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Design and Testing of a Cellphone RF Signal Detector

Emmanuel G. Dada*, Stephen B. Joseph, Digima Mustapha

Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State, Nigeria

Abstract This study presents a report of our research work on the design, construction and testing of a cell phone detector. It has become obvious that blocking or jamming of cell phone signals is difficult, expensive, and/or illegal in many situations. A more practical means of controlling cell phones involves detecting their RF signals, followed by confiscation or other intervention. With this, a cell phone detector is a device designed to detect the presence of a cell phone within a certain range of vicinity (from a distance of one and- a-half metres.). Our aim is to design a cell phone detector that can be used to prevent the use of mobile phones in examination halls, confidential rooms, banks, petrol filling stations, military intelligent gathering etc. We made use of two signal detectors each with a dipole antenna, choke, and diode. Each dipole antenna is tuned to 900MHz. When the antennas resonate at 900 MHz a charge is induced in the inductor. A diode then demodulates the signal, which is amplified by an op - amp and passed along to a 3.5mm headphone jack. The results of our experiment shows that the technique used in this design can detect Global System for Mobile Communication (GSM) signals at 900MHz. The realised cell phone detector has been tested and found working and is detecting the cell phones as desired within the design range.

Keywords Cell Phone, RF (Radio Frequency), GSM (Global System for Mobile Communication), Signal Detector, Dipole Antenna.

1. Introduction

Cell phone jammers and cell phone detectors are devices that have recently appeared in the market. The jammers cut-off communications between the cellphone and cellular base-stations by transmitting radio signals without interference with any communications other than cellular within the defined regulated zone.Cell-phone signals usually emanate from a base-station that is usually made up of a very tall building and a small-building housing the radio-equipment [1]. "Cellbuster Cell Phone Detector" [15] is of the opinion that a cellular telephone uses radio signals to communicate between the set and an antenna. The served area is divided into cells something like a honeycomb and an antenna is placed within each cell and connected by telephone lines to one exchange devoted to cellular-telephone calls. This exchange connects cellular telephones to one another or transfers the call to a regular exchange if the call is between a cellular telephone and a non-cellular telephone. The special cellular exchange, through computer control, selects the antenna closest to the telephone when service is requested. As the telephone roams, the exchange automatically determines when to change the serving cell based on the power of the radio signal received simultaneously at adjacent sites. This change occurs without interrupting conversation. According to Frieden and Robert [2], practical power considerations limit the distance between the telephone and the nearest cellular antenna, and since cellular phones use radio signals, it is very easy for unauthorized people to access communications carried out over cellular phones. Currently, digital cellular phones are gaining popularity because the radio signals are harder to intercept and decode.

Cellular Radio Telephone also called cellular telephone or cell phone are low-powered, lightweight radio transceiver (combination transmitter-receiver) that provides voice telephone and other services to mobile users. Cell-phones provide an unbelievable collection of functions [3]. Subject to the cell-phone model, it is possible to store contacts-information, make to-do lists, monitor events, schedules and set reminders or alarm, do arithmetic computation using the built-in calculator, send or receive emails, browse the internet to get information (news, entertainment, and business updates), do audio and video recording, play games, watch TV, send and receive SMSs, and Incorporate devices like PDAs, MP3 players and GPS receivers among others [4].

Cellular telephones primarily operate like portable or cordless telephones. However, unlike conventional wire-based cordless phones, cellular telephones are completely portable and do not require proximity to a jack to access the wire-based networks operated by local telephone companies [2]. There are three key technologies that are being applied by mobile phone providers. They include 2G, 3G, and 4G. A distinct transmission protocol was employed by each generation of technology. The way the mobile phone communicates with the tower will determine the transmission protocols. Typical examples of such protocols include: Frequency division multiple access (FDMA); Time division multiple access (TDMA); Code division multiple-access (CDMA);Global system for mobile communications (GSM) CDMA2000; Wideband code division multiple-access(WCDMA), and Time-division synchronous-code-division-multiple-access (TD-SCDMA) just to mention few [1].

