DESIGN AND CONSTRUCTION OF A GSM-BASED MULTI-PURPOSE MEASURING DEVICE FOR UHF SIGNAL STRENGTH LEVELS.

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Abstract— **It has become common for many business entrepreneurs to move with two or three mobile phones at any particular time in Nigeria. The reason is usually anchored on the epileptic reception of the telecommunications networks and their desire to keep in touch with their businesses. This burden can be made lighter if signal strength levels of Telecommunications' operators can be periodically measured and predicted without resorting to the Network operator; like weather forecasting. The design and construction of this GSM-based multi-purpose measuring device for Ultra-High Frequency (UHF) signal strength levels was conceived as a pilot project to monitor signal strength levels of operating networks in any particular area. This programmable electronic controller can also be used for plethora of applications such as controlling and tracking of household appliances. In this study, it was tailored to exploit measurements of UHF signal, with a view to determining the response time of signal strength levels of operating networks within a location. Results obtained from test measurements shows that there were severe delays in some locations at certain time; while it was almost impossible to establish good communication link at some areas. It was further noted that the switching ability of this device took 03 to 04 seconds after the instruction had been given in areas of strong mobile signal strength levels. It also took 12 to 14 seconds in areas of weak signal strength levels; and at times, failed to respond under fluctuating and weaker signal conditions.**

***Keywords*—Design, Base, Transceiver Stations, Switching Centers, Mobile system, GoS, HLR, MSC.**

1. Introduction

In the Information and Communications parlance, signal strength levels assume the establishment of an effective and efficient communication network. Poor signal reception is usually regarded as unacceptable to the subscriber, the operator and the regulator. Yet, there are places where very poor signal are received in our locality to an extent that poor audio calls are established to the detriment of the service users and the advantage of the operators' account. Pathetically, this is a precursor to the reason why service consumers are disposed to lugging more than one cell phone in their hands since they cannot vouch for the quality and reliability of the service quality they may likely receive as they change their locations. This poor quality of service in our telecommunication industry is an issue that calls for cognate attention. This is why the design and construction of this controller device is timely. Based on the results of the study, consumers within the study locations can be guided on the signal strength levels and the ideal period to communicate at any particular location, irrespective of the network operator. This programmable electronic controller can be configured for plethora of applications; such as door locking security system and bit rate measurements of UHF signal. The study focused on determining the signal strength levels of all the network operators in a particular location.

2. MATERIALS AND METHOD

The controller encompasses four major sub-units which are [4]: PIC Microcontroller, DTMF decoder, Relay and Voltage Regulator. Nevertheless, the modus operandi of a mobile phone for voice call (dialing) is applicable since the device uses mobile phone to accomplish its task. Each key on the DTMF keypad is linked to a combination of two non-harmonically related tones in the audible range. At the receiving side, the tone pairs are decoded into a designated code (0-9, #, *). For this application, the mobile phone was set to auto-answer mode.

The program was certified to run without errors before it was written into the microcontroller using Super Pro 6100 universal IC-programmer. In operation, the PIC microcontroller continuously monitors the level at RA4 (pin 3). A ring signal will wake up the microcontroller from its idle state and the program running inside the PIC waits for certain DTMF tones to be entered by the user on his/her mobile phone. The received DTMF signals were decoded into the matching numbers by DTMF decoder labeled U1, which supply binary output information through pin 11 (Q1) to pin 14 (Q4), with output STD (pin 15) flagging reception of valid code to the microcontroller [5]. Hence, causing it to activate the relay control board and in turn light-up the LED. The signal strength was determined by checking the response time between when the call was initiated and how long it took the controller to activate the LED for all the selected locations. This process was repeated for four registered telecommunication networks used in Nigeria. However, pseudo codes (alphabets A, B, C and D) where used in place of corporate operators in order to maintain secrecy.

