Design And Implementation Of A Mini Radio Transmitter On A Locally Made PCB

[1]Onah, Nicodemus C., [2]Ezike, Afamefuna M. [3]Udechukwu Felix
[1]nicodemus.onah.191775@unn.edu.ng [2]afamefunameanwellezike@gmail.com
[3]felix.udechukwu@unn.edu.ng
Department of Electronic Engineering, University of Nigeria.

ABSTRACT
This work aims at designing and constructing a low cost and low power FM transmitter with simple locally sourced components to cover a range of five hundred metres (500m) with an embedded 3 channel audio console which accepts audio input signals for transmission to any receiver tuned to the transmitter within the 500m range. This work was divided into three parts namely: transmitter, audio console and the power supply unit for ease of design and implementation. The design phases of the work include: bread board phase, Vero board phase and lastly the PCB phase. In testing the work, an audio signal is generated using an MP3 player, this audio signal from MP3 player is sent to the transmitter through one of the inputs of the audio console, after transmission, the signal is picked up using a radio set.

Keywords: Frequency modulation, transmitter, printed circuit board, audio console.

INTRODUCTION

There are so many ways to modulate a carrier signal for transmission. A sine wave carrier signal can be modulated by varying its frequency, amplitude or phase shift. When the frequency is being varied, the modulated signal produced is referred to as Frequency Modulated (FM) signal. According to Frenzel (2016), the basic equation for a sine wave carrier is shown by equation 1 below:

$$v = V_c \sin(2\pi f t \pm \theta) \quad \ldots (1)$$

where:

V_c = peak voltage, f = frequency, θ = phase shift

A FM is produced by impressing an information carrying signal on the carrier wave by varying its frequency. In Elprocus (n.d), the FM transmitter is a lower power transmitter and it uses FM waves for transmitting the sound, this transmitter transmits the audio signals through the carrier wave by the difference of frequency. The carrier wave signal is equivalent to the audio signal of the amplitude and the FM transmitter produce VHF band of 88 to 108MHz range. In addition to their use in broadcasting, transmitters are necessary component parts of many electronic devices that communicate by radio, such as cell phones, wireless computer networks, Bluetooth enabled devices, garage door openers, two-way radios in aircraft, ships, and spacecraft, radar sets, and navigational beacons. The term transmitter is usually limited to equipment that generates radio waves for communication purposes; or radiolocation, such as radar and navigational transmitters.

A transmitter can be a separate piece of electronic equipment, or an electrical circuit within another electronic device. A transmitter and receiver combined in one unit is called a transceiver. The term transmitter is often abbreviated TX in technical documents. The purpose of most transmitters is radio communication of information over a distance. The information is provided to the transmitter in the form of an electronic signal, such as an audio (sound) signal from a microphone. The transmitter combines the information signal to be carried with the radio frequency signal which generates the radio waves, which is often called the carrier. This process is called modulation. The information can be added to the carrier in several different ways, in different types of transmitter. The antenna may be enclosed inside the case or attached to the outside of the transmitter, as in portable devices such as cell phones, walkie-talkies, and garage door openers. In more powerful transmitters, the antenna may be located on top of a building or on a separate tower, and connected to the transmitter by a feed line, that is a transmission line. The advantages and disadvantages of FM transmitters as outlined in Elprocus (n.d) are summarized as follows: the FM transmitters are easy to use and the price is low, has a large operating range, high efficiency and reject the noise signal from an amplitude variation. On the other hand, in the FM transmitter the (sic) huge wider channel is required, transmitter and receiver will tend to be more complex and due to some interference, there is poor quality in received signals.

PROBLEM STATEMENT

Wireless communication using FM transmitter is a widely used medium of communication; which has been improving ever since its discovery in 1986. A rapidly growing demand for the use of FM transmitter exists among individuals and institutions. For example, universities and other tertiary institutions need to broadcast educational, entertainment and even news programme that are particularly designed for campus audience. FM transmitters are also required in the laboratories for practical and hands-on teaching of students who have interest in communications. Hence, the need for FM transmitter system cannot be overemphasized.

However, the problem is that most FM transmitter systems in Nigeria are foreign-made especially from China and the cost is always at the peak. This work demonstrates that such systems as FM transmitters can be made locally and be optimized for use in our locality. We intend to design and construct, an FM transmitter that can be used for both teaching and research purposes at a relatively cheap rate compared to the ones that are not locally made.

AIM AND OBJECTIVES

The aim of this work is to design and implement a low cost and low power FM transmitter. This aim will be achieved through a methodological approach with the following set objectives:

- Analysis, review and study of previously implemented FM transmitter systems.
- Implementing our own locally sourced FM transmitter system with audio console.
- Testing the strength of our transmitter with the help of an already-made signal source (MP3 player) and receiver set (mobile phone).

