

# Design of a Simple Cell-Phone Radio-Frequency Detector

Simiyu Sitati\* Diana Starovoytova Madara Edwin Ataro  
School of Engineering, Moi University P. O .Box 3900, Eldoret, Kenya

## Abstract

Recently, we have witnessed, locally and globally, a dramatic-boom in the wireless-communications industry, hence increasing the number of mobile-devices-users. This magnified the need for developing more-efficient and reliable-means of mobile-phone-signal-detection. The following-study aimed at developing a circuit that would be able to detect any mobile-phone activities such as: sending or receiving calls and text-messages, unauthorized-audio or video-transmission or any other type of data-transmission, yet the phone is kept in the silent-mode. Overall, the results of this brief-study are potentially-useful, as the mobile-phone-transmission-detector can sense the presence of an activated-mobile-cell-phone from a distance of about 4 meters. It can therefore be potentially used to prevent use of mobile-phones in restricted and unauthorized-places, such as examination-halls, confidential and private-government meetings-venues, and business-companies-seminar-halls among others. It is also useful for detecting the use of mobile-phone for spying and unauthorized-video-transmissions. Another potential application is in hospitals and airplanes where mobile-signals might interfere with the electronic-equipment, possibly resulting in fatal- consequences and most-importantly, the circuit would also help to reduce the use of mobile-phones for terrorist-activities, thereby improving national and personal-security. The prototype, however, has a limited-range of detection, of only about 4 meters, therefore future and more-deeper-research on improvements should be conducted, so as to make the device more-efficient.

**Keywords:** cell-phone, radio-frequency, detector.

## 1. Introduction

### 1.1. Relevant background information

Communication is one of the most-vital attributes of life. Without communication things do not happen, excellent-illustration being the tower of Babel, where communication-breakdown killed a generation's vision to reach, to see, and to communicate with God in a physical-form. Over the last 2 decades or so, we have witnessed very-radical-transformation in the telecommunication-sector, a revolution that has been named greater than the wheel-invention-revolution (Nicholas, 2011).

The mobile-phone has been one of the fastest-growing-technologies and everyday-life-requirements in the world today; it is also the most-common-electronic-equipment used today, which typically-transmits and receives radio-frequency-signals with a wavelength of about 30cm in the range of approximately 872 to 2170MHZ. The signals are transmitted in the form of sine-waves and contain electromagnetic-radiations that are picked-up by the receiver in the base-station (Flood, 1995).When the first-mobile-phone was released to the public, not many were impressed with it, mainly because of the outrageous-price and bulkiness of the first-model. Mobile-phones have advanced so much since their first-prototype. Today when one buys a mobile-phone, they are not looking at if it can make a telephone call, but what else it can do including: GPS, PDA, MP3-capabilities, and having front and back high-resolution video-cameras among others; the possibilities are endless. This-technology has not only transformed our world into one that is fully- connected 24/7; it is a technology that has made the 21 Century completely-different from any other in our history of existence.

It was in the late 1990s that cell-phones paved their way into the Kenyan-market and ever-since- then, it has been expanding endlessly. Although the first-mobile-operator (the service-provider-company) was only licensed in 1997, Kenya's mobile network subscriber-base exceeded that of the fixed-network in 2000, and has since experienced phenomena-growth, as fixed lines dip. Mobile-subscription-numbers in Kenya hit 22 million in September, 2010 (out of the total country-population of around 40 million). Today, even the very-young-residents, children, who are still in school, do own mobile-phones. This gives them access to the internet and exposes them to all sorts of sites, some of which may not be appropriate for young-persons and may potentially corrupt their-not-yet-fully-developed-minds. On the other hand, nearly 70 percent (the highest percentage of any country on earth) of Kenyan adults transfer money to each other via their mobile-phones-app (MPESA), where more than US\$320 million dollars are transferred via Kenyan mobile-phones each month. According to *The Economist*, this adds up to a quarter of Kenya's GDP. As a result, cash-payments are rapidly being replaced by mobile-phone payments in virtually every-sector of the nation's economy (Mengistu & Imende, 2015).

