On reception of the 4G Outdoor-extender the amplitude measured at the central frequency of the 4G band is -65 dBm.

4.2.3. Test carried out in the village of Lupoto (Lubumbashi- Democratic Republic of Congo)

This test was carried out at a distance of 12.06 km between the 4G base station and the booster network station.

❖ **screenshot of Google Earth software**:

which measures and shows the distance

Table 7 Google Earth

❖ **Test the phone's connectivity to the 4G network**

At the reception we took a signal level reading with a RHODE & SCHWARTZ spectrum analyzer and a smartphone, the smartphone shows the signal level it has received by entering the options in the Settings application: "**Settings - System – About Phone - Status - SIM Card Status**"

Table 8 results of the descent

	Airtel	Orange	Africell	Vodacom
Before installing 4G Outdoorextender	0 mW	0 mW	0 mW	0 mW
After installing 4G Outdoorextender	-68dBm	-64dBm	-83dBm	-65dBm

On reception of the 4G Outdoor-extender booster the amplitude measured at the central frequency of the 4G band is - 73 dBm

	AIRTEL	ORANGE	AFRICELL	VODACOM
Before installing 4G Outdoor extender	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Inconnu Intensité du signal 0 Type de réseau mobile Inconnu État du service Hors-service
After installing 4G Outdoor extender	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Celtel Intensité du signal -68 dBm 27 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM CELTEL DRC ORANGE DRC Réseau Orange Intensité du signal -64 dBm 29 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Africell Intensité du signal -83 dBm 14 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC VODACOM DRC Réseau Vodacom Intensité du signal -65 dBm 24 asu Type de réseau mobile LTE État du service Service en cours

4.2.4. Test carried out in the village Mimbulu (LubumbashiDemocratic Republic of Congo)

This test was carried out at a distance of 14.04 km between the 4G base station and the Outdoor-extender booster.

- **Screenshot of Google Earth**

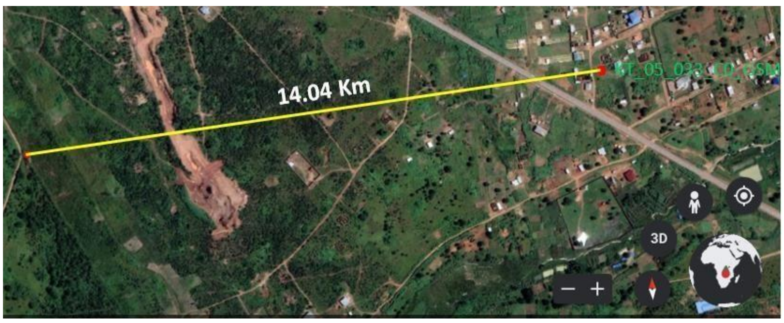


Figure 8 Google Earth

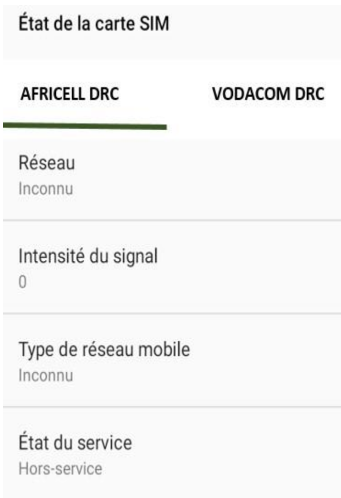
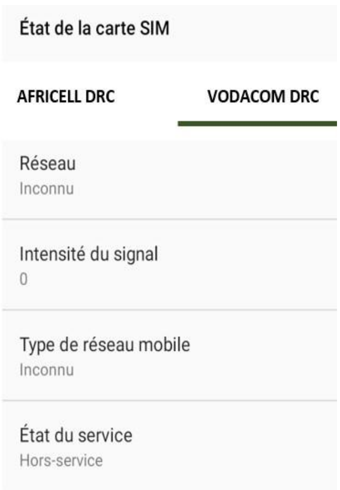
❖ Software test the phone's connectivity to the 4G network