WORK SCOPE

This work work is limited to a short wireless distance of 500**m** and a low power rating of 1watt; this implies that if a signal is generated anywhere within the range of 1-500**m** and transmitted using our FM transmitter, the receiving set within the given range can get tuned to the transmitting frequency. The signal source is limited to an MP3 player as other information sources like text from keyboards, camera pictures, signal generators, etc. were not put into consideration.

The work is completely hardware based.

LITERATURE REVIEW

Radio development began as "wireless telegraph", later radio history increasingly involves matters of broadcasting. The idea of wireless communication predates the discovery of "radio" with experiments in "wireless telegraphy". Bellis (n.d). According to www.sparkmuseum.com (n.d), ***James Clerk Maxwell*** showed in theoretical and mathematical form in 1864 that electromagnetic waves could propagate through free space. In 1888 ***Heinrich Rudolf Hertz*** was able to conclusively prove transmitted airborne electromagnetic waves in an experiment confirming Maxwell's theory of electromagnetism. (Baierlein, 1992). Over several years starting in 1894 the Italian inventor ***Guglielmo Marconi*** built the first complete, commercially successful wireless telegraphy system based on airborne Hertzian waves (radio transmission). In 1901, Marconi conducted the first successful transatlantic experimental radio communications.

Around the start of the 20th century, the ***Slaby-Arco*** wireless system was developed by ***Adolf Slaby and Georg von Arco.*** (Klooster, n.d). The period from the 1920s to the 1940s is often called the ***"Golden Age of Radio",*** it began with the birth of commercial radio broadcasting. Radio was the first broadcast medium, and people regularly tuned-in to listen. (Donna, 2007).

Amplitude Modulation (AM) was the first method developed for making audio radio transmissions, and is still used worldwide, primarily for medium wave (also known as "AM band") transmissions, but also on the longwave and shortwave radio bands. (Nahin, 2001).

FM broadcasting is a method of radio broadcasting which came later, it uses frequency modulation (FM) technology invented in 1933 by American engineer ***Edwin Armstrong***, wide-band FM is used worldwide to provide high-fidelity sound over broadcast radio.

The earliest radio stations were ***radiotelegraphy systems*** and did not carry audio. For audio broadcasts to be possible, electronic detection and amplification devices had to be incorporated. The basic forms of radio broadcast are AM and FM.

FM broadcasting is capable of better sound quality than AM broadcasting (under normal listening conditions). Theoretically, wideband AM can offer equally good sound quality, provided the reception conditions are ideal. FM radio stations use the VHF frequencies. The term "FM band" describes the frequency band in a given country which is dedicated to FM broadcasting. (ITU, n.d).

*R*adio broadcasting is transmission by radio waves intended to reach a wide audience. Stations can be linked in radio networks to broadcast a common radio format, either in broadcast syndication or simulcast or both. The signal types can be either analogue audio or digital audio. (*Lathi, 1998).*

EVALUATION OF PREVIOUS STUDIES RELEVANT TO THIS WORK

In Ogbuanya (2017), a Frequency Modulated (FM) Transmitter was designed and constructed with Output Capacity of 10 Watts and Range above 4km. This work is very similar to our work but differ in power rating and distance covered by the signal as ours will have a power rating of ***1 watt*** and will cover a distance of ***500m*** which seems simpler but then this work aims at minimising power usage and optimising transmission and signal strength. It also differs from ours as we try implement using ***audio console*** to control the input and output signal.

Also as seen in Shin (1998), the work involved the design and construction of a Frequency Modulation (FM) transmitter and receiver. His design involves a wireless communication system with frequency modulation (FM) technique operating at a frequency of 90MHz and limited at simplex communication only. The transmitter and receiver is "hand-set" sized which is impressive as the designer took deeply into consideration "portability" of his design which is vital in the design of any electronic circuit.

His work was similar to ours but did not take into consideration the range of coverage as in ours but then his design of a receiver system is indeed impressive.

Therefore, our work is advantageous in that we try to:

- Minimize power and optimise transmitting signal strength
- Take into consideration distance covered by signal
- The implementation with an audio console

From the work in Adamu (2009**),** the work was from the department of Electronics and Computer Engineering, Federal University of Technology, Minna, a long-range FM transmitter was designed and constructed. Just like ours, distance was taken into consideration but in *Zakari Adamu's* work, he tried to design a system that travels a very long distance i.e. several kilometres of transmission.

The major advantage of ours over his is the use of an audio console, the clarity of our transmitting signal over 500m and the minimization of power to 1 watt.

As seen in Nnolum and Mamah (2018), in the department of Electronic Engineering, University of Nigeria, Nsukka, two students designed and implemented a laboratory dual antenna receiver system. In this work, a wireless communication system that could be used for teaching purposes was constructed. A low-cost transmitter and receiver system that is equipped with space diversity scheme was designed and implemented. In their design, they discovered that there was an improvement in the audio intensity of the signal received form the diversity scheme was better and clearer than that received from the single antenna.

