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RESEARCH ARTICLE

IMPLEMENTING AND TESTING OF A MOBILE JAMMER AT ESATIC

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Abstract

The GSM, DCS, UMTS and LTE systems which constitute a very vast telecommunication world remain in continuous evolution with regard to the greatest number of regions and sites coverage in Côte d'Ivoire. All these cell phone systems use radio signal that can be completely interrupted for specific goals. Indeed, at ESATIC, a project has enabled the design and implementation of a simple and inexpensive mobile phone jammer that aims to provide a solution to the cheating problem through cell phones during students' national exams. The Denial of Service (DOS) jamming technique which blocks communications absolutely has been used to implement this device. Here, the jamming principle consists in releasing an important noise at the same frequency as that used by the mobile operator in order to completely block the user signal. In fact, satisfactory jamming of the various mobile signals has been observed by blocking these signals in the jammer action areas. The experiment was carried out on the 2G, 3G and 4G networks operated by the three main national operators: ETISALAT, MTN and ORANGE. However, the general recommendation of this project is to use higher capacity power amplifiers to achieve the effective range of 50 meters, especially for DCS 1800, UMTS 2100 and LTE 2600 systems.

Introduction:-

Today, cell phone jamming devices or software are becoming civilian products rather than devices designed for electronic warfare. They were developed and used initially by the military for the radio communications control during electronic warfare. Each side had an interest in stopping communications from the enemy side by adopting the signal jamming technique. However, the jamming devices development situation in the civil domain is due to the mobile phone users increasing number. Therefore, the need to disconnect mobile phones in some specific places where the cell phone ringing would be disruptive has increased. These places generally include places of worship, conference rooms, libraries, cinemas, meeting rooms or other places where silence is strongly recommended. Moreover, a mobile phone jammer is a device that transmits signal or noise at the same frequency and at the same power as those of the radio system to be jammed. Jamming succeeds when mobile phones stop receiving and transmitting signals. Paper [1] mainly reviews mobile phone jammer technologies and suggests improvement to existing design. This paper also presents possible approaches for smart design of jammers. In addition, it highlights a design allowing low energy consumption and taking into account health and cost issues. In fact, the present paper main objective is to define a project of a mobile jammer design and implementation at ESATIC, an Information and

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Communication Technologies (ICT) college in Côte d'Ivoire. The project will obviously rely on the existing technologies to design and implement a simple and inexpensive jammer. It is conducted with a view of providing an adequate solution to the cheating problem through mobile phones in the country. These cheating acts are the proof of the mobile phone wrong utilization and they have taken now a very significant proportion and disrupt the smooth running of state examination.

The rest of the paper is organized around five sections. The section 2 sets out the aim of this project while section 3 deals with the literary review of similar works. Section 4 focuses on the methodology adopted for the mobile phone jammer implementation. Then, section 5 presents the project results and the underlying discussions, and finally, the paper conclusion is given in section 6.

Project motivations:

It is important to be able to call anyone, at anytime and anywhere in the world. However, restaurants, cinemas, malls, hospitals, banks, libraries and places of worship are all suffering today from the mobile phones proliferation. This is due to the fact that some users do not make any restriction in their mobile phone use. People very often lose the ability to manage the limit between proper and improper use of their cell phones. It is indeed a nuisance when a mobile phone rings in a church, a mosque or at a private meeting. It is even more worrying and dangerous when these mobile phones are used illegally by prisoners in jail to conduct and organize their criminal activities. In some special places, to avoid constantly having to beg people to turn off their phones, a picture is displayed on the walls showing the cell phone inside a red circle with a strike through as shown in figure 1. A radio frequency jammer would therefore be useful in such situations.

Figure 1:- Prohibited use of mobile phone. (Source : internet)

To come back to the present project that implements and tests a mobile phone jammer, it should be noted that cases of students who wrongly use mobile phones in the examinations are widespread and constantly increasing. This is the situation unfortunately experienced in Côte d'Ivoire in recent years, especially during the national organization of the baccalaureate exams. The cheating facts put forward by the national directorate in charge of examination include social networks such asWhatsApp, emails, MMS, SMS or sometimes illicit telephone communications to share the correcting tests. Some astute students still find ways to cheat, particularly with these more powerful tools than ever available for them in this ICT world nowdays. Therefore, new more advanced solutions must be adopted according to these realities. Cheating on exams through cell phones or their improper utilization could easily be avoided if radio frequency jammers were used. This situation analysis motivated the national directorate in charge of examinations to contact ESATIC for a jamming system implementation which will prevent mobile phones use during the tests in the examination centres.