Despite the many-benefits and developments mounting-up from the use of mobile-phones, however, the rapid increase of cell-phones-users at the beginning of the 21st Century to near omnipresent status, eventually raised problems such as their potential-misuse to invade privacy and being an intrusive-disruption in every-daily-life (Hämäläinen, 2008). Many people, willingly or unwillingly, abuse their mobile-phones in restricted and unauthorized-places (as there is an unwritten-believe that we simply *must* be connected all-the-time). The places

include: banks, seminar-halls, conference-rooms, and private-meetings-venues, which is highly-inappropriate. Others use them to spy confidential government-meetings and transmit unauthorized-videos which still pose a danger to national and personal-security. This has also proved to be a threat to national-security as mobile-communication now being used by terrorists to plan and execute their-attacks. The main problem with ensuring that a mobile-phone is not used in a secure-facility is that an accurate and affordable method of its detection is yet to be developed. The only-way to be certain that the mobile phone is not used in the restricted areas is to perform full-body-searches/physical-inspections on a compulsory-basis which is awkward, very-tedious, even embarrassing and also requires a great deal of manpower of both-genders. Owing to this fact, it has become necessary to design a mobile-phone-detector so as to prevent entry into secure-facilities and unauthorized-places and also prevent unauthorized data-transmission in the event that someone manages to sneak a mobile-phone in the secure-facility.

Misuse of mobile-phones is another-latest-threat to the information-dependent-businesses and to the education-sector. Many-businesses depend on keeping information protected and build fortresses that called secure-facilities to protect their investment. The technology added to mobile-phones in the last 15 years has made them a “jack-of-all-trades” for information storage and transmission. Features like Bluetooth, USB, micro USB, high-resolution-cameras, microphones and internet make cellular-phones perfect for stealing data and also for cheating in examinations by students (Nicholas, 2011). New-useful-features make cellular-phones today very versatile, such as, for example, that they can store huge amount of data in deferent-formats, and connect with almost any storage-medium or computer. In the years to come, cellular-phones will continue to gain more and more-features.

Some of the increasingly-growing-negative-ways in which phones are being used today, which are quickly surpassed their benefits, are some of the key-motivations for undertaking this study.

### *1.2 Relevant- to the-study, selected-definitions and information (Lee, 2009)*

*Detection* – is the process of locating, tracking, and identifying various sources of radio transmissions. Detection, or direction-finding, is used in a wide-variety of applications including, for example, cell- phone assignments, the location of 911 emergency calls and marine distress calls.

*Radio frequency (RF)*-is any of the electromagnetic-wave-frequencies that lie in the range extending from around 3 kHz to 300 GHz, which include those-frequencies used for communications or radar-signals. RF usually refers to electrical rather than mechanical-oscillations, however, mechanical-RF-systems do exist.

*Radio-Frequency-Detector*-is refers to a small-mobile-bug or cell-phone-detector, pocket-size mobile phone transmission-detector or a sniffer that can sense the presence of an activated-mobile-phone from a relatively short distance (1-15 meters). The circuit can detect; the incoming and outgoing calls, SMS and video-transmission, even if the mobile-phone is kept in the silent-mode. The moment the bug detects RF-transmission-signal from an activated-mobile-phone, it starts sounding a beep-alarm and the LED blinks. The alarm continues until the signal transmission ceases.

*Ordinary LC (Coil-Capacitor)* circuits are used to detect low-frequency-radiation in the AM and FM bands. The tuned-tank-circuit having a coil and a variable-capacitor retrieve the signal from the carrier-wave. But such LC circuits cannot detect high-frequency-waves near the micro-wave region. Hence in the proposed circuit, a capacitor is used to detect RF from mobile-phone considering that, a capacitor can store energy even from an outside-source and oscillate like LC circuit.