2.1 The Design Perspective of the Controller

The operational principle of this work used Dual Tone Multi Frequency (DTMF) decoder, to decode the DTMF signal transmitted through the mobile phone network [5]. The DTMF-based load-control system was designed using modular approach; with four different modules combined together to form the full work. The discrete components consist of smaller components. The modules were used to build circuit in line with the design. The four

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major components of the circuit design were: the PIC microcontroller, the DTMF tone decoder, and the relay and voltage regulator [7, 8]. The sequence of operation of the device and the mode of interaction of the various units are represented in the Fig. 1

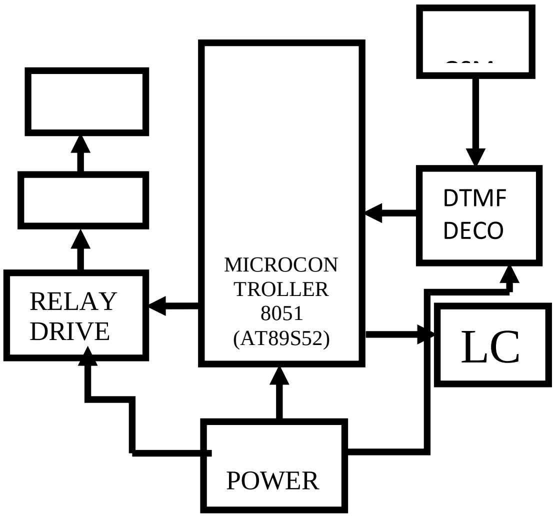

Fig.1 Block diagram of GSM-based multi-purpose measuring device

2.1 PIC Microcontroller

Programmable Interface Controller (PIC) is an electronic circuit which was programmed using SuperPro 6100 universal IC programmer to carry out many tasks [2,3]. It can be programmed to be a timer or to control a production line, and many more. It was written into the microcontroller using SuperPro 6100 universal IC programmer. Fig. 2 is the pin out diagram of PIC microcontroller (type 16F84A) used for this work [2,3].

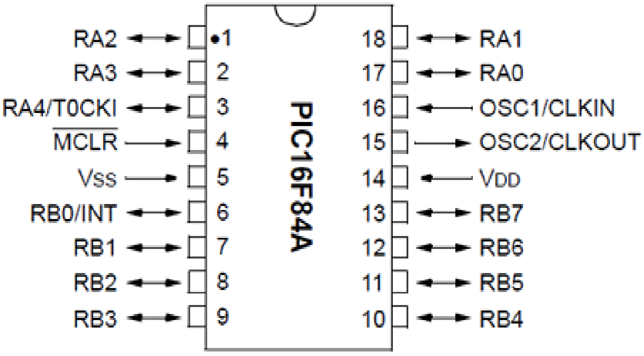

Fig. 2: Pin out diagram of PIC Microcontroller (type 16F84A)

The dual in-line package format of the IC (PIC16F84A) is an 8 bit microcontroller, made it easy to be inserted on breadboard and strip board; thereby assisting to get straight forward connections to the pins. The flash memory also can be programmed and erased electrically without disconnecting the chip from the circuit [6].

2.1.1 Microcontroller and Relay Driver Unit Design

The microcontroller and relay driver unit consist of PIC16F84A and ULN2003. In operation, the PIC microcontroller will continuously monitor the level at RA4 (pin 3). A ring signal will wake up the PIC from its sleep state and cause it to activate the transistor array. This process supplies the activating current to the coil of the relay as shown in Fig. 3 [4]. The microcontroller IC drives the base of the transistor.

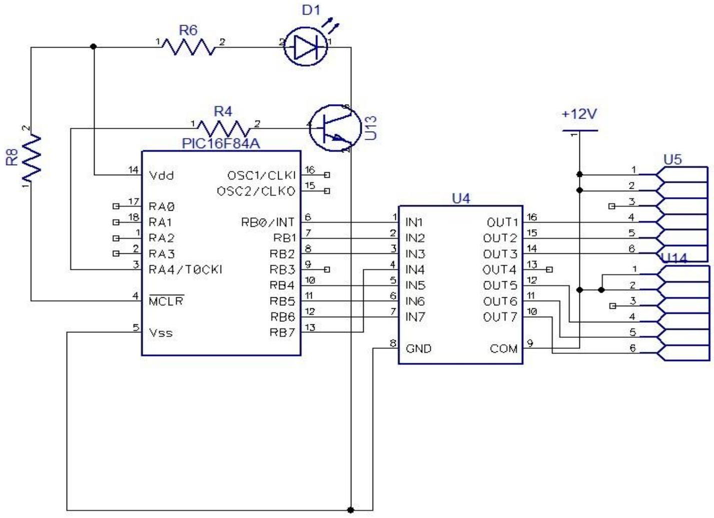

Fig.3: Circuit diagram of the output relay module

2.2 DTMF Tone Decoder

Figure 4 shows the internal functional block diagram of a DTMF decoder integrated circuit. The DTMF tone decoder is an integrated receiver for the band split filter and digital decoder functions. The filter section employs switched capacitor techniques to trigger the high and low group filters. It uses binary counting techniques to detect and decode all 16 DTMF tone pairs into a 4-bit code [5].