At the reception we took a signal level reading with a RHODE & SCHWARTZ spectrum analyzer and a smartphone, the smartphone shows the signal level it has received by entering the options in the **Settings** application**: "Settings - System – About Phone - Status - SIM Card Status".**

Table 9 results of the descent

	Airtel	Orange	Africell	Vodacom
Before installing 4G Outdoorextender	0 mW	0 mW	0 mW	0 mW
After installing 4G Outdoorextender	-76dBm	-72dBm	-93dBm	-70dBm

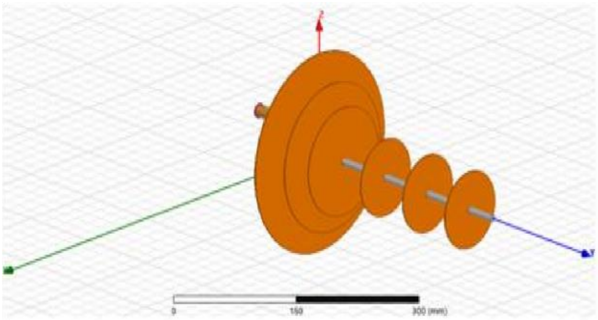
On reception of the 4G Outdoor-extender the amplitude measured at the central frequency of the 4G band is - 78 dBm.

	AIRTEL	ORANGE	AFRICELL	VODACOM
Before installing 4G Outdoor extender				

After installing 4G Outdoor extender	État de la carte SIM CELTEL DRC · ORANGE DRC Réseau Celtel Intensité du signal -76 dBm 14 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM CELTEL DRC · ORANGE DRC Réseau Orange Intensité du signal -72 dBm 26 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC · VODACOM DRC Réseau Africell Intensité du signal -93 dBm 11 asu Type de réseau mobile LTE État du service Service en cours	État de la carte SIM AFRICELL DRC · VODACOM DRC Réseau Vodacom Intensité du signal -70 dBm 26 asu Type de réseau mobile LTE État du service Service en cours

5. Outdoor extender Booster antenna sizing

The elements of the 4G LTE antenna have a shape based on the polarization of the 4G waves.



A reflector element of 215 mm diameter.

- A radiating element: the radiating element is dimensioned based on the frequency of 850 MHZ, and its diameter is half the wavelength (176 mm).
- 4 steering elements: with diameters of 79 mm and 72 mm.

Figure 9 Antenna

These Four Directional Elements have the goal to concentrate the radiation energy more in one direction to increase the gain of the antenna.

5.1. Geometrical, electrical and radiative characteristics of the outdoor extender booster antenna

1. Impedance at the feed point of antenna: 50 ohms
2. Standing wave ratio: ≤ 1.5
3. Sensitivity: - 128 dBm
4. Polarization: circular
5. Frequency band: 825 MHz – 875 MHz
6. Opening angle: horizontal opening = 60^0, vertical opening = 60^0
7. Emission power: 18 dBm
8. Gain: 45 dBi, Diversity gain: Gd = Gain × number of antenna, Gd = 45 dBi × 2, Gd = 90 dBi,
9. Radiation diagram