*Mobile phone* uses RF with a wavelength of 30cm at 872 to 2170MHz. That is the signal is high-frequency with huge-energy. When the mobile-phone is active, it transmits the signal in the form of sine-wave which passes through the space. The encoded audio/video-signal contains electromagnetic-radiation which is picked up by the receiver in the base-station. Mobile-phone-system is referred to as “Cellular Telephone system” because the coverage area is divided into “cells” each of which has a base-station. Figure 1 shows the Parts of the Global-Wireless-infrastructure. The transmitter-power of the modern-2G antenna in the base station is 20-100 watts. Mobile-phone uses high-frequency-RF-wave in the micro-wave-region carrying huge- amount of electromagnetic-energy. That is why burning-sensation develops in the ear if the mobile is used for a long-period. Just like a micro-wave-oven, mobile-phone is ‘cooking’ the tissues in the ear. The strongest-radiation from the mobile-phone is about 2 watts which can make connection with a base-station located 2 to 3 km away.

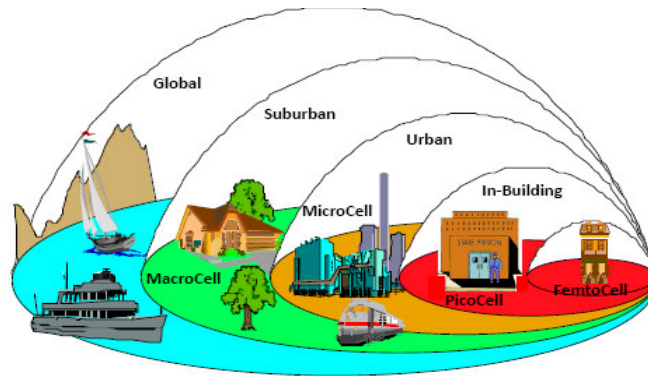


Figure 1: Parts of the Global Wireless infrastructure (Cellular Detection & Control, 2011).

### 1.3. Purpose and the Scope of the study

Taking into account that Kenya is a growing-economy in terms of technological advancements, research, innovations and industry, there is a need to develop home-grown-solutions to our-problems in order to achieve Kenya Vision, 2030 “to become a middle-income country with high-standards of leaving”.

This study will try to provide a means of detecting the presence of an active-mobile-phone even when it is in silent mode, which would help in identifying students who use their phones to cheat in examinations and penalize them accordingly, thereby reducing such-cases. It would also prevent unauthorized video transmissions by spies from confidential-government-meetings held and to avoid terrorists or other enemies of the state from acquiring important-government-information to plan their malicious-attacks. This study attempts to contribute, in its small way, to reduction of the misuse of mobile-phones thereby positively impacting the whole nation at large.

This research involves a design of a radio-frequency-detector which includes a capacitor that acts as a loop-antenna to collect the RF-signal from the mobile-phones, store the energy and transfer the stored-energy in the form of minute-current to the input of the op-amp. Op Amp IC CA3130 with very-high-input- impedance acts as a current to voltage-converter and the output is fed to transistor BC 548, then the 555 Timer for time delay and precision timing.

The circuit would be able to detect the presence of an active-phone from a distance of about 4-5m and upon detection of RF-signal, it would sound a beep-alarm and the LED would start blinking, until the transmission ceases. The circuit would also be able to prevent a mobile-phone from transmitting or receiving RF-signals.

*Specific Objectives of the study are to:* design a circuit that can detect the presence of an activated mobile-phone within a certain area of concern; and interface a microcontroller to an LCD which would exhibit the presence of RF- signals.