Literary survey:

This section provides a non-exhaustive literary review of the work done in the mobile phone signal jamming systems context. Indeed, S. Madhuvanthi and R. Anitha deal in [2] with an advanced model design of mobile phone signal jammer. This model uses particularly in its communication blocking system, a microcontroller, a regulator, passwords and identifiers for GSM networks. The paper [3], titled "Intelligent Mobile Signal Jammer" provides techniques for designing a mobile phone jamming device that have proven to be a complete success. Furthermore, in [4], a low cost jammer is implemented through a new jamming unit, capable of blocking the cell phone operation without however jamming the signal received from the base station. This jammer type uses the technologies FPGA and RF. Chetan T. Sai and al, presented in [5], an efficient intelligent jammer design to jam 4G signal, mainly in bands 3 and 40 used in India. Their jammer also incorporates a detection circuit and a trigger circuit which allows jamming only if a signal is detected in order to save energy. The project achieved in [6], highlights the design of a simple and inexpensive mobile phone jammer operating in 800 MHz to 1.4 GHz band. The project aims to present a solution to the inappropriate use problem of cell phones in restricted areas. This jammer has been successfully tested on 2G and 3G (UMTS / WCDMA) networks operated by service providers such as Safaricom, Airtell, Orange and YU. Sharad B. Gholap and Harshal R. Patil in their paper [7] particularly discuss an android application designed for an advanced jamming system. This system blocks communication by allowing incoming calls and messages notification to a smartphone. This new system enabled smart mobile phones implementation and management. Paper [8] discusses the design and development of a mobile phone presence detector that can be activated at 1.5 meters through an interfering circuit. The circuit is able to detect both incoming and outgoing calls, SMS and video transmission even if the mobile phone is in silent mode. Furthermore, the detection is accompanied by a beep emission with an LED flashing until the signal transmission ends. As for [9], it deals with a cell phone signal jammer device design and implementation for GSM and CDMA using a predetermined duration allowed by a component named ARM7. The on and off times can be programmed with a microcontroller through a real time clock chip referred to as DS1307. The paper [10] entitled "Design and Development of Mobile Phone Jammer", presents a dual-band mobile phone jammer design, implementation and testing. This jammer works simultaneously on GSM 900 and GSM 1800, and has been successfully tested on GSM networks in Nigeria (MTN, GLO, AITEL and ETISALAT). With the aim of preventing accidents due to the mobile phone use while driving, paper [11] proposes a very efficient automatic electronic system allowing the base station signal jamming inside a car. The jamming area only covers the driver's seat. Finally, paper [12] focuses on a mobile phone jammer design to prevent mobile communications in restricted areas without however interfering with communication channels beyond its range.

Methodology:-

Mathematical foundations of radio signal jamming:

The frequency jamming principle is to interfere with a useful signal in order to totally block it or significantly deteriorate its quality of service (QoS) on a mobile network. In fact, the propagation loss between transmitter and receiver is one of the common QoS degradation factor for a communication systemand can be expressed as follows[12]:

The power at the transmitter side:

$$\mathrm{P_{RT}} = \frac{\mathrm{P_T G_{RT} G_{TR}}}{\mathrm{L_T L_{TR}}} (1)$$

At the receiver side, the power received at the antenna is expressed by the thereafter formula:

$$\mathrm{P_{RN}} = \frac{\mathrm{P_N G_{RN} G_{NR}}}{\mathrm{L_N L_{NR}}} (2)$$

Furthermore, the jamming effects depend on the noise-to-signal ratio ($\mathrm{N/S}$), the distance between the transmitter and the receiver, the modulation scheme, the channel coding, the system interleaving, the transmitter and receiver bandwidths.The noise-to-signal ratio can usually be given by the undermentionedformula:

$$\frac{\mathrm{N}}{\mathrm{S}} = \frac{\mathrm{P_{RN}}}{\mathrm{P_{RT}}} \times \frac{\mathrm{R_{TR}^2}}{\mathrm{R_{NR}^2}} = \frac{\mathrm{P_N G_{NR} G_{RN} R_{TR}^2 L_R B_R}}{\mathrm{P_T G_{TR} G_{RT} R_{NR}^2 L_N B_N}} (3)$$