The merits of our work over this work include

- ✔ The longer range of distance we intend to transmit our signal. Theirs was transmitted over 15m but try to implement over a distance that is 33.33 times theirs (i.e. 500m).
- ✔ The use of an audio console which welcomes the idea of the choice and selection of the desired audio signal so desired for transmission.
- ✔ Quality and strength of the signal over this distance.

DESIGN, IMPLEMENTATION, TESTING AND RESULT ANALYSIS

The construction of this work took three phases, these phases are followed with their respective simulation and analysis upon implementation. These phases are:

- ❖ First Stage (Breadboard construction phase)
- ❖ Second Stage (Vero - board construction phase)

- Third Stage (PCB construction phase)

FIRST STAGE

In this stage, a simple transmitter circuit is designed and implemented on a breadboard with the aim of simply generating a carrier signal and modulating this signal with an audio signal obtained from a mic.

With this aim achieved successfully, improvements can be done as well as progress in the work.

The audio signal obtained from the mic is amplified with a simple transistor, and as it is amplified, it modulates the carrier signal generated by a tank circuit.

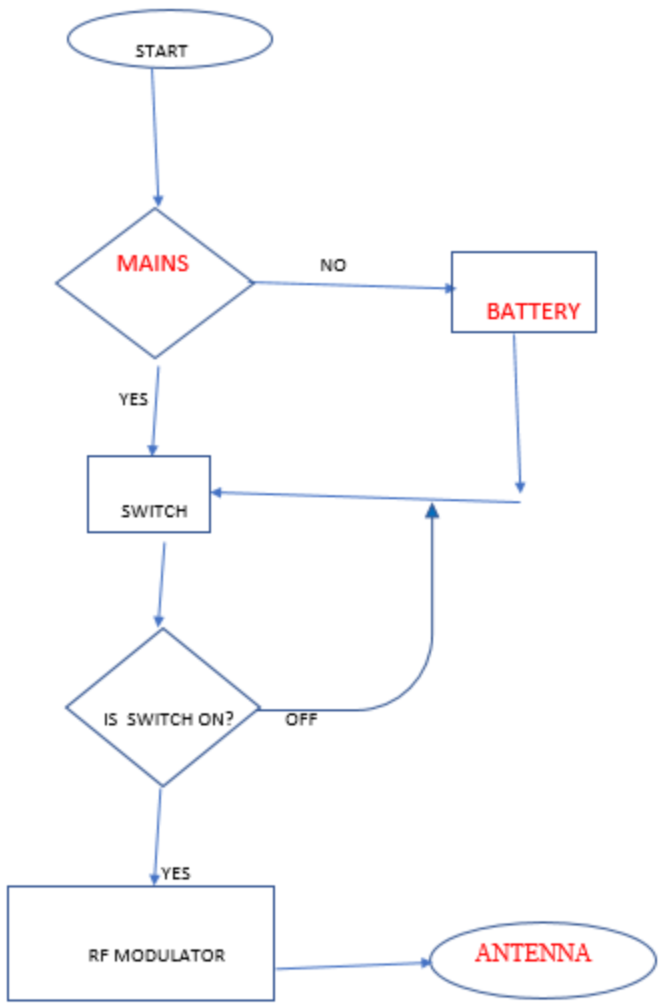

Figure 1: System flowchart

The following equipment were used in this phase:

- ✔ 2N3904 transistor
- ✔ MIC
- ✔ Capacitors (10pF X 2, 10nF, 1nF)

- ✔ Resistors (10k-ohms and 470-ohms)
- ✔ Inductor
- ✔ 9volts battery with a battery cap
- ✔ Connecting wires.

The above circuit components were coupled on the breadboard and the circuit diagram described as follows:

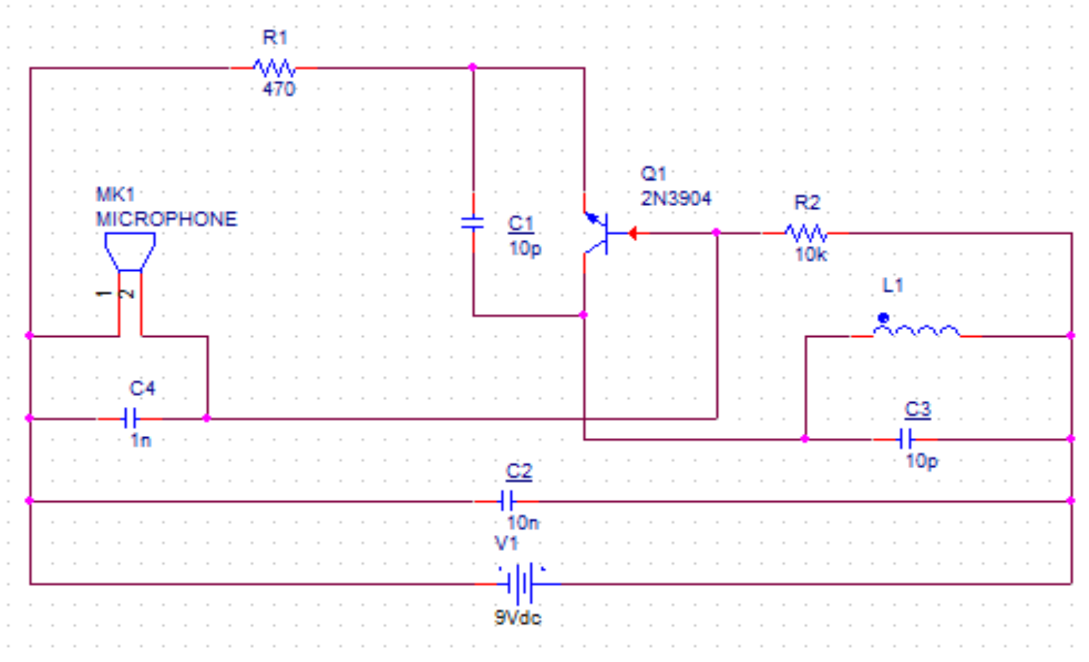

Figure 2: SEQ Figure * ARABIC 2: breadboard phase transmitter circuit diagram

The basic quality of the breadboard phase implementation is the simplicity of the design and also the fact that there is no soldering involved.

Drawbacks of the breadboard construction phase:

- Too much noise is generated in the system
- Transmission distance is as far as 5 metres
- Poor audio signal amplification
- Weak signal
- Components are not firm resulting in partial contact between component Fs in the board.

It is observed that despite the simplicity of the circuit, the results obtained were poor and hence pushing this work to the next phase for better results.

SECOND STAGE

To solve some of the draw backs of the breadboard construction phase (i.e. stage one), the circuit was implemented on a Vero – board and the result was relatively better but the following needed to be done:

- Better signal amplification with a high gain
- Efficient transistor biasing
- A better Antenna
- Test the transmitter with an audio console
- Better power supply
- Efficient soldering to minimise noise

The signal amplification and gain problem were resolved by using an LM386 I.C. The gain of the input audio signal was increased 200 times.

A radio frequency transistor is used and properly biased with the right resistors.

For effective transmission, a good antenna must be used. A coaxial cable is used to construct a dipole antenna. The length of the dipole antenna is obtained by using the formula below:

Length in inches = $\frac{2832}{Frequency\ in\ MHZ}$

Since it's a dipole antenna, the impedance is 73-ohms, while the impedance of the transmission line in the circuit is about 50-ohms. VSWR is a measure of mismatch in a transmission line

Therefore, VSWR = $\frac{73}{50}$ = 1.46

Since the VSWR less than 2, it is acceptable.

The major reason for using coaxial cable other than other electrical wiring cable are:

- Minimal noise introduction to circuit
- Crosstalk not observed as in twisted pair cables
- Shielding from interference, and
- High signal conduction for audio, video and RF signal.

The new circuit design is described in figure 3.

Figure 3 was designed with "Eagle" software and implemented on a Vero-board.

The input signal to the transmitter circuit was obtained from the audio console (mixer), the circuit design of the audio console is described in figure 4.

The circuit was designed in PROTEUS software and also implemented on a Vero-board

The 0.1uF capacitor acts as filter to the incoming signals which are regulated by the 250k-ohms potentiometer. The 250k-ohms was carefully chosen so the audio input from a source can be completely cut out if need be.

The power supply was designed for redundancy, for reliability and to create room for variations and choices with the two sources of power. Figure 5 is the circuit diagram of the power supply unit.