## 2. Materials and methods

### 2.1. Methods

The design was conducted according to the fundamental-engineering-design-principles, with Deshpande & Jadhav (2015); Ajasa *et. al.*, (2014); Amaan *et. al.*, (2013); Ludwig & Bogdano (2009), and Kainka (2002) were chosen as the major points-of-reference for the design. The EdrawSoft –Electrical-Drawing-Software was used for creating the circuit of the mobile-phone-detector. Figure 2 shows the operational-concept of the detector.

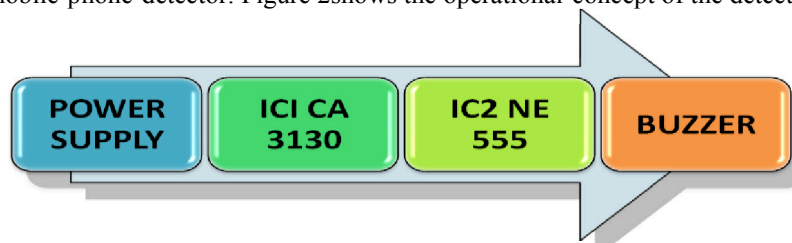


Figure 2: Concept of the circuit-detector

Before the assembling of circuit on PCB, it was tested on the breadboard using the components, connecting wires, and a 9V battery. A PCB populated with electronic-components is called a printed circuit assembly (PCA), printed-circuit-board-assembly or PCB-Assembly (PCBA). In informal use, the term "PCB" is used for both; bare and assembled-boards.

#### 2.1.1 PCB Fabrication

Printed-Circuit-Boards (PCBs) are certainly the most-important-element in the fabrication of electronic-equipment. It is the design of properly laid-out PCBs that determine many of the limiting properties with respect to noise-immunity, as well as to fast-pulse, high-frequency and low level characteristics of equipments.

*PCB Fabrication-steps-used according to (Amaan, 2014)* are as follows: Printed Circuit Board- Copper Clad Laminate- Board Cleaning Before Pattern Transfer- Screen Printing- Etching- Drilling- Component Mounting- Soldering. Following is the synopsis-explanations of the steps.

*A laminate* (can be simply described as the product obtained by pressing layers of a filler-material impregnated with resin under heat and pressure. Copper-Clad laminate was used); *Board Cleaning before Pattern Transfer* (After choosing the copper-clad laminate it should be cleaned. The cleaning of the copper-clad prior to resist application is an essential step for any PCB process; etch was used in this study); *Screen Printing* (Screen-printing is the process by which the conductor-pattern which is on the film-master is transferred on to the copper-clad- laminates. With the screen-printing process one can produce PCBs with a conductor width as low as 2.5mm and registration-error of just 0.1mm on an industrial-scale with a high reliability); *Etching* (After drying of the resist of the copper-clad- laminate the next process is etching. The final-copper-pattern is formed by selective-removal of all unwanted-copper, which is not protected by etch-resist. Ferric chloride was used as etchant. After etching is over the ferric chloride, contaminated surface should be cleaned. After a simple-spray-water-rinse, a dip in a 5% (volume) oxalic- acid-solution was done to remove the copper and iron-salt. A vigorous-final-water-rinse has to flow); *Drilling* (After the etching operation, the next step is drilling of component-mounting-holes in the PCBs. This is done using a drilling machine with suitable size-drill-bits. To compensate for laminate-resilience the drill-bit-diameter is chosen 0.05mm bigger than the holes-diameter-expected); *Component Mounting* (Component mounting on the PCB in such a way to minimize the cracking of solder-joints due to mechanical-stress on the joint. It was done by bending of the axial-component-lead in a manner to guarantee and optimum-retention of the component on the PCB, while a minimum-stress is introduced on the solder joint). *Soldering* (Soldering is the process of joining metals by using lower-melting-point-metal or alloy with joining-surface. Soldered joints in electronics-switches will establish strong-electrical-connection between components-leads. Alloy of tin was used as well as a Soldering Iron, which is a tool used to melt solder and apply at the joint in the circuit. It operates at 230v supply. The iron bit at the tip of it gets heated within few minutes. 25W soldering iron was used for soldering purpose); *Flux* (In order to make the surface accept to make the solder readily, the component-terminals should be free from oxide and other-obstructing- films. The leads should be cleaned-chemically and by abrasion using blades or knives. A small-amount of lead coating was done on cleaned-portion of the lead using soldered iron. This process is called thinning. Zinc Chloride (in petroleum jelly as paste flux) was used as fluxes. The residue which remains after soldering should be washed out with more water accompanied by brushing); *Soldering Steps used are as follows:* (i) Make the layout of component in the circuit. Plug in the cord of the soldering iron into the mains to get heated; (ii) Straighten and remove the coating of components leads using a blade or knife. Apply a little flux on the leads. Take a little solder on soldering iron and apply the molten-solder on the leads. Care must be taken to avoid the components to getting heated up; (iii) Mount the components on PCB by bending the leads of components using nose pliers; (iv) Apply flux on the joints and solder the joints. Soldering must be done to avoid the dry soldering and heating up of components; and (v) Wash the residue using water and brush.