Many researches have been done on the design of cellphone detector to curb the menace of using cellphones in places such as banking hall, Churches/Mosques, university lecture halls, libraries, hospitals, fuel stations, meeting rooms and some other places where serene atmosphere is of paramount importance. Madara and Sitati [5] designed a mobile phone jammer. They made use of resistors, capacitors, inductors and transistors to design the jammer and also generate the required frequency (noise) and then amplifies the frequency generated to range of 800 MHZ to 1.4 GHZ in order to match the frequency of the mobile-phone being transmitted by the base-station. Their proposed technique have a comparatively good jamming capability. The performance of their technique was confirmed by the blocking of the signals of the mobile-phones in 2G and 3Gnetworks (UMTS / WCDMA) operated via Safaricom, Airtell, Orange, and YU service-providers.

Kumar [6] designed a Cellphone RF Signal Detector and Jammer. The proposed mobile detector or sniffer can detect the existence of an activated cell phone from a distance of one and-a-half meters. It can therefore be used to check use of mobile phones in examination halls, confidential rooms, etc. It is also beneficial for sensing the use of mobile phone for espionage and illegal video transmission. The circuit can detect the incoming and outgoing calls, SMS and video transmission even if the mobile phone is kept in the silent mode. Scott [7] opined that a cell phone detector is a device designed to detect/recognize the presence of a cell phone within a certain range in vicinity. It is made in a handy and pocket sized form. This handy, pocket-size mobile transmission detector can sense the presence of an activated mobile phone from distance of one and- a-half metres. So it can be used to prevent the use of mobile phones in examination halls, confidential rooms, banks, petrol filling stations, military intelligent gathering etc. It is also useful for detecting the use of mobile phone for spying and detecting unauthorised video transmission. 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 (Radio Frequency) 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. An ordinary RF detector using tuned LC circuits is not suitable for detecting signals in the GHz frequency band used in mobile phones. The transmission frequency of mobile phones ranges from 0.9 to 3 GHz with a wavelength of 3.3 to 10 cm. So a circuit detecting gigahertz signal is required for a mobile bug.

Oke, Falohun and Adigun [8] designed and implemented a mobile phone detector with frequency jamming cabability. Their approach can measure a mobile phone's electromagnetic properties and clarify the recognizable signature by measuring the RF spectrum and satisfy the jamming requirements.EVI Technology, LLC [9] designed a cell phone detector for detecting and locating cell phones in correctional facilities. The system not only detects the RF emissions from a cell phone, but also uses proprietary software to determine the phone's location. The system is fully compliant with all FCC regulations and does not require any licenses, court orders, or warrants for operation. The system detects and locates any type or brand of phone used on any cellular network.Many people often use the cell phone in an unauthorized area such as schools, colleges (theatre halls and examination centres), banks, petrol filling stations, top government official meeting, and military intelligent gathering.

It is a renowned fact, that the mobile-phones, despite their many benefits to the society, also have become a device used for carrying out nefarious activities which have negative influence on the society as a whole [10]. Generally speaking students in schools have abused the use of cellphone [11]. Berkeley [14] presents a mobile phone sniffer circuit that can detect the signals being used in the GSM (Global System for Mobile Communication) band at about 900 MHz. Since the signals are digitally encoded, it can detect only the signal activity, not the speech or the message contents. A headphone is used to hear the detected signals. There are two separate detector units. Every detector unit consists of a dipole antenna, a choke and a diode. The antenna receives the GSM signals in media. Then a small amount of charge is induced in the choke. The diode demodulates the signal and finishes detecting. The diodes must be schottky diodes or germanium diodes. Since the forward voltage of a silicon diode is high, it won't give a sufficient result in this circuit. LM358 amplifies the received signal. It contains two separate op-amps that are supplied by a common power source. R3 and R7 resistors determine the gain of the amplifiers. When the resistor values are greater than 10M then the noise level increases. If they are small like about 100k, this time it becomes harder to hear the signal.