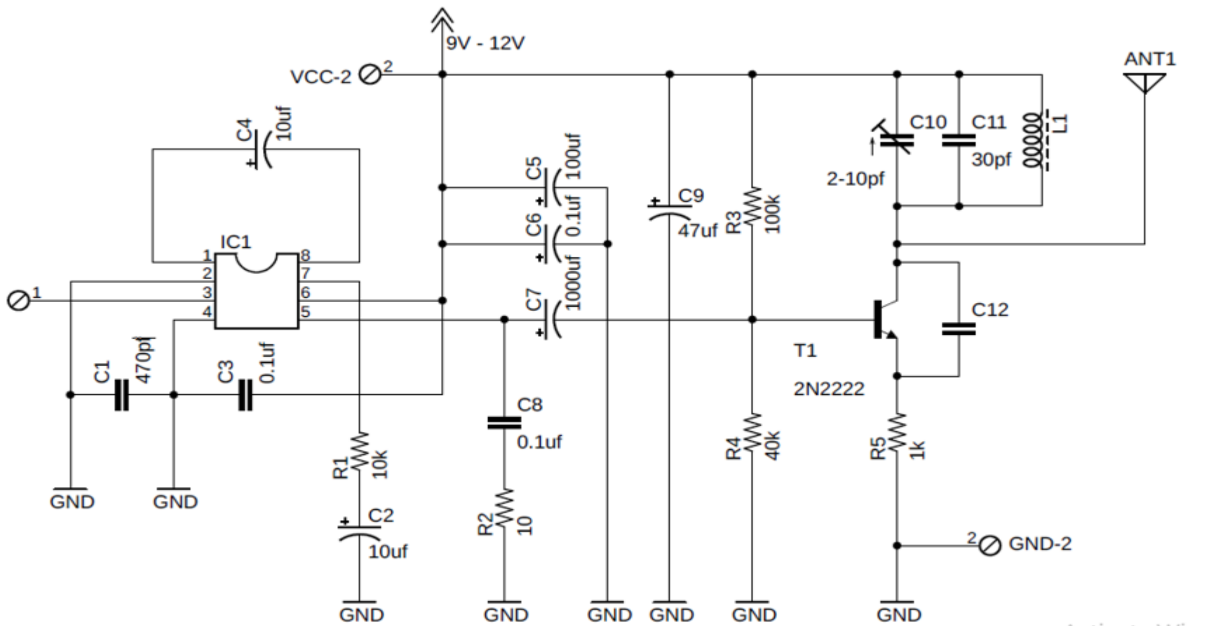

Figure 3: Implemented circuit for work

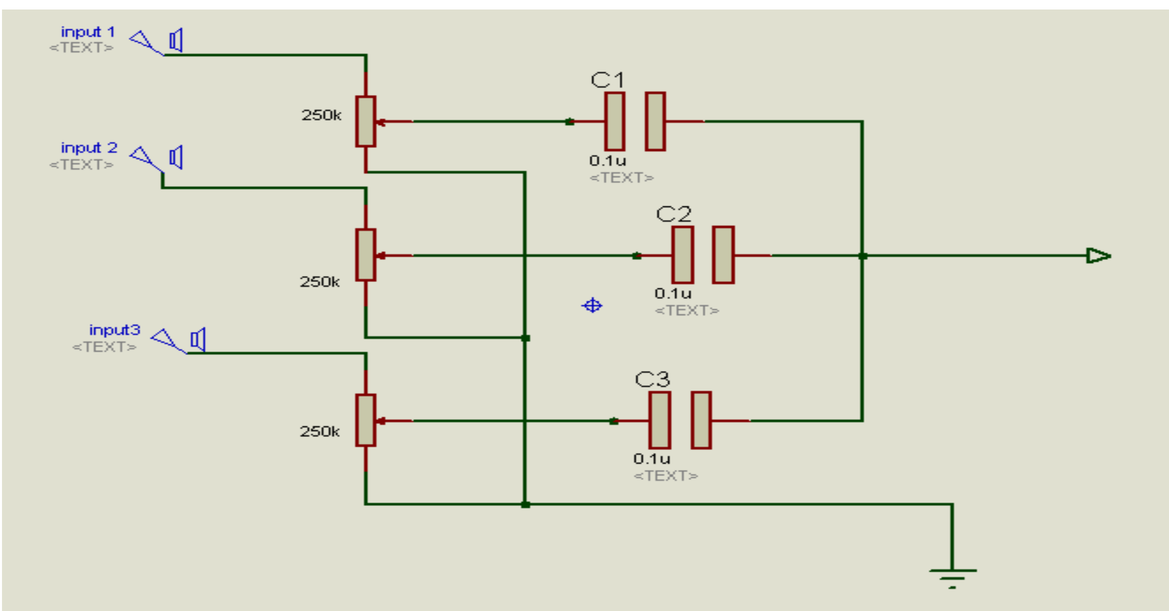

Figure 4: Circuit Diagram of Audio Console

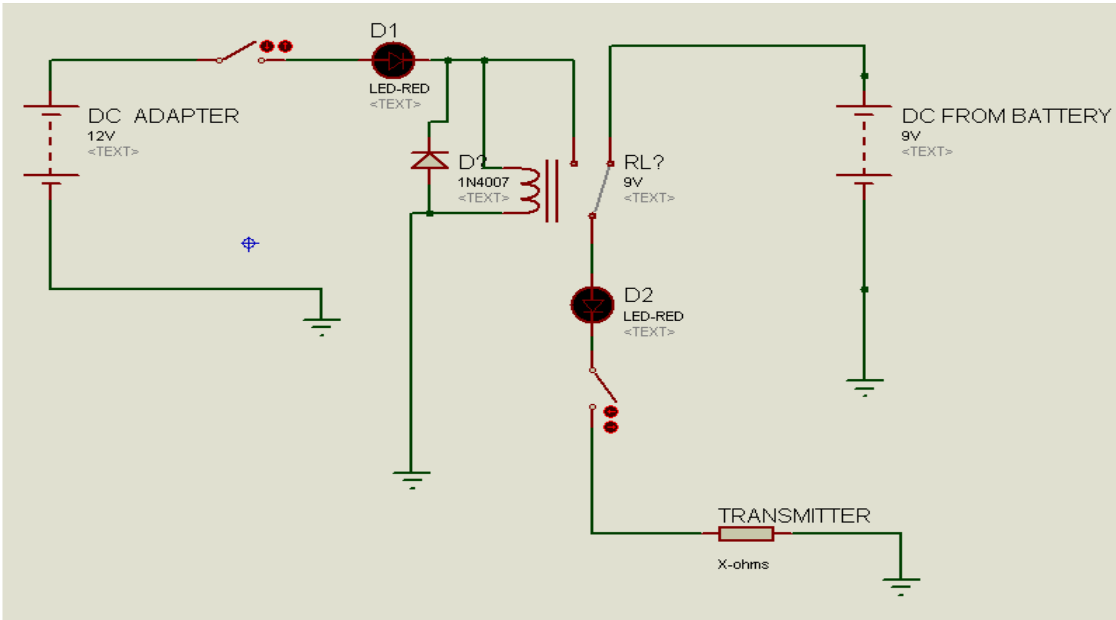

Figure 5: SEQ Figure * ARABIC 5: Circuit Diagram of Power Supply Unit

The design of figure 5 was done with PROTEUS.

Coupling the transmitter circuit, audio console and power supply unit together with an antenna, better results were obtained:

- Improved signal strength
- Improved distance of coverage of over 30 meters realistically.
- Less noise introduced to the circuit as compared to the breadboard circuit
- Better signal amplification

Though the work is better, but there needed to be more improvement in the circuitry especially in the transmitter circuit. The transmitter circuit is then implemented on a printed circuit board (PCB) to reduce the amount of soldering. As a circuit dealing with modulation and signal transfer a better place to implement such designs will be a PCB. This drives us to the next stage of the work design.

THIRD STAGE:

Implementation on a PCB would reduce the number of wires and soldering on the work but designing and constructing the PCB is the most important thing in this phase. Since this was done manually at “home”, it requires the following:

- Software for circuit design (Eagle or Proteus)
- PCB with copper coating
- Ferric chloride ($FeCl_3$)
- Water
- Art paper(white)

- Black Marker
- Electric Iron
- Hand saw drilling
- Drilling bit of 1mm.
- Masking tape
- Iron sponge or san paper
- Acetone or “Spirit”

The PCB layout of our circuit after design on Eagle is described in figure 6: The following steps