### 2.3. Materials

Table 1 shows the materials used for the detector.


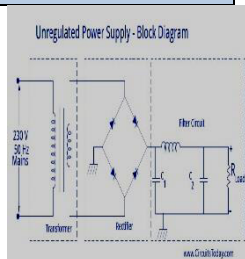

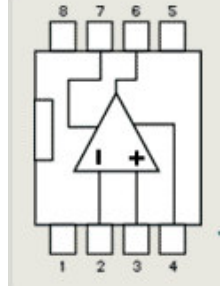
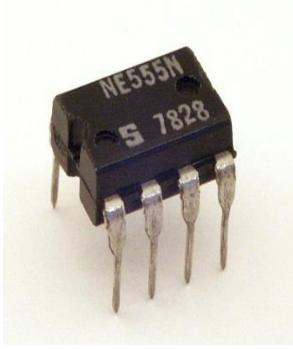
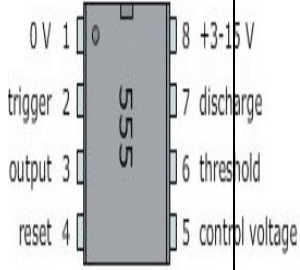

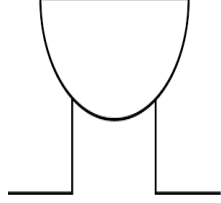


#### 2.3. 1. Use of capacitor to sense RF-signals

Capacitor plays a key-role in this design; therefore additional explanations are given below.

A capacitor has two electrodes separated by a 'dielectric' like paper. The non-polarized disc-capacitor is used to pass AC and not DC. Capacitor can store energy and pass AC-signals during discharge. 0.22 $\mu$ F capacitor is selected because it is a low-cost and has a large-surface area to accept energy from the mobile-radiation. To detect the signal, the sensor part should be like an aerial. So the capacitor is arranged as a mini-loop-aerial (similar to the dipole antenna used in TV). In short, with this arrangement, the capacitor works like an air-core-coil with ability to oscillate and discharge current.

One lead of the capacitor gets DC from the positive-rail and the other lead goes to the negative-input of IC1. So the capacitor gets energy for storage. This energy is applied to the inputs of IC1 so that the inputs of IC are almost balanced with 1.4 volts. In this state output is zero. But at any time IC can give a high-output if a small-current is induced to its inputs. The natural-electromagnetic-field around the capacitor is caused by the 50Hz from electrical-wiring. When the mobile-phone radiates high-energy-pulsations, capacitor oscillates and release energy in the inputs of IC. This oscillation is indicated by the flashing of the LED and beeping of Buzzer. In short, capacitor carries energy originated from an electromagnetic-field. So a slight change in field caused by the RF from a mobile-phone will disturb the field and forces the capacitor to release energy.