More recently, in the University of Maiduguri, the security finds it inconvenient to overcome the scourge of students using cell phones in the examination halls as a means of cheating by either transferring the whole lecture notes with key points or downloading directly from the internet during an examination as they called it (Microchips). This research work presents a novel approach for the detection of a cell phone within in unauthorized vicinity by triggering an alarm. The device comprises of power supply, sensor circuit, main circuit, alarm, and a display. The sensor antennas are normally coils of 10 turn molded chokes with a diameter of about 0.5 – 0.6mm wound around a 5mm cylindrical object. The main circuit constitutes the main unit containing two high gain comparators which boast the radio microwave signal received from the antennas. The alarm unit constitute a buzzer that serves as an alarm and can also be replace with a head phone jacket so that the detection can be hear over ear piece. Then the display serves as an indicator which displays an LED when a cell phone is detected.

2. Cell Phone Detector

Broadly speaking, a cell phone detector is devised to sense the activities such as texting, calling, SMS and MMS, being carried out in a cell phone within a specified range. It is an easy to use handy mobile device, sometimes also called as sniffer or pocket-size mobile transmission detector. A number of phone detector manufacturing companies have sprouted in the industry, each offering some or the other exceptional features in their products. You can choose the one as per your own requirements.

2.1. How a Cell Phone detector works

According to [12], a cell phone detector can sense the presence of an activated cell phone within the range of around one and a half metres. The cell phone detector circuit has been designed to perfection so that it may be able to track the appearance of a mobile phone and all its activities, including SMS, video transmissions, incoming calls as well as outgoing calls. “Cell Phone Detection Techniques” [13] by the U.S. Department of Energy argued that the device is quiet capable to function properly even if the cell phone under surveillance is on silent mode. As soon as the detector senses the RF transmission signals from a phone located somewhere in its vicinity, it starts raising a beep alarm which continues till the signal transmission is not ceased [16].

2.2. Uses of cell phone detector

Each of the cell phone detectors have been devised to serve distinct purposes at home, in schools and colleges and other places. Some of their uses are mentioned below:

- ✓ A cell phone detector could be used by school and college administrations to track certain non-permissible activities by the students in the classroom, mostly during tests and examinations. The students often leverage the capabilities of their highly functional cell phones to transfer the academic notes through calls, SMS, MMS and in other forms. With the help of the specialized cell phone detector circuit, this device detects the transmission of any such data between the cell phones kept within a specified range.

- ✓ At places where the cell phones are not allowed at all, a cell phone detector once again is of much use. It could easily sense the presence of a mobile phone inside the restricted area, being carried either intentionally or intentionally. The places under consideration could be examination halls, conference rooms, operation theaters, police stations etc.
- ✓ The company owners and entrepreneurs can also use the cell phone detector to help them track the activities being performed in the cell phones of their employees. This could help them to know if there is some illegal transfer of sensitive data to and from the company premises in the form of text, image, audio or video files being transmitted via cell phones. The detector device being incorporated in the cell phone takes care of that significantly.

3. Materials and Methods

The design of the various units of the system built up the theory of operation of the devices used and the operations are considered. The design is based on the cost, availability of the components for the system realization. The various units were designed and tested separately. It also reverses some calculations made in order to make proper selection of required components in conformity to regulation were taken into account before choosing the components. The cell phone detector system consists of the following combination of sections: Power supply section, Sensor section, Detector section, Alarm section. Under this section a simple techniques was employed to realize the practical value of the components used in the circuit construction.

3.1. The Power Supply Unit

The power supply section (unit) of the circuit provides the driving force that is the electrical energy needed to drive all other sections (units) of the system. This is successfully achieved by using a 9 volt battery as its power supply section.

3.2. Battery

A battery is an electrical device that produces electrical current with collection of cells. Battery, also called electric cell, is a device that converts chemical energy into electricity. Strictly speaking, a battery consists of two or more cells connected in series or parallel, but the term is also used for single cells. All cells consist of a liquid, paste, or solid electrolyte and a positive electrode, and a negative electrode. The electrolyte is an ionic conductor; one of the electrodes will react, producing electrons, while the other will accept electrons. When the electrodes are connected to a device to be powered, called a load, an electrical current flows.

Batteries in which the chemicals cannot be reconstituted into their original form once the energy has been converted (that is, batteries that have been discharged) are called primary cells or voltaic cells. Batteries in which the chemicals can be reconstituted by passing an electric current through them in the direction opposite that of normal cell operation are called secondary cells, rechargeable cells, storage cells, or accumulators. The figure 1 below depicts the schematic diagram of cell.