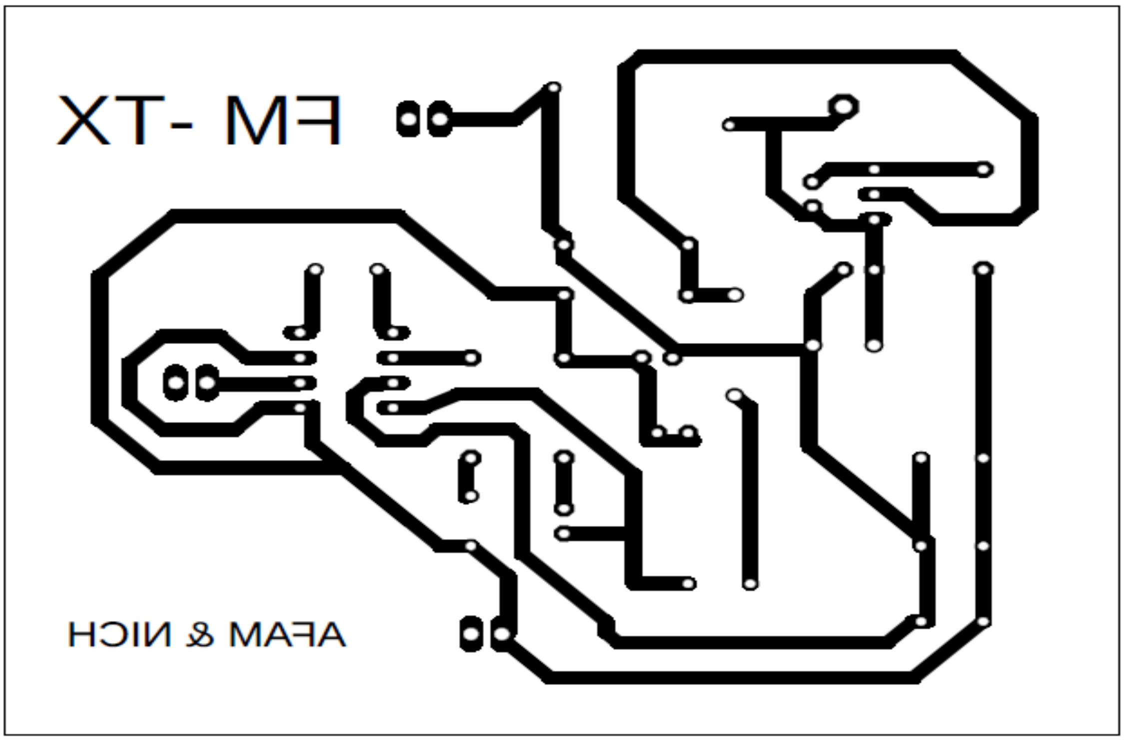

Figure 6: SEQ Figure * ARABIC 6: PCB layout from the Eagle Software

were taken in the PCB construction:

(1) The PCB layout is designed and printed on a magazine paper
(2) A suitable size of the copper coated board is cut
(3) The surface of the board is cleaned with spirit
(4) The printed PCB layout is placed on the copper board with the printed layout facing and touching the copper surface.
(5) The layout is attached and held firmly with the masking tape
(6) The magazine paper is ironed on the copper board so the PCB layout could transfer to the copper board, this is done by applying lots of pressure with the hand.

(7) The ironed paper on copper board is then soaked in water

(8) Carefully, the magazine is removed and it is observed that the PCB layout is transferred to the board. Suppose the lines of the layout were broken, they are completed with a marker.

(9) The board is then placed in water mixed with ferric chloride for 15 to 20 minutes to etch the surface of the copper. It is observed that PCB layout lines are intact.

(10) The board is then rinsed in a clean water and dried.

(11) Carefully, the surface of the board is scrapped off with an iron sponge. It is observed that the copper coating takes the pattern of the PCB layout.