Table 1: Materials used in the design (extracted from respective datasheets)

S. N.	PART NAME	BRIEF DESCRIPTION	PHOTO	SYMBOL
1	<b>Regulated Power Supply</b>	It is an embedded-circuit; it converts unregulated-AC into a constant-DC. With the help of a rectifier it converts AC supply into DC.		
2	<b>IC CA 3130</b>	This IC is a 15 MHz BiMOS Operational-amplifier with MOSFET- inputs and Bipolar-output. It has high-speed of performance and suitable for low-input- current-applications.		
3.	<b>IC NE555</b>	The 555- timer IC is an integrated- circuit (chip) used in a variety of timer, pulse generation, and oscillator-applications. The 555 can be used to provide time-delays, as an oscillator, and as a flip-flop element.		
4.	<b>Buzzer</b>	A buzzer or beeper is an audio-signaling- device, which may be mechanical, electro-mechanical, or piezoelectric.		
5.	<b>Resistors</b>	Resistors are elements of electrical- networks and electronic- circuits and are ever-present in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).		

6.	<b>Capacitors</b>	A capacitor or condenser is a passive-electronic- component consisting of a pair of conductors separated by a dielectric.		
7.	<b>Light-Emitting-Diode (LED)</b>	(LED) is an electronic light source, based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light.		
8.	<b>Transistor BC548</b>	Transistor BC548 is general purpose silicon, NPN, bipolar junction-transistor. It is a CMOS version using gate protected -channel MOSFET-transistors in the input to provide very-high-input-impedance and very-low-input-current .		
9.	<b>Battery 9V</b>	The nine-volt battery in its most common form was introduced for the early <a href="#">transistor-radios</a> . It has a rectangular-prism shape with rounded edges and a polarized snap connector at the top.		

### 3. Results

#### 3.1. Final assembly and detection results.

Upon making a call, the LED of the mobile-phone-detector circuit starts blinking, simultaneously the buzzer starts sounding a beep-alarm. This continues until the transmission ceases. The detector is able to detect the presence of an active-phone within a distance of about 4meters, giving the warning-indication if someone uses mobile-phone within the radius. The simulated circuit of mobile-phone- detector is as shown in Figure 3, while Figure 4 shows breadboard-assembly of the same.

It was observed during the experiments, that the use of purely-analog-circuits made troubleshooting and debugging more difficult as compared to software-related-circuits. Also, the presence of RF-signals from the numerous colleagues' phones all around made the detector circuit over-responsive.

#### 3.2. Operations of the designed-circuit

Here the circuit uses a  $0.22\mu\text{F}$  disk capacitor (C3) to capture the RF-signals from the mobile-phone. The lead-length of the capacitor is fixed as 18 mm with a spacing of 7 mm between the leads to get the desired-frequency. The disk- capacitor along with the leads acts as a small-gigahertz-loop-antenna to collect the RF-signals from the mobile-phone.