Figure 1: Schematic Symbol of Cell and Battery

The figure 2 below is the diagram for the battery used in the design of the cell phone detector is showed below:

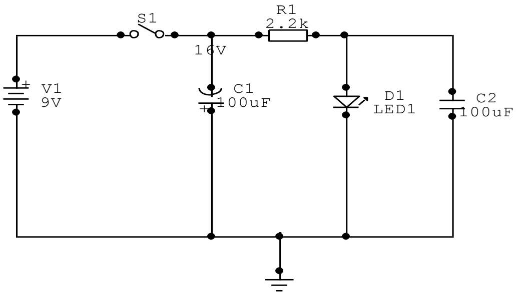

Figure 2: Schematic diagram of Battery

3.3. Sensor Section

The sensor antennas are normally coils of 10 turn molded chokes with a diameter of about 0.5 – 0.6 mm wound around a 5 mm cylindrical object. There are two separate detector units. Every detector unit consists of a dipole antenna, a choke and a diode. The antenna receives the GSM signals in media. Then a small amount of charge is induced in the choke. The diode demodulates the signal and finishes detecting. The diodes must be schottky diodes or germanium diodes. Since the forward voltage of a silisium diode is high, it won't give a sufficient result in this circuit.

3.4. Detector Section (Main Circuit)

The main circuit constitutes the main unit containing two high gain comparators (op-amp LM358). Op-amp IC CA3130 (IC1) 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 (47pF) is connected across 'strobe' (pin 8) and 'null' inputs (pin 1) of IC1 for phase compensation and gain control to optimise the frequency response.

3.5. Alarm Section

This unit constitutes a buzzer that serves as an alarm and can also be over heard through a head phone jacket so that the detection can be heard over ear piece. It will also be helpful in a situation when the security is much tied. The bearer of this device can make the detection in a secret manner in which the defaulter will be unaware. So the detection is more secured in terms of intense security. When the mobile phone 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 monostable timer IC2 through capacitor C7. Capacitor C6 maintains the base bias of transistor T1 for fast switching action. The low-value timing components R6 and C9 produce very short time delay to avoid audio nuisance.

3.6. The 555 Timer Chip

It is a versatile and widely used device capable of generating very stable clock pulse, whose frequency and duty circle are controlled by external resistors and capacitors. The output of the 555 timer goes high (near Vcc) when the 555 timer receives a trigger input, and it stays there until the threshold input is driven at which time the output goes low (new ground) and the discharge transistor is turned on. The trigger input is activated by an input level below ⅓Vcc, and the threshold is activated by an input level above ⅔Vcc. The pin layout of the 555 timer IC is as shown in figure 3 below;

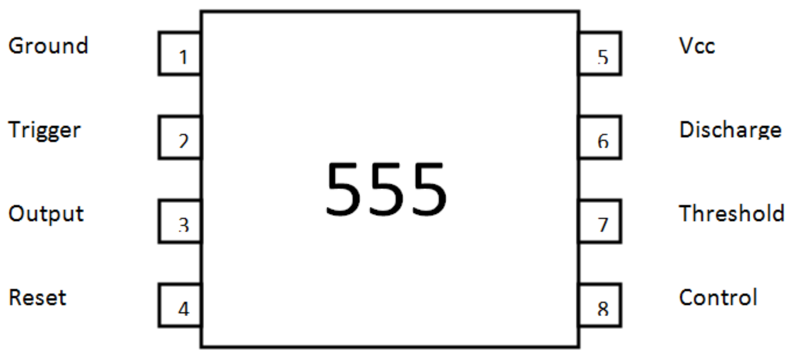

Figure 3: Pin layouts of 555 timers IC

The 555 timer is widely used because it can be configured in two different modes which are: Monostable Multivibrator (one shot) and a stable Multivibrator (oscillator). For the purpose of this research work, a Monostable multivibrator is used.

4. System Design, Implementation and Testing

For the physical design of the cell phone detector that can detect Global System for Mobile Communication (GSM) signals at 900MHz. There are two separate detector units. The block diagram of the cell phone detector is indicated in figure 4.