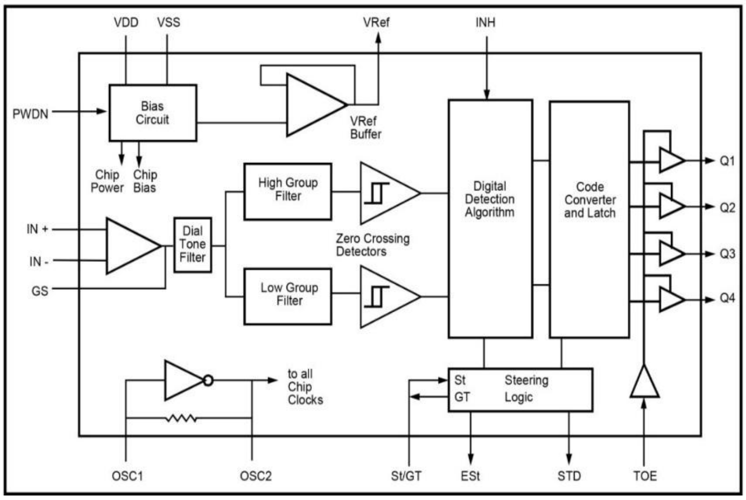

Fig.4: Functional block diagram of a DTMF tone decoder chip

Usage of external components was limited during the design and construction processes. This was achieved through chips with differential input amplifier, clock oscillator and latched three-state bus interface [1]. Figure 5 shows the pin configuration of MT8870 DTMF tone decoder chip used in this study.

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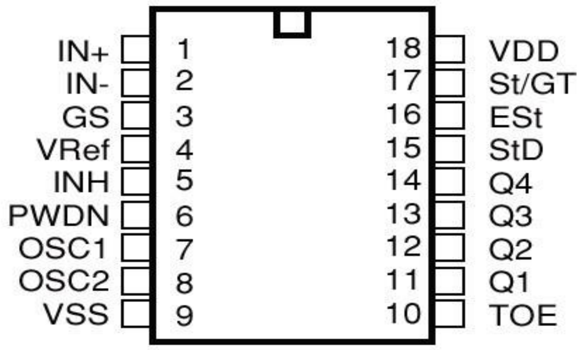

Fig.5: Pin configuration of MT8870 DTMF decoder

2.2.1 DTMF Decoder Circuit Unit design

Figure 6 is the DTMF decoder unit. The circuit is used to decode the mobile phone signal transmitted through the mobile set to produce the required information using 4 bits. The output of the circuit (Q1 to Q4) are connected to RA0 through RA3 inputs of the microcontroller. Through this unit, dial tone from a mobile line is detected and decoded by pressing the keypad.

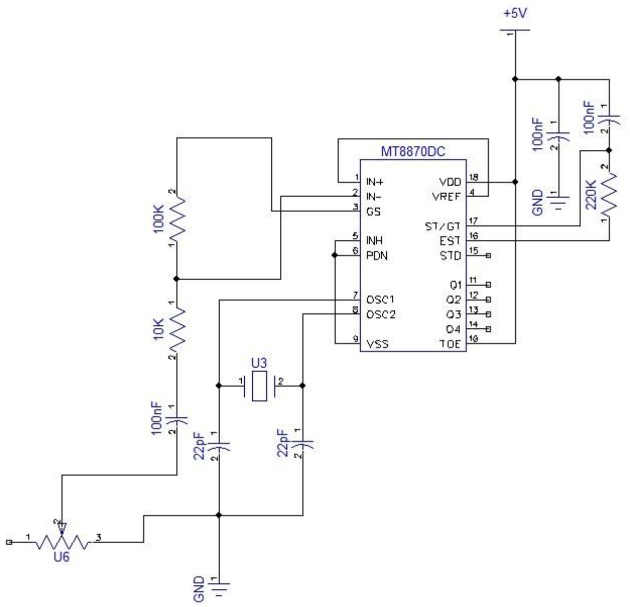

Fig. 6: Circuit diagram of the DTMF decoder module

2.3 Relay Control Module Circuit

The Relay control module circuit shown in Figure 7 can be used to remotely control three different home appliances electronically. The module is controlled through the activation of the correct DTMF on the phone keypad. This turns on the proper relays.