In equations (1), (2) and (3), the parameters are defined as follows: $\mathrm{P_N}$ and $\mathrm{P_T}$, respectively point out the power emitted by the jammer and that of the transmitter. The antenna gains are respectively indicated by$\mathrm{G_{NR}}$ from jammer to receiver, $\mathrm{G_{RN}}$ from receiver to jammer, $\mathrm{G_{TR}}$ from transmitter to receiver and $\mathrm{G_{RT}}$ from receiver to transmitter. Then, the bandwidths are denoted by $\mathrm{B_R}$, for the receiver communication bandwidth and $\mathrm{B_N}$, for the jammer transmitter bandwidth. The parameter$\mathrm{R_{TR}}$ denotes the distance between the communication transmitter and the receiver, and $\mathrm{R_{NT}}$, the distance between the jammer and the communication receiver. Meanwhile, the losses are denoted by $\mathrm{L_N}$, for the transmission or communication signal loss and $\mathrm{L_{NR}}$, for the free space loss between the jammer and the receiver (including the loss due to the polarization shift). Thus, the jammer performance is a function of the noise-to-signal ratio (NSR) γ, espressed as follow:

$$\gamma = \frac{\mathrm{N}}{\mathrm{S}} (4)$$

The reciprocal of γ is commonly known as signal-to-noise ratio ($\mathrm{SNR = S/N}$) which makes it possible to assess the signal quality received at a receiver.

Table 1:- Operating frequencies, output power and sensivity for mobile stations.

Operating band	Uplink (Mobile station to Base station) (MHz)	Downlink (Base station to Mobile station) (MHz)	Peak power for Mobile Station (W)	Max output power for Mobile Station (W)	Minimum Sensivity for Mobile Station (mW)
GSM 900	880 - 915	925 - 960	2	0,250	4×10^{-12}
DCS 1800	1710 - 1785	1805 - 1880	1	0,125	4×10^{-12}
UMTS 2100	1920 - 1980	2110 - 2170	0,25	0,25	4×10^{-12}
LTE 800	791 - 821	832 - 862	0,25	0,25	4×10^{-12}
LTE 2600	2500 - 2570	2620 - 2690	0,25	0,25	4×10^{-12}

The present project is limited to implement a jammer with a powerful jamming capacity for 2G, 3G and 4G systems operating on the frequency bands adopted at the national level. These frequency bands are: GSM (925 - 960 MHz), DCS (1805 - 1880 MHz), 3G (2110 - 2185 MHz) and 4G LTE (725 - 785 MHZ / 2620 - 2690 MHz) as shown in table 1.Moreover, the successful jamming of a specific zone requires a very important parameter consideration which is the signal-to-noise ratio (SNR), the inverse of γ determined in equation 4. It should be noted that any device operating according to radio communication principles can only allow noise at a certain level: this is its SNR handling capability. In theory, the SNR handling capability of a mobile phone is around $12\ \mathrm{dB}$, but in practice this value might be 9 dB for a very good device [3]. Hence, to ensure a cell phone jamming, the signal carrier SNR must be reduced to less than 9 dB ($\mathrm{SNR} = \frac{S}{N} = 9\ \mathrm{dB}$). Based on the cell phones minimum sensitivity and certain statistical data on the powers radiated by base stations in the country, the maximum receptionpower adopted here is $S = -15\ \mathrm{dBm}$ for a mobile device. This case amounts to having a jamming signal power equal to $N = -24\ \mathrm{dBm}$ at the mobile receiver for an effective jamming. However, it should be important to precise that the transmitted jamming signal will be attenuated during its propagation in free space from the jammer antenna to the mobile phone antenna. This leads to consider basically the path loss by a simple approximation through Friis formula given by the following equation 5:

$$\mathrm{L}\ (\mathrm{dB}) = 32.44 + 20\mathrm{Log}[\mathrm{d(km)}] + 20\mathrm{Log}[\mathrm{f(MHz)}] (5)$$

Where f is the operating frequency in MHz and d, the distance between the jammer and the cell phone in kilometers. Knowing that cell phones are full duplex devices, there will be simultaneous communications on uplink and downlink. For this purpose, the downlink jamming signal can easily jam the uplink signal. This is obviously possible given that the mobile phone transmitted power is very low compared to base station power which commonly varies from 20 to 35 watts. So, for theestimates, the mobile systems downlink will be usedwith50 meters around the jammer as target jamming range. Thus, the jammer different resulting output power values (J) are obtained by adding the noise value ($N = -24\mathrm{dBm}$) to the free space loss value L (see table 2).

Table 2:- Jam output power for the different mobile systems.