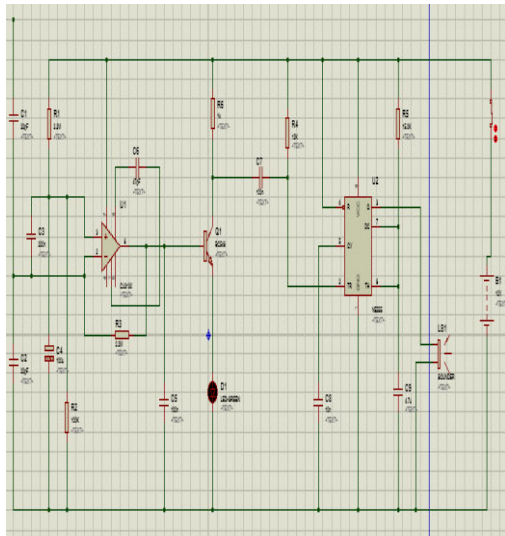


Figure 3: Detector-circuit

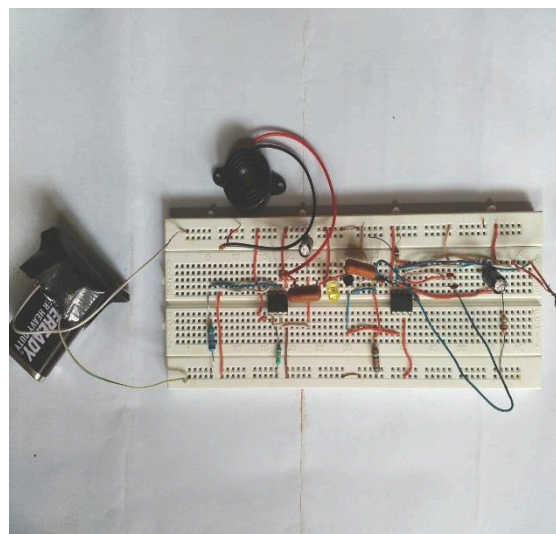


Figure 4: Breadboard-assembly of the detector

Op-amp IC CA3130 is used in the circuit as a current-to-voltage converter with capacitor C3 connected between its inverting and non-inverting inputs. It is a CMOS-version using gate-protected p-channel MOSFET-transistors in the input to provide very-high-input-impedance, very-low-input-current and very-high-speed of performance. The output CMOS-transistor is capable of swinging the output-voltage to within 10 mV of either supply voltage-terminal.

Capacitor C3 in conjunction with the lead-inductance acts as a transmission-line that intercepts the signals from the mobile-phone. This capacitor creates a field, stores energy and transfers the stored energy in the form of minute-current to the inputs of IC1. This will upset the balanced-input of IC1 and convert the current into the corresponding- output-voltage.

Capacitor C4 along with high-value resistor R1 keeps the non-inverting-input stable for easy-swing of the output to high-state. Resistor R2 provides the discharge-path for capacitor C4. Feedback-resistor R3 makes the inverting- input high when the output becomes high. Capacitor C5 is connected across 'strobe' (pin 8) and 'null' inputs (pin 1) of IC1 for phase-compensation and gain control to optimize the frequency response.

When the cell-phone-detector-signal is detected by C3, the output of IC1 becomes high and low alternately according to the frequency of the signal as indicated by LED1. This triggers mono-stable timer IC2 through capacitor C7. Capacitor C6 maintains the base bias of transistor T1 for fast-switching-action. The timing-components R6 and C9 produce very-short-time-delay to avoid audio-nuisance.

#### 4. Conclusions and Recommendations

Overall, the results of this brief-study are potentially-useful, as the mobile-phone-transmission-detector can sense the presence of an activated-mobile-cell-phone. It can therefore be potentially-used to prevent abuse of mobile-phones in examination halls, secretive rooms, seminar halls, private government meetings venues among others. It is also useful for detecting the use of mobile-phone for spying and unauthorized video transmissions.

#### Recommendations

This project has been developed and implemented. However, it can be improved to target more-advanced and better-applications in the next-stage of research. For future improvement, there are several suggestions stated below:

1. The prototype has a limited-range of detection, of only about 4 meters, and therefore future and more-deeper research on improvements should be conducted, so as to increase the range and make the device more-efficient. As such, the response can be optimized by trimming the lead-length of C3 for the desired-frequency; a 12V battery (instead of 9V) of a remote-control may also be used; and a smaller- buzzer should be used to make a pocket-size-gadget. Another sensor-design can be developed to detect how many phones available in that particular area.
2. Due to time-constraint, the testing of the system was conducted only by the use of an activated mobile-phone. Therefore, the 3 additional laboratory-tests(1-to check if the Op-Amp could amplify the received signal; 2- on how the LED working in conjunction with the buzzer; and 3- to see how bright and loud the LED and buzzer could be when the circuit receives signals from the signal-generator) are recommended via an oscilloscope, frequency-analyzer, spectrum-analyzer, bode-plot, and signal generator.
3. Inaccuracy in signal-detection due to presence of noise in signal is responsible for fading/interference, this noise needs to be reduced for optimal-signal-detection, and detection must be accurate-enough to minimize the risk of

false-alarm. A noise-reduction-model developed by Ogunti *et.al.* (2015) to improve signal-detection using component-improvement-strategy is recommended.