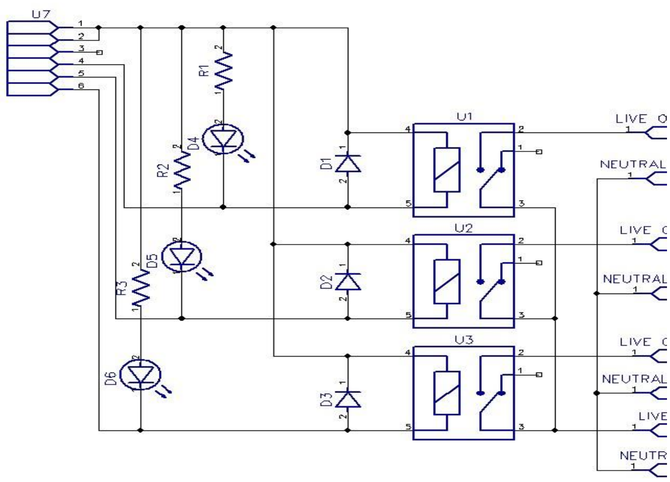

Fig.7: Circuit diagram of the output Relay Module

The relay controller interfaces with the microcontroller and the driver unit to switch on the appliance whenever it receives a valid DTMF code from the Decoder Integrated circuit. In this design, a ULN2003 transistor is used and it activates the current needed to energize the relay in the circuit [6]. The transistor is turned on by supplying a positive pulse signal to the base of the transistor. This process transmits the required current to close the relay.

2.4 Power Supply Unit

The power supply unit as shown in Fig. 8 is designed to convert the input alternating current (ac) to direct current (dc). The dc is required to drive the circuit for proper functionality. This is achieved through the aid of a 12V/500mA step down transformer, diodes arranged in a full bridge rectification mode and a 1000µF smoothing capacitor [2]. Instead of using resistors and zener diodes for regulation, two voltage regulators numbered 7805 and 7812 were used to tailor the voltage to their respective loads.

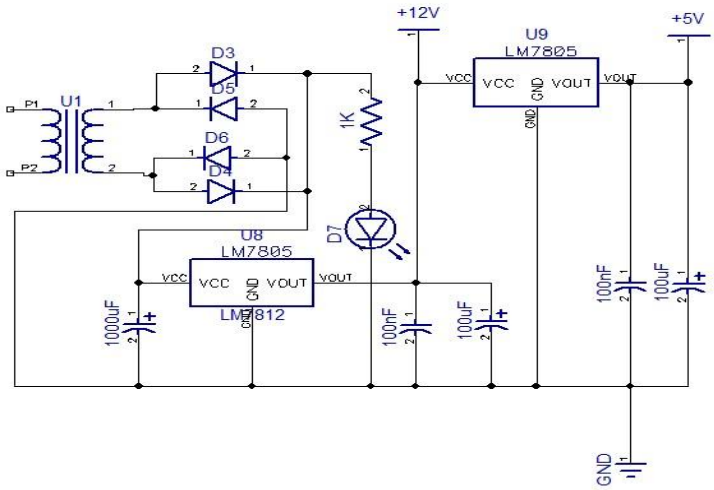

Fig. 8: Circuit diagram of the power supply module

2.5 Software Programs for the Microcontroller:

Microcontroller device is the core intelligent component of the module. Through this unit, the module was programmed to support the operation of the hardware. The source code was compiled through M-IDE studio and MC-51 software development, and written in assembly language. The compiled source code was burned into the microcontroller through the aid of the universal programmer [3]. Series of steps were followed in order to develop and sustain a reliable and maintainable software.

2.5.1 Writing of the Project Source Code:

Man- machine language commands were initiated to configure all the component-units of the module for effective communicate. The codes used were written in assembly language with visual basic software and compiled with M-IDE [3]. These procedures were effective for Window XP environment in view of the reduced errors noticed.

2.7 Device Circuitry and Analysis.

The modular parts of the design were combined to achieve the schematic of a GSM-based multi-purpose measuring device for UHF signal strength levels of Fig. 9. The connector for the headset was plugged into the mobile phone and the wires to the earphone pieces were connected to any of the inputs labeled U7, U11 and U12, which in turn, served as inputs to the DTMF decoder (IC type MT8870 (U1). The received signals were applied to pin RB2 of the central microcontroller, a PIC16F84A labeled U2 in the circuit.