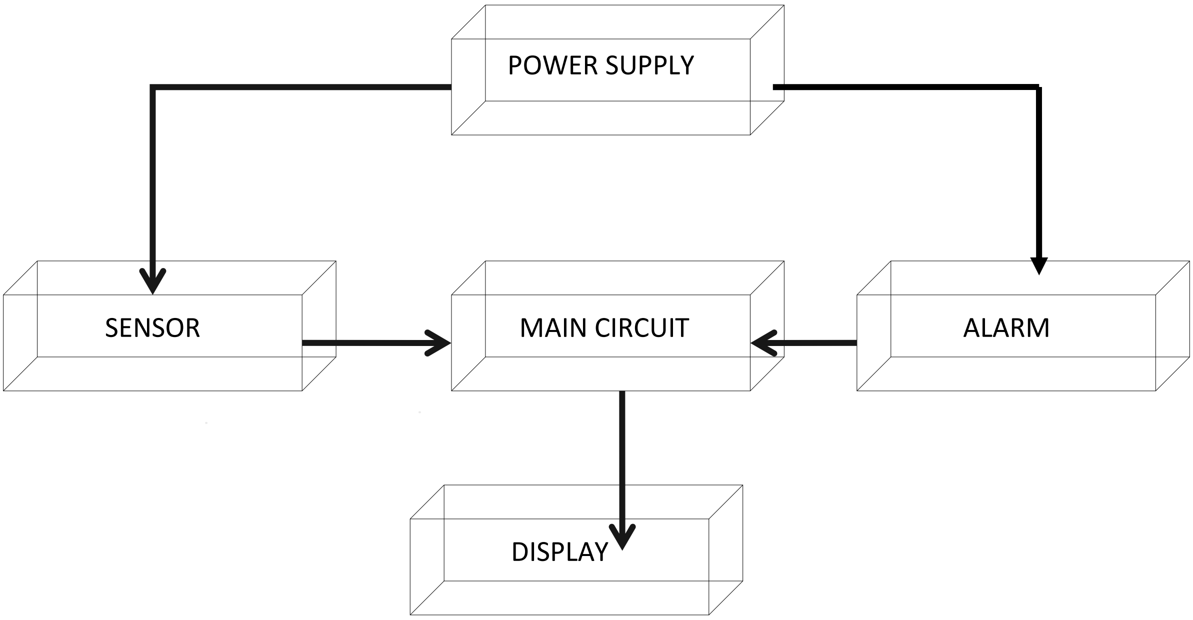

Figure 4: Block Diagram of the Implemented Cell Phone Detector

Every detector unit consists of a dipole antenna, a choke and a diode. The antenna receives the GSM signals in media. Then a small amount of charge is induced in the choke. The diode demodulates the signal and finishes detecting. The diodes must be schottky diodes or germanium diodes. Since the forward voltage of a silisium diode is high, it won't give a sufficient result in this circuit.

LM358 amplifies the received signal. It contains two separate op-amps that are supplied by a common power source. R3 and R7 resistors determine the gain of the amplifiers. When the resistors' values are greater than 10M then the noise level increases. If they are small like about 100k, this time it becomes harder to hear the signal.

R1,	R5	-	:	100K	1/4W	Resistor	
R2,	R6	-	:	1k	1/4W	Resistor	
R3,	R7	-	:	8.2M	1/4W	Resistor	
R4,	R8	-	:	220Ohm 1/4W		Resistor	
R9	-	-	:	2.2K	1/4W	Resistor	
D1,	D2	-	:	BAT43 Schottky	Diode		
C1,	C2,	C4	:	100nF	Polyester	Capacitor	
C3	-	-	:	100uF	16V	Electrolytic	Capacitor
L1,	L2		:				
U1			:	LM358			
J1			:	8Pin	Socket		
J2			:	Stereo Jack			
1			×	9VBattery			
1			×	9VBattery	Socket		
1			x	LED			
1			x	On/Off Switch			

The diodes, gain of the amplifiers and the length of the antenna are critical in this circuit. Calculating the length of the antenna is simple. The formulation is given below.

$$\lambda = c/f = (300.000\text{km/h})/900\text{MHz} = 33.3 \text{ cm Then; Antenna Length} = \lambda / 2 = 16.6 \text{ cm}$$

So there are four pieces of antenna and each one is about 8.3 cm long. The wire type is not critical but it's better to choose a fairly thick wire that will not bend too easily. It is a 1.5 mm diameter wire seen in the photo that we used. The two antennas must be positioned perpendicularly.