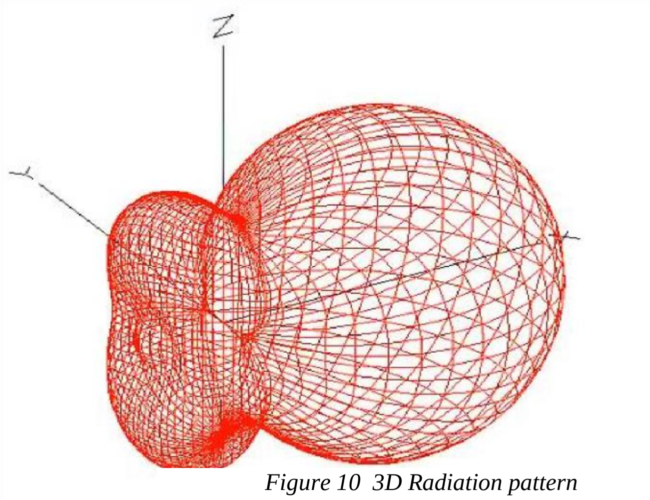


Figure 10 3D Radiation pattern

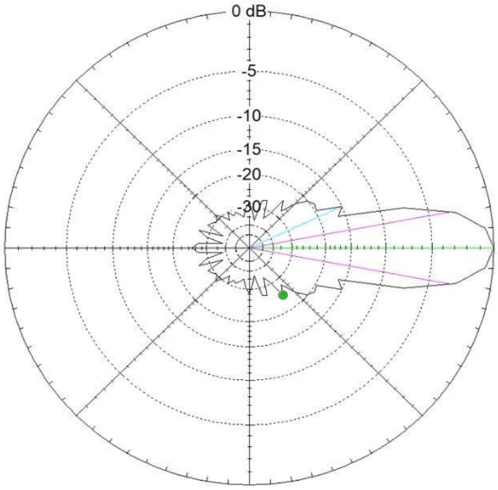
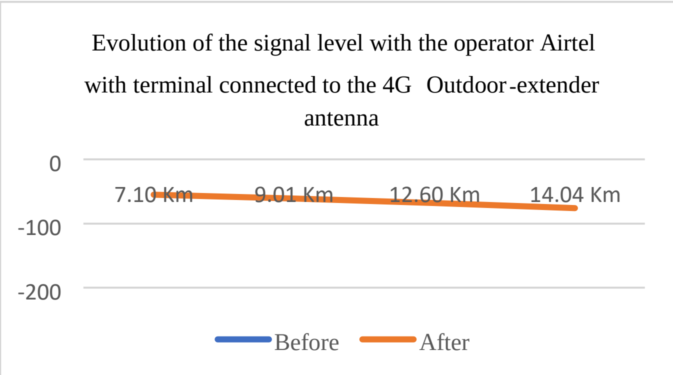
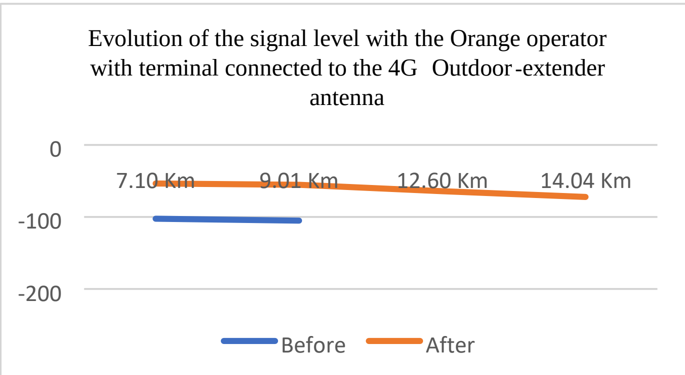


Figure 11 2D Horizontal radiation pattern

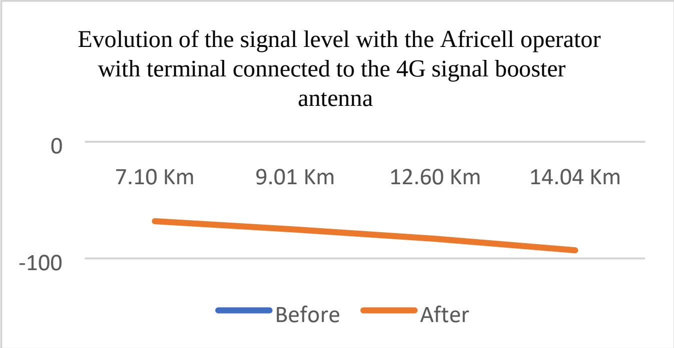
5.2. Distance-Signal intensity diagram



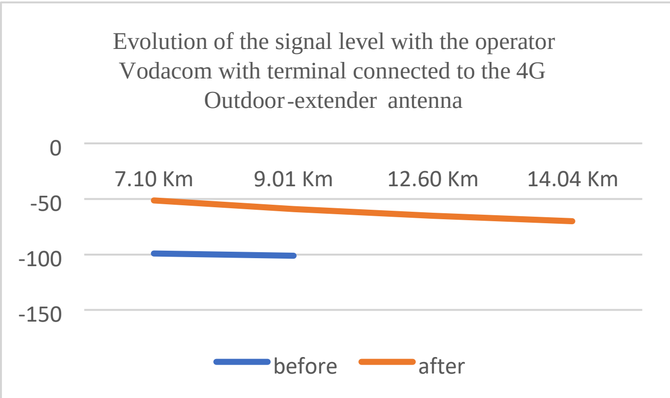
The mobile phone did not pick up the network signal to the 4 runs before switching-on the 4G Outdoor-extender antenna.