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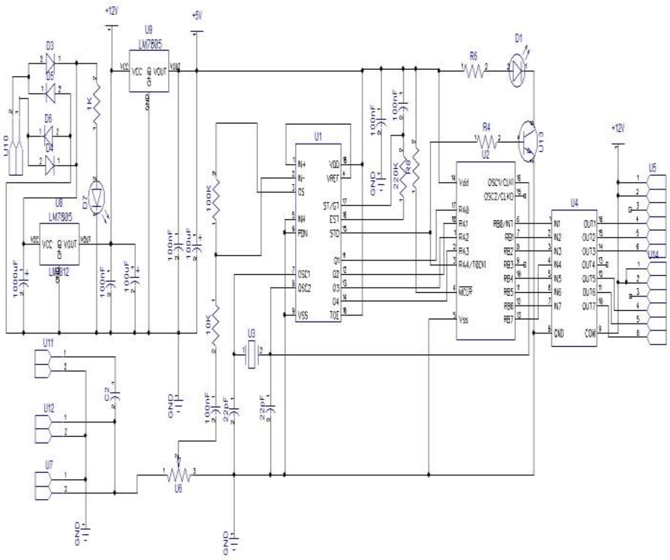

Fig.9: Device circuitry

2.8 Construction, Packaging and Testing of the Device.

2.8.2 Testing of Device

The circuit was tested using a digital multi-meter through the following ways:

- Short circuit test was first carried out by placing the multi-meter probes at different terminals with reference to the ground terminal, while observing the continuity of the meter.
- Open circuit test was then carried out by testing the continuity of the device circuitry. This test was carried out to ensure that no component was left unconnected and broken PCB tracks were not left open.
- Finally, voltage test was carried out to ensure that the correct and maximum allowable voltage was passed to the circuit from the internal power supply. This test also helped to make sure that the integrated circuits and other circuit components received the correct voltage so that they may not get damage during operation. This was achieved by connecting the 12V d.c to the circuit and checking the voltage between pins 5 and 14 of the microcontroller IC socket, while the microcontroller IC was yet to be installed. Pin 14 was positioned at +5V with respect to pin 5 (GND).

The microcontroller was finally installed and electrical energy reapplied. Lighting of the red LED and a faint click of the corresponding relays were observed as the completed project turned on.

3. RESULTS AND DISCUSSION.

3.1 Results:

Signal strength was monitored and confirmed in terms of it response time between when the call was initiated and how long it took the second phone connected to the audio jack controller to activate the LED. This was observed for all the selected locations. The response time was measured using a Gheko 15BC digital stopwatch. These locations were: Uyo (Lat. 5.02^0 N, Long. 7.56 E), Afaha-Nsit (Lat. 4.820N, 7.88E), IkotEkpene (Lat. 4.38N, Long. 7.44E), Eket (lat. 4.38N, Long. 7.56^o) and Oron (Lat.4.49N, Long. 8.14N).

This process was repeated for four registered telecommunication network used in Nigeria. Though, the result is presented using pseudo codes (alphabets A, B, C and D) and not their networks corporate names.

When the device was connected to a.c supply, a red LED indicator showed that the device was ready for use. A mobile phone set to **auto-answer mode** was connected to the jack of a cell phone as shown in Fig. 10.

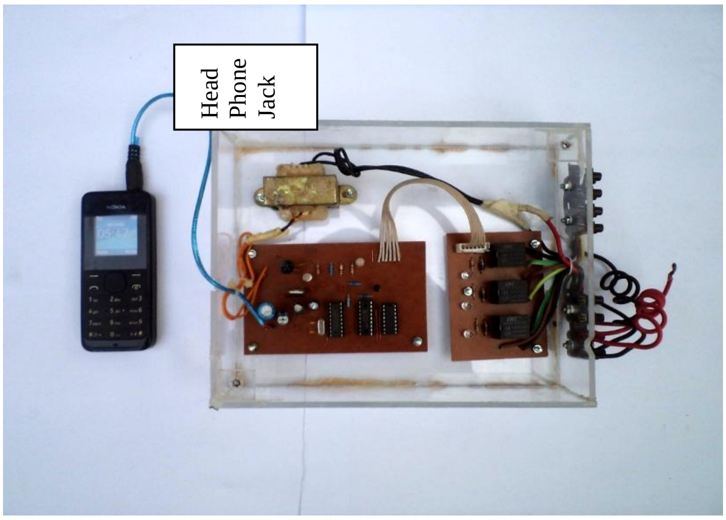

Fig.10: Device Display

Operating the device requires the following instructions:
Dial the phone number of the receiver from your mobile phone, followed by the instruction(s) as supplied in Table 1.