Operating band	Frequency (MHz)	PathlossL (dB)	Jammer output power : $\mathrm{J(dBm)} = \mathrm{L} + \mathrm{N}$
GSM 900	900	66	42
DCS 1800	1800	72	48
UMTS 2100	2100	73	49
LTE 800	800	65	41
LTE 2600	2600	75	51

These propagation losses obtained in table 2 relate only to the free space and the trajectory losses in the air will in reality be much greater. This approximation leads to consider that the effective jamming range could be less than 50 meters. To simplify the jamming device design, a uniform output power adopted is $51\ \mathrm{dBm}$ as target jamming signal power for all the mobile systems. And, four omnidirectional antennas are chosen that including one for LTE 800 and GSM 900 bands, one for DCS 1800 band, one for UMTS 2100 band, and one for LTE 2600 band. The jammer will be so designed according to the different parameters and hypotheses mentioned in this theoretical part, starting with the components choice.

Architecture and implementation:

Generally, there are several techniques for jamming a radio frequency device. The three most common techniques can be specified as follows[12]: the first is referred as Spoofing which is very difficult to be implemented since the jamming device first detects any mobile phone in a particular region, then the device sends a signal to deactivate the cellphone. The second technique is referred as Shielding Attacks, known as TEMPEST or EMF shielding. This technique necessitates closing off an area in conductive mesh faraday cage so that any device inside that cage cannot transmit or receive RF signal from outside the cage. The third and final technique is the Denial of Service also known by the acronym DOS. In the latter technique, the device transmits a noise signal at the same operating frequency of the mobile phone in order to reduce the signal-to-noise ratio (SNR) of the mobile below its minimum value.

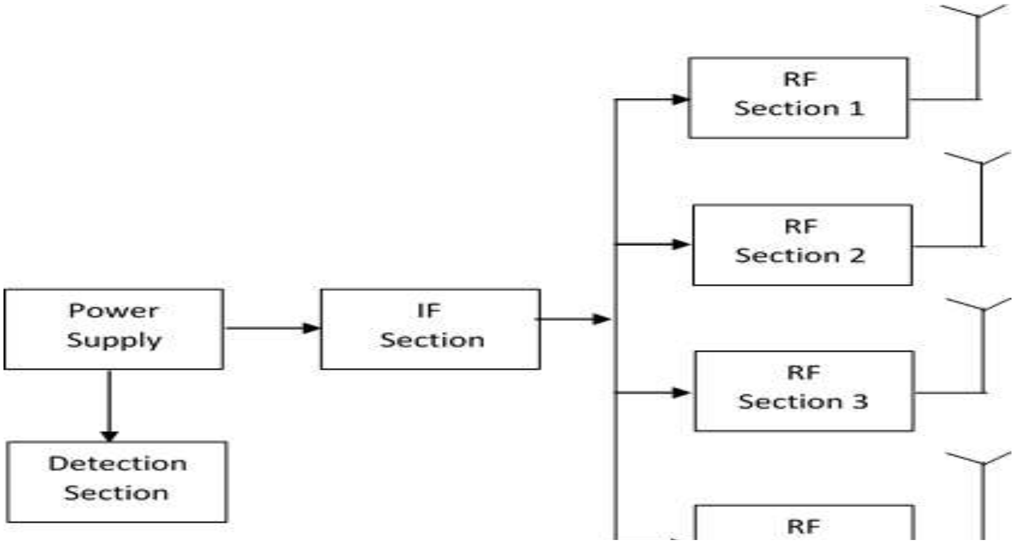


Figure 2:- Block diagram of the jammer device.

After having analyzed these different jamming techniques, the technique adopted here for the jammer implementation is the Denial of Service (DOS), because it is the simplest and the least expensive to implement. In this technique, the jamming is obtained when the device transmits a high power signal in the same frequency band used by the mobile phone, thus degrading its signal-to-noise ratio. The signal from the jammer is considered as noise by the mobile device, thereby increasing the system noise threshold. To achieve the noise level at the required frequency in order to jam the downlink signal, emphasis has been put on a certain number of design parameters to establish the device specifications. These parameters are:the range to be jammed, the frequency bands, the noise-to-signal ratio and the free space path loss. To do this, the jammer consists of a power section, a detection section, an intermediate frequency (IF) section and a radio frequency (RF) section, as shown in figure 2. The power section supplies power to the jamming device other sections. Here it consists ofatransformer with 24 volts, a rectifier made up of two rectifying diodes, a filter and a 12 volts voltage regulator. The power section supplies 9 volts to the detector section and 12 volts to the IF and RF sections. The jammer is also designed with a backup battery of 12 volts which takes over the power supply in power failure event. The detector section emits light through a LED of 10 mA to indicate the jamming device start-up and operation. The IF section behaves globally like a noise generator and is a circuit that produces electrical noise which is a random and non-deterministic signal. Its circuit incorporates basically atriangular waveform generator, a noise generator, a mixer and a clamper. And, the IF section mainly generates a tuning voltage for the voltage controlled oscillator.In this project, four 1/4 waveform monopole antennas areused with a gain of 2 dBi and an impedance of 50 Ohms to match the transmission system. These antennas respectively cover the four aforementioned frequency bands adopted in the country for 2G, 3G and 4G systems.