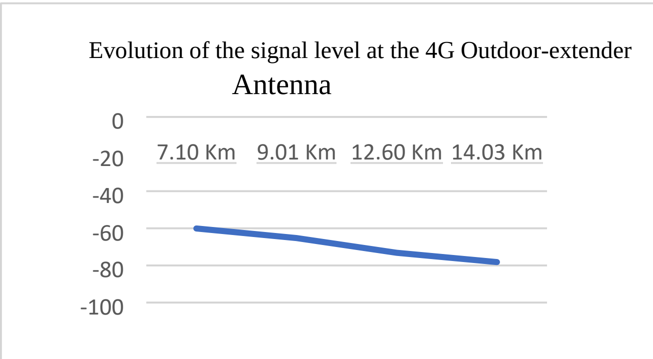
The mobile phone did not pick up the network signal to the 2 last runs before switching-on the 4G Outdoor-extender antenna.



The mobile phone did not pick up the network signal to the 4 runs before switching-on the 4G Outdoor-extender antenna.



The mobile phone did not pick up the network signal to the 2 last runs before switching-on the 4G Outdoor-extender antenna.

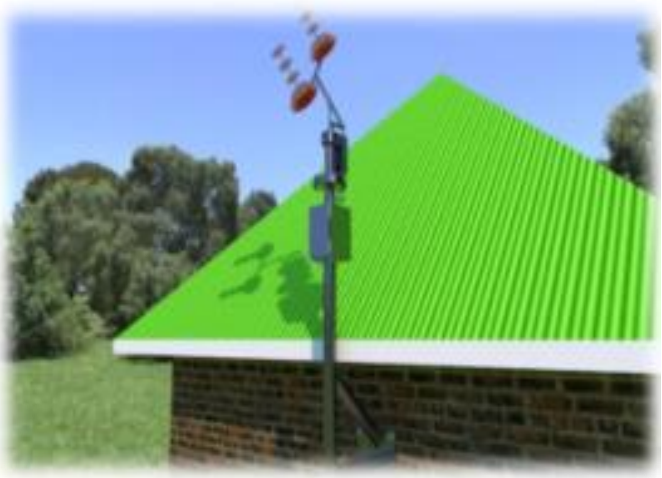


Each time you move away from 2.5 Km from the 4G base station, at the output of the 4G outdoor-extender antenna the signal decreases linearly.

Conclusion

The 4G Outdoor extender network booster is a network station which help to increase coverage areas that were not getting 4G LTE signal, it has a directional antenna whose the localization of the direction of the best 4G signal is not manual, that direction is found through a mechanical system driven by a stepper motor to control the antenna in elevation and azimuth via an algorithm in microcontroller.

Figure 12 Fixing the antenna



With improved radiative, geometric and electrical properties, the present research allows to pick up the 4G signal in the worst radio conditions, given its low price it is suitable for environments less profitable for mobile operators.

The experience during the different runs (shown in the 4 graphics) shows that the place where the mobile phone did not pick up the network signal before, after switching-on the 4G Outdoor extender antenna, the mobile phone did pick up the network signal.

A 4G Outdoor extender antenna is designed and experimentally tested. The motivation of this work was to detect a weak signal from different mobile network operators in areas far from the 4G base station, amplify it, then transmit it via a transceiver module. The smart embedded part of the system determines the optimal direction at which the maximum signal power from the operator base station could be collected. The 4G Outdoor extender network booster system was characterized in terms of signal sensitivity, distance span and gain after field testing, -128 dBm, 12.06 km and 90 dBi were successfully demonstrated for the antenna, respectively: sensitivity, distance between the 4G Outdoor extender booster and the operator base station and antenna gain.

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