4. To enhance the quality of the signal, further-experiments with the antenna-length and shape is recommended (to find the best length or shapes (for example, a short-telescopic-type-antenna) taking into account the frequency involved and chip-circuit-breadboard layout).

## 5. Acknowledgement

The authors wish to express gratitude to the technical-staff of the Electrical Laboratory of ECE, SOE for providing necessary facilities for this study, and to Muthiora Linet for the valuable-assistance in conducting experiments and validation of the system.

## References

- Ajasa, A.; Shoewu, O and Nwamina, P. (2014). "Design and Development of a Mobile Phone Signal Detector". *Pacific Journal of Science and Technology*. 15(2):167-172.
- Amaan, A.; Sahu, M.; Maurya, R.; and Gupta, P. (2013) Project Report. Cell phone detector. Azad institute of engineering & technology, Lucknow (Affiliated to Gautam Buddha Technical University, Lucknow), Department of Electronics Engineering.
- Cellular Detection & Control (2011). Corrections Technology Association, A forum for collaboration. [Online] Available: <https://www.ntia.doc.gov/files/ntia/comments/100504212-0212-01> (May 9, 2016).
- Deshpande, T. and Jadhav, N. (2015) Active cell phone detection and display using Atmega-8 microcontroller. *International Journal of Research in Engineering & Technology. (IJRET)* ISSN (E): 2321-8843; ISSN (P): 2347-4599 Vol. 3, Issue 8, Aug 2015, 21-24.
- EdrawSoft -Electrical Drawing Software.
- Electronics Components Catalog and Datasheets. [Online] Available: <http://www.datasheets4u.com> (June 1, 2016).
- Flood, J. (1995) Telecommunication Switching, Traffic and Networks. Prentice Hall; 1st edition.
- Hämäläinen, J. (2008) Cellular Network Planning and Optimization. [Online] Available: [http://www.comlab.hut.fi/studies/3275/Cellular\\_network\\_planning\\_and\\_optimization\\_part11.pdf](http://www.comlab.hut.fi/studies/3275/Cellular_network_planning_and_optimization_part11.pdf) (June 14, 2016)
- Kainka, B. (2002). "Mobile Phone Sniffer". [Online] Available: <http://www.electronics-circuits.net/mobile-phone-sniffer-vt39.html> (May 21, 2016).
- Lee, W. (2009) "Wireless and Cellular Telecommunications: 3<sup>rd</sup> Edition". McGraw- Hill Engineering.
- Ludwig, R. and Bogdano, G. (2009) "RF Circuit Design: Theory and Applications". Second Edition, Pearson International Edition.
- Mengistu, A. & Imende, S. (2015) Kenya's Mobile Tech Revolution: Nairobi takes its place among the global IT community. [Online] Available: [https://www.kenya\\_tech\\_revolution.pdf](https://www.kenya_tech_revolution.pdf) (June 10, 2016).
- Nicholas, W. (2011). Study of Cellular Phone Detection Techniques, M.Sc. Dissertation, Computer and electronics Engineering, Department of Dissertations & Student Research in Computer Electronics & Engineering, University of Nebraska-Lincoln.
- Ogunti, E.; Lawal, W.; Olatunji, S.; Apena, W.; and Kareem, D. (2015) Detection under Noise Using Component Improvement Strategy. *Universal Journal of Electrical and Electronic Engineering* 3(4): 132-140, 2015.