Results and Discussions:-

Testing of the jammer:

The first test type carried out within the project framework is a simulation through the device assembled on breadboards, a low frequency generator and an oscilloscope. Figure 3 shows the noise generation device assembly.

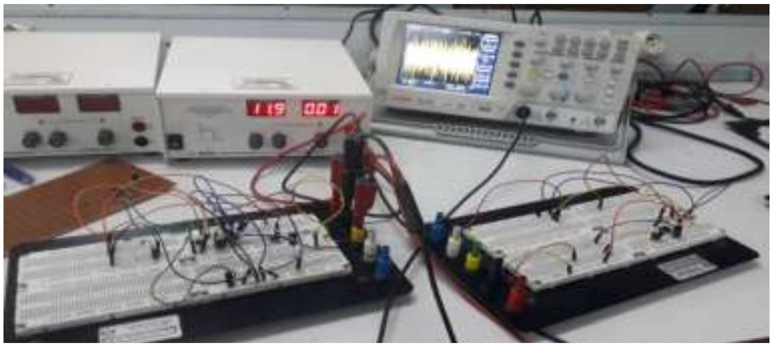


Figure 3:- Breadboard-Assembly of the jammer.

This simulation results were conclusive and are observed with the oscilloscope screenshot on figure 4. The jammer first part is the tuning circuit namely the IF section and the second is the RF section which generates the jamming signal. The output waveform after the device implementation can be compared with the IF section simulation that is the noisy signal with the triangular waveform signal.The noises observed for the two outputs of the example on figure 4 are much more intense because they underwent new amplifications. In the simulation, the signal considered is triangular with a variation from 0 to 5 volts and a period of 50 µs. But, it is important to specify that any periodic signal would lead to the same results.

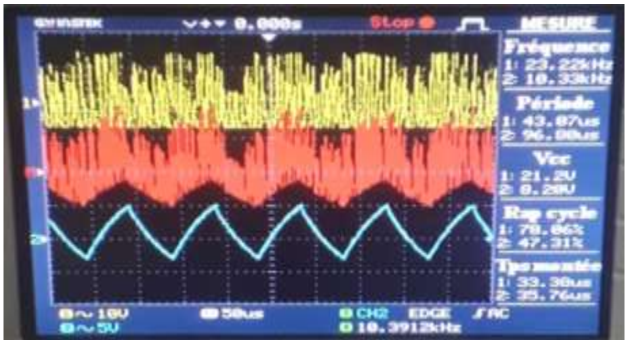


Figure 4:-Simulated triangular waveform of the jammer device output.

In situ measurements:

The second test type carried out in the framework of this project was the in situ power measurement performing. Here, the power meter used is the Aronia HF60105 spectran, shown in figure 5. It is capable of measuring power levels and electromagnetic fields for frequencies ranging from 10 MHz to 10 GHz. In addition, it can measure the signal strength levels for different technologies such as GSM, CDMA, UMTS, LTE, etc. This device was used to measure the base station power level for the target mobile systems and the jammer power level in the radiation zone from its position to a distance of 50 meters around.

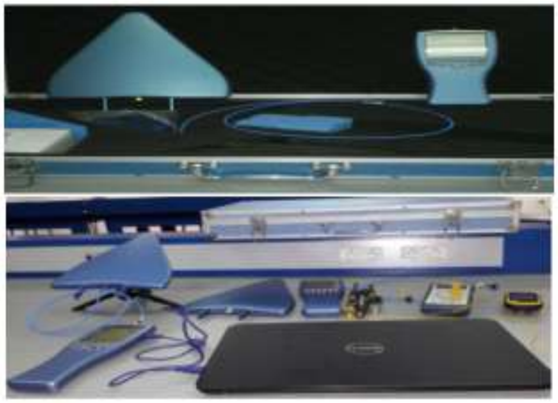


Figure 5:-Aronia Spectran HF60105used for in situ measurements.

Measurements were realized in several points with the aim of varying the jammer position comparatively to base station positions. Moreover, for each jammer position, measurements are performed in outdoor environment every 5 meters from its position to 50 meters around. For the different radius, four measurement points have been selected as shown in figure 6.