The chokes are 10 turn molded chokes. The wire diameter should be about 0.5 – 0.6 mm and wound around a 5 mm cylindrical object. Diodes are very critical. You should use one of BAT43, BAT45, AA112, AA116 or AA119. When a selenium diode is used the circuit also works but the detecting area becomes very narrow. In this design.BAT 43 was chosen due to the advantages.

4.1. Implementation

For this implementation however, a breadboard and wire wrapped connections were used. This was done so that it would be easier to change connections later. Below in figure 5 is the constructed cell phone detector.

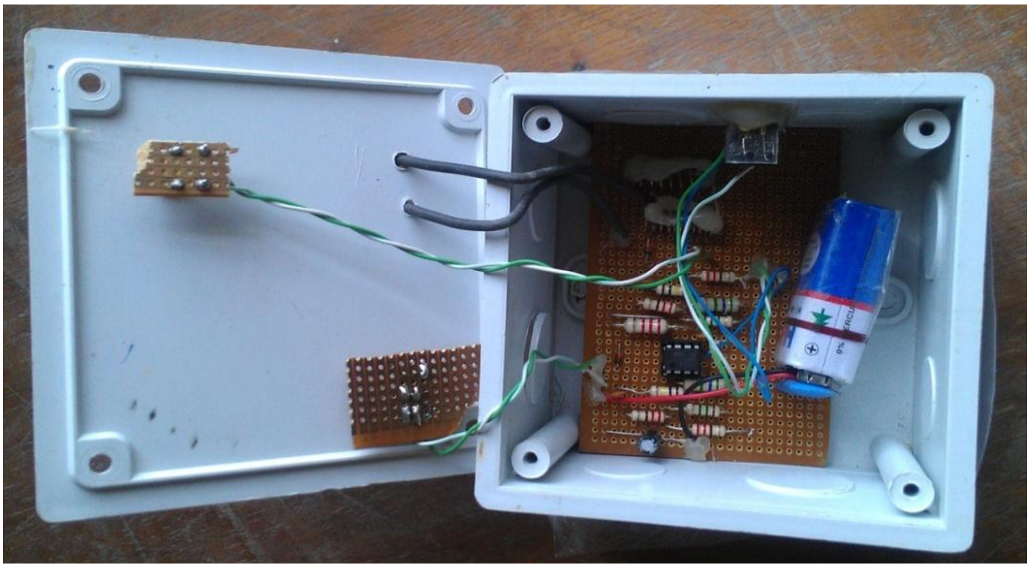

Figure 5: Picture of the completed Cell Phone Detector (Inside view)

4.2. Testing

The first test with this cellular phone detector was to just have an active cellular phone detector in the room. So the LG cellular phone was turned on and a phone call was placed with the detector nearby. Absolutely nothing came out of the connected headphones. To troubleshoot this problem, the circuit was tested with a spectrum analyzer and signal generator. The antenna was connected to the signal generator at 900 MHz with 10dB of amplitude and the spectrum analyzer was connected to the headphone jack using the available probes (only 500 MHz was available). Injecting the 900 MHz signal into the antennas resulted in a lower amplitude signal on the output. To test whether the circuit was resonating at 900MHz, a bandpass test was performed by stepping the frequency at 100 MHz intervals from 600 MHz to 1.2GHz. The amplitude changed at each interval, but was actually lower at 900 MHz than anywhere else and didn't have a bandpass response. The wire wrapped connections may have changed the impedance of the circuit.

5. Conclusion

Obviously, the total effort put in together in this design and construction of the detector device was aimed at solving the problem of cell phone detection. The design, construction and testing of the system was satisfactory and successfully carried out. The system was found very effective and operates in accordance with the design specifications. Consequently, limitations were encountered, one of which was unavailability of some of the required components for the construction of this device in the immediate environment. Further work will be done for the cell phone detector's antenna to be able to direct the cell phone detected and where there are more than one cell phones to indicate the number of cell phones that were been detected.

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