Table 1. Device command Function.

Command	Relay terminal number	Green led
*10#	All	On
*00#	All	Off

Each instruction (activation code) was set to default as shown on Table 1, when dialed from the user's cell phone activated the corresponding indicator and relay. This in turn activated the green LED. This device was operational with any available mobile telecommunication networks within the vicinity, provided the signal strength was strong enough to drive (flip-flop) the DTMF decoder. Below are Tables showing the response time measured with a Gheko 15BC digital stopwatch for the four selected networks and locations.

TABLE 2. Network Provider and Response Time for Uyo (Lat. 5.02^0 N, Long. 7.56^0 E)

Network Providers	Response Time(second)		
	Morning	Afternoon	Evening
A	05	09	07
B	09	11	06
C	06	07	04
D	10	12	09

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TABLE 3. Network Provider and Response Time for Afaha-Nsit (Lat. 4.82^0N, 7.88^0E)

Network Providers	Response Time(second)		
	Morning	Afternoon	Evening
A	12	14	05
B	05	10	12
C	09	06	03
D	07	07	13

TABLE 4. Network Provider and Response Time for IkotEkpene (Lat. 4.38^0N, Long. 7.44^0E)

Network Providers	Response Time		
	Morning	Afternoon	Evening
A	09	12	11
B	10	09	07
C	07	10	05
D	08	11	12

TABLE 5. Network Provider and Response Time for Eket (lat. 4.38^0N, Long. 7.56^oE)

Network Providers	Response Time		
	Morning	Afternoon	Evening
A	07	05	09
B	07	10	09
C	06	08	04
D	08	09	07

TABLE 6. Network Provider and Response Time for Oron (Lat.4.49^0N, Long. 8.14^0N).

Network providers	Response time		
	Morning	Afternoon	Evening
A	14.	13	10
B	16.	14	12
C	10	11	11
D	06	10	09

3.2 Discussion

From the results presented above, it can be adduced that the transmitting and the receiving phones attached to the controller were able to communicate effectively. Though, there was severe delay in some locations at some time; where it was almost impossible to establish a good communication link. However, this was circumvented by continuous trial. A critical look at Tables 2 to 6 , show that network provider C had the lowest response time at Uyo, Afaha-Nsit, Ikot-Ekpene and Eket. This suggests that this telecommunication company provided a relatively better signal strength and may be operating close to the Key Performance Standard (KPS) specified by the Nigerian Communication Commissions (NCC). However, network D was better-off at Oron.

Furthermore, communication link was seemingly easy to establish across the locations in the morning. However, it was protractedly difficult to establish a good communication link across the study locations in the afternoon time. This may be attributed to the fact that business transactions at this time of the day were at its peak and many users were transacting through their phones. This situation can be termed as network congestion. During the evening period, the number of users seemed to have reduced moderately as the signal strength increased and there was reduction in the response time.

It is also worthy of note that the variation in response time across the study locations was a cursor to some factors like: the location variables, demographical variables, weathering condition at that time, antenna capacity and signal strength, etc.

4. CONCLUSION.

Test operations carried out with the device in Uyo capital city, Afaha-Nsit, IkotEkpene, Eket and Oron Local Government Area headquarters in AkwaIbom State, showed that delayed response was depended on the signal strength transmitted by the mobile network provider. The switching ability of this device took 03 to 04 seconds after the instruction had been given in areas of strong mobile signal strength. But it took 12 to 14 seconds in areas of weak signal strength; and at times, failed to respond under fluctuating and weaker signal conditions. From this empirical study, users of this instrument are advised to allow some time interval after each DTMF tone has been processed for appropriate response from the device.

The use of ICs made the designing aspect of the circuitry simple and less stressful when compared to using discrete transistors. However, the various ICs used in this work were carefully studied before installing into the circuit design. The piece was fascinating: sandwiching raw electronics into telecommunications and practically putting it to use. Putting this device to use at homes, offices, etc., in line with previous studies, will enhance full control of home electronic gadgets. Through these measures, inherent hazards caused by leaving them on while away can be avoided. It can also safe-guide wasteful electrical energy consumption.

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