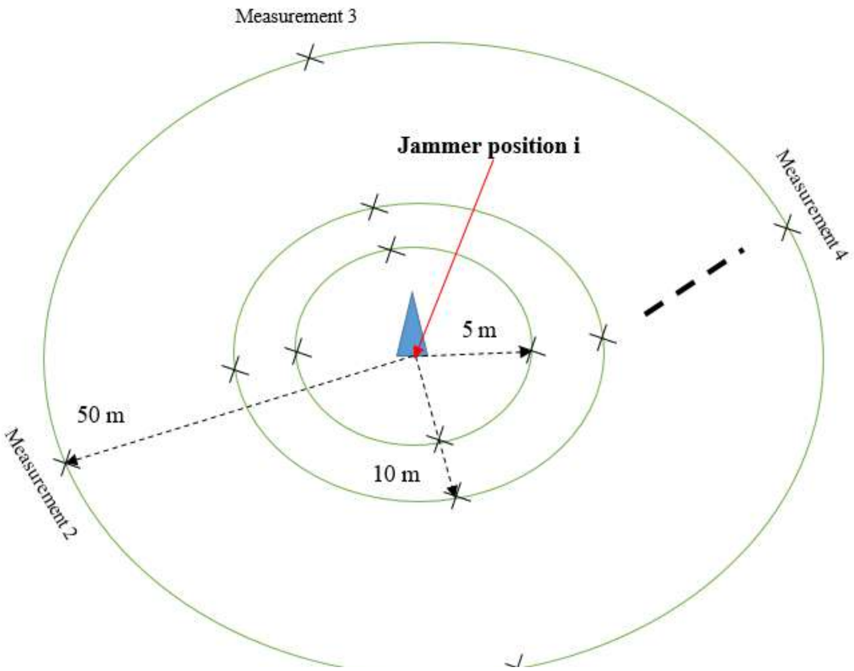
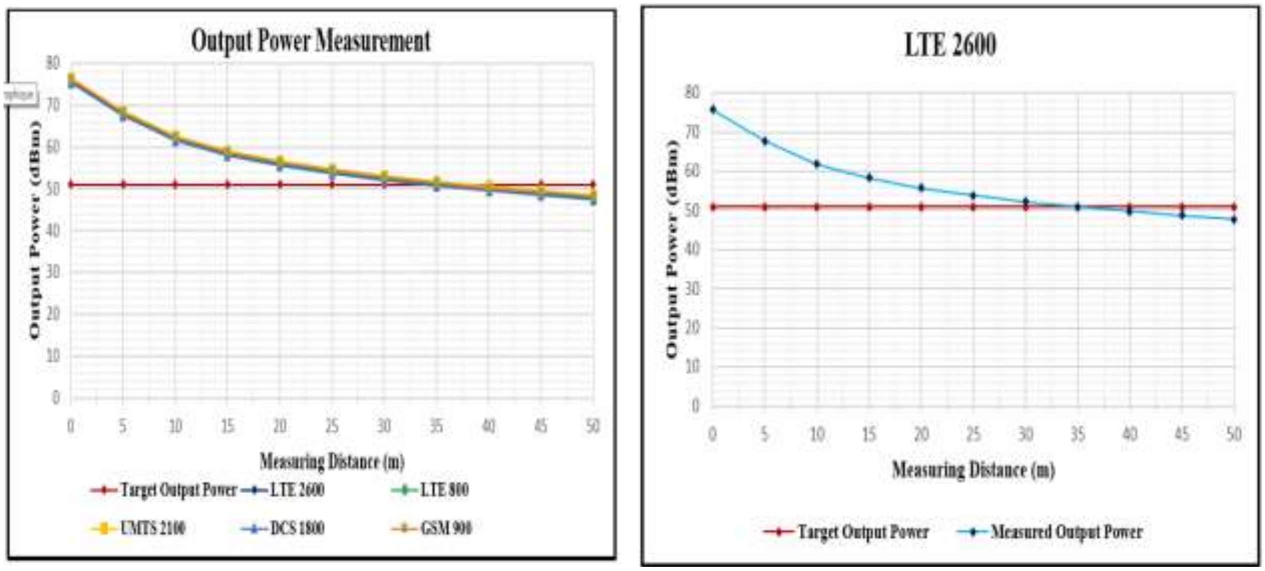


Figure 6:- Methodolgy for the in situ measurements.

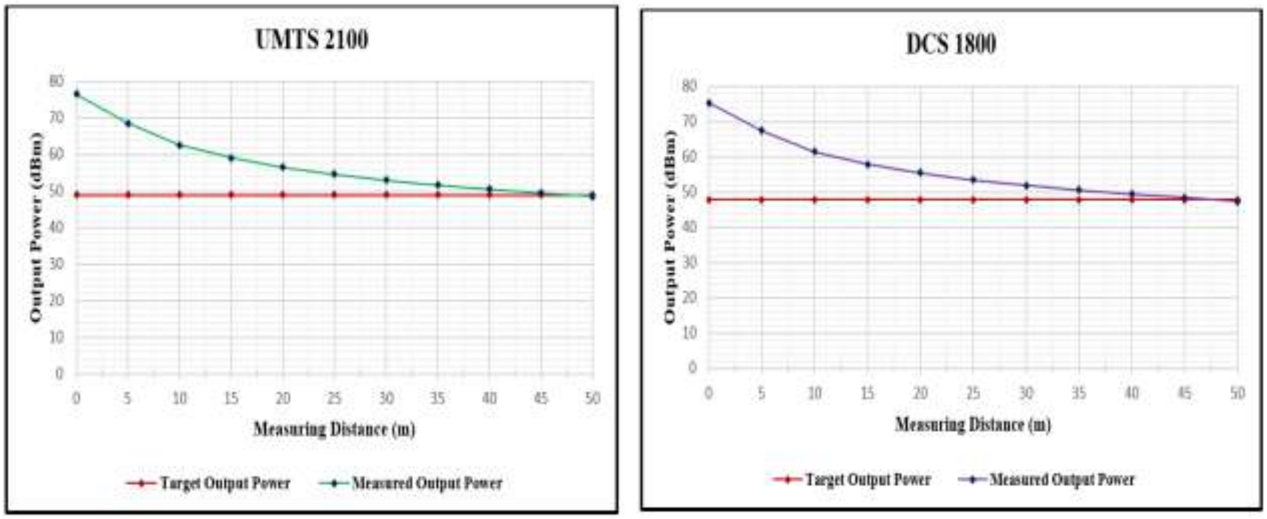
For each point, two measurements were performed successively in a time interval not exceeding one minute. The first measurement focused on the base station signal strength with the jammer in stopped state. The second was carried out to measure the overall signal with the jammer device on. Furthermore, several series of measurements are been carried out for the jammer positions at different distances from the base stations. These measurement series made it possible to deduce the curves on figures 7, 8 and 9 which highlight the output powers delivered by the jammer relatively to the different mobile systems.



(a) (b)

Figure 7:- Jammer output power curves for all the mobile systems (a) and LTE 2600 (b).

As a reminder, the target output power of 51 dBm was adopted for the jammer design in order to reach a range equal to 50 meters for all the systems. It can be seen through figure 7 (a) that the target powerof 51 dBm has not been reached for all the mobile systems. Indeed, after 35 meters, all the jammer output powers fell below 51 dBm.



(a) (b)

Figure 8:- Jammer output power curvesfor UMTS 2100 (a) and DCS 1800 (b).

On the other hand, it is noted that the output power objectives to obtain 50 meters as an circular action zone radius have been achieved respectively for GSM 900 and LTE 800 compared to the values in table 2 (see figures 9). It is therefore important to notice that the output powers for DCS 1800 and UMTS 2100 systems are slightly below their target values (see figures 8). The DCS 1800 has an output power measured at 50 meters which is 47.415 dBm instead of 48 dBm as real target value. For UMTS 2100, this measurement is 48.515 dBm instead of 49 dBm as real target value. And, for LTE 2600 system, the measured output power is 47.715 dBm instead of 51 dBmas real target value (see Figure 7 (b)). Indeed, these results have shown that increasing the target output power respectively from 41 and 42 dBm to 51 dBm for GSM 900 and LTE 800, made it possible to easily reach the range of 50 meters.

(a) (b)

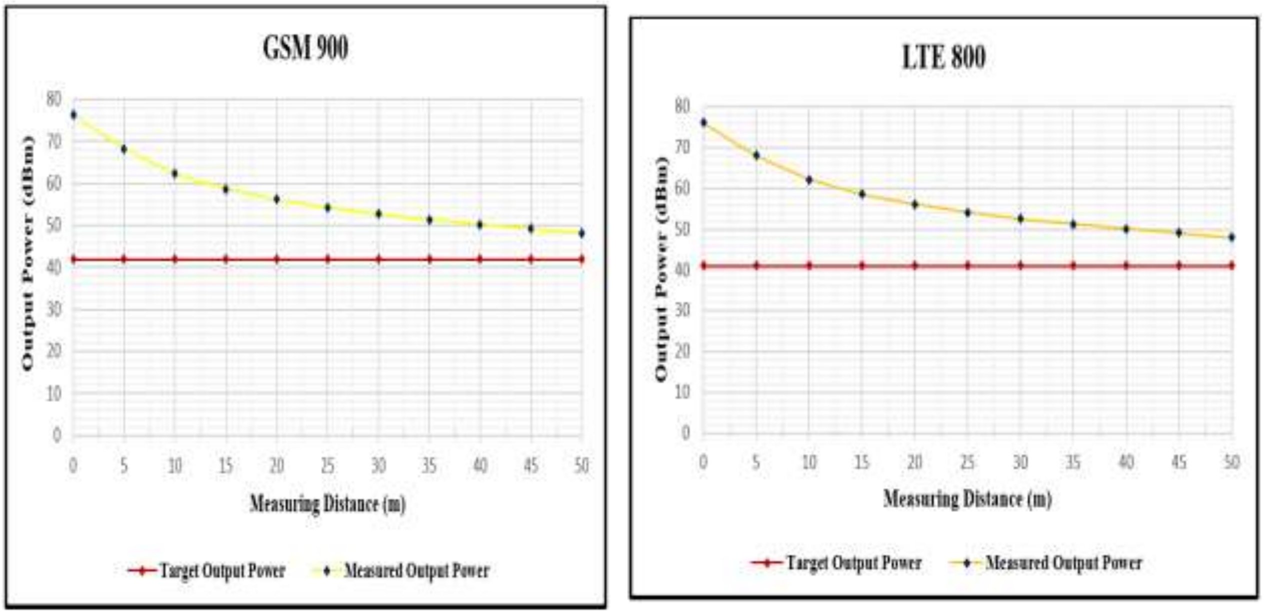


Figure 9:-Jammer output power curves for GSM 900 (a) and LTE 800 (b).

Discussions:-

The mobile phone jammer implemented here transmits the signals without any modulation type. Furthrmore, only the carrier waveform is generated by the jammer and radiated in all directions due to the omnidirectional antennas used. The generated carrier reaches the mobile phones located in the action zone where the device can act with great efficiency. Generally, it should be noted that the signal from the base station transmitted to the mobile station has a very high power compared to the one delivered by the jammer. But the signal from the base station always follows a long path to reach the receivers. This makes the base station signal small at the receiver, even smaller than the mobile station signal. In this case, the jammer having a strong power in its radiation zone will be able to jam the signal coming from the base stations once its power becomes close to or much greater than that of this signal. The jammer once triggered, as mentioned above, has a LED which indicates the operation start. The jamming circuit is triggered by a switch and contains an input that charges its battery when it becomes empty after approximately two operation hours. Roughly speaking, the jamming circuit dissipates a total of 0.5 watts for a supply voltage of 5 volts.In its action area, the device was able to jam various mobile systems signals on the three main national operators' networks: ETISALAT, MTN and ORANGE. This was verified in particular by the absence of signal reception for all the mobile phones placed in the action area. The effective jamming range is at least 50 meters for GSM 900 and LTE 800 systems, but is around 47.5 meters for DCS 1800 and UMTS 2100, and approximately 35 meters for LTE 2600. It was also observed that as the distance between the cell phone and the base station increases, the effective jamming range increases. This is certainly due to the fact that the amount of energy reaching the cell phone from the base station decreases as the cell phone moves away from the base station. The jammer has therefore been effectively tested and worked correctly on 2G, 3G and 4G networks. However, the jamming range turns out to be smaller than the 50 meters for DCS 1800, UMTS 2100 and LTE 2600 systems. This could be explained by the fact that the jammer effect can vary considerably in depending on factors such as proximity to base stations, indoor and outdoor settings, buildings and vegatation presence, and even temperature and humidity play a role. Optionally, a higher power RF amplifier can be used to improve the jammer range in the case of these systems. Therefore, further studies are needed to ensure the success of this option.

Conclusion:-

In this paper, the implemented jammer has ensured effective jamming in its action areas for GSM 900, DCS 1800, UMTS 2100, LTE 800 and LTE 2600 bands currently adopted in Côte d'Ivoire. This device can be used a priori in the examination centres of the country to prevent cheating through mobile phones. The effective jamming range is not what was expected for some frequency bands. This is notably due to an insufficiency of the currents supplied to the chosen power amplifiers and a more stable power supply necessary for robust operation. However, the mobile services absolute disenabling effectiveness in the jammer action areas, allows here to consider the device mass production.

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