(12) Carefully, holes are drilled on the board

(13) Surface is cleaned with spirit and the PCB is ready for use

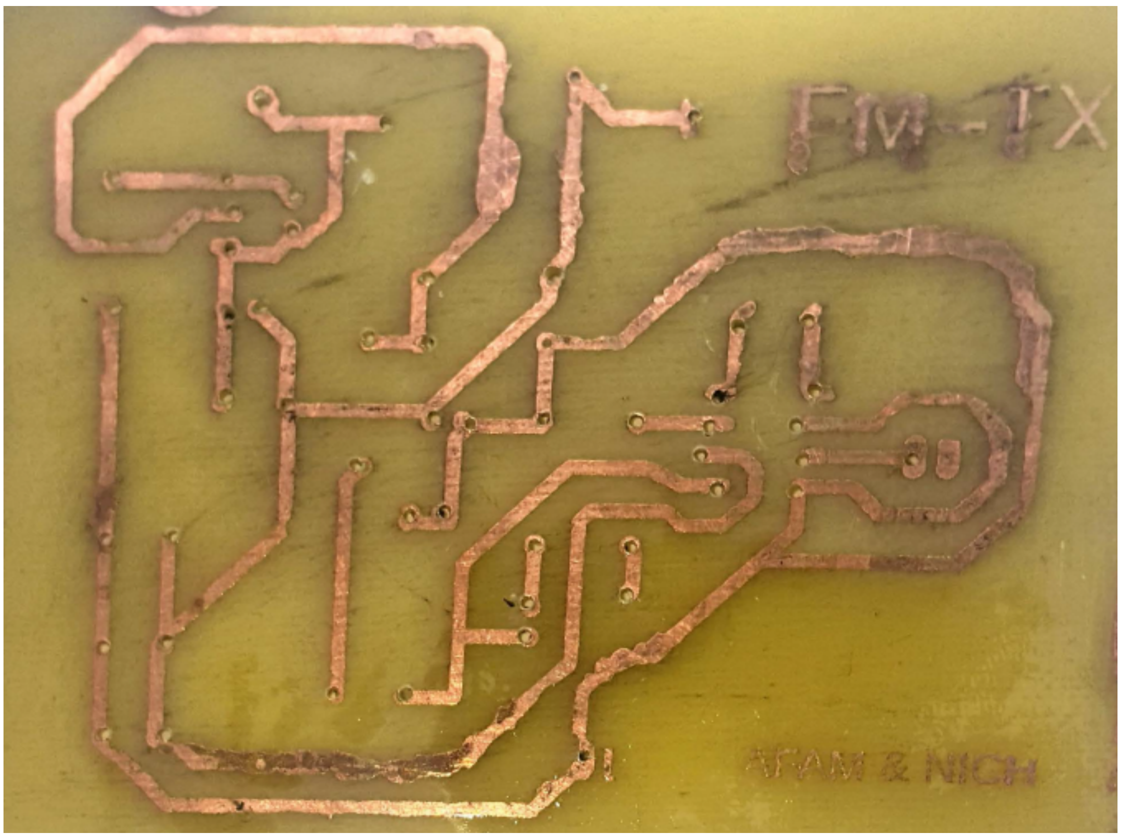

Figure 7: Manufactured PCB circuit

Having constructed the PCB, the components are carefully placed on the PCB and soldered to make contact with the board. It is observed that upon implementation with the PCB, the noise in the circuit was highly minimised and every other result obtained in the previous stage was improved in this stage.

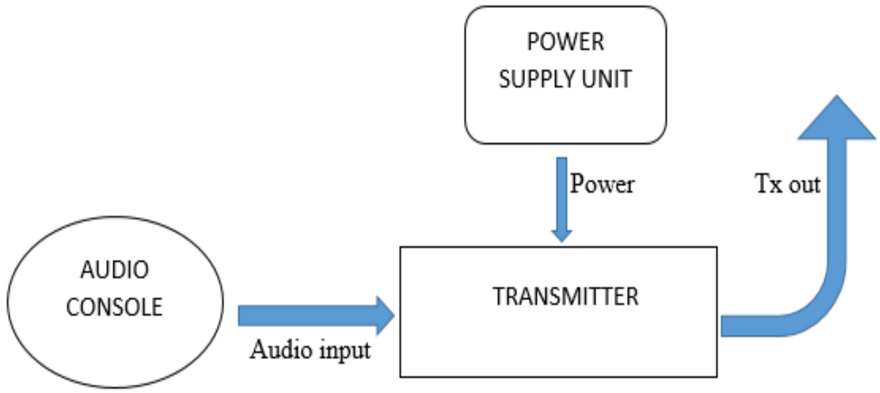

Figure 8: Diagrammatic illustration of the work

FURTHER RESULT ANALYSIS AFTER TESTING THE WORK

Having tested the work, the following are deduced:

- Voltage supply over 10 to 11 volts will introduce noise to the system and can also cause signal transmission failure
- Switching between power sources cause a brief temporal disruption in circuit
- It will not be wise to use all three channels of the audio console simultaneously. It is advisable to use one at a time to avoid signal interferences.
- PCB produces better audio signal for transmission compared to Vero board.

WORK CHALLENGES

In the course of the work, the following challenges and issues were encountered:

- **Antenna design and construction issue:** this is the biggest issue in the design of the transmitter because the distance and strength of the transmitted signal depends on it. As indispensable as it, it is difficult to design and construct because it takes into consideration the length, ohmic impedance, material type, and other variables.
- **Noise problem:** noise is one of the fundamental problems in transmission, the noise in this system can be caused by imperfection in the circuit components, impurities along transmission line, impedance mismatch
- **Power disruption issues:** it was observed that an abrupt change in the voltage across the transmitter contributes to distortion and disruption in the signal in the system
- Interferences in audio console

Table of Components.

Table 1: components estimation table

S/N	COMPONENTS	QUANTITY
1.	LM386	3
2.	IC SOCKET	5
3.	CAPACITORS	33

4.	VARICAP	6
5.	RESISTORS	33
6.	TRANSISTORS	10
7.	ANTENNA (CO-AXIAL)	1
8.	IRON (III) CHLORIDE (100g)	2
9.	PCB SHEET	2
10.	ART PAPER	2
11.	HANDHELD SAW	1
12.	METHYLATED SPIRIT	1
13.	DRILLING BITS (1mm)	1
14.	DRILLING MACHINE	1
15.	MASKING TAPE	1
16.	INDUCTOR	1
17.	SOLDERING IRON	2
18.	LEAD	1
19.	BATTERY CAP	3
20.	BATTERY	3
21.	DC ADAPTER	1
22.	POTENTIOMETER	6
23.	AUDIO FEMALE JACK	6
24.	AUDIO MALE JACK	6
25.	JUMPER WIRES (yds)	7
26.	RELAYS	5
27.	DC FEMALE JACK	3
28.	COMPONENTS CONTAINER	1
29.	INDICATOR BULBS	4
30.	DIODES	4
31.	TWO-WAY SWITCH	2
32.	THREE-WAY SWITCH	2
33.	BREADBOARD	1
34.	VERO BOARD	2
35.	WORK CASE	1

RECOMMENDATION

- ✔ Extensive research should be done before commencing both the paper work and implementation of the system.
- ✔ It is essential to always seek for clarification by engaging in discussions with people doing similar works or by asking more knowledgeable persons.
- ✔ Always carry your supervisor along as the work progresses.
- ✔ Always observe best engineering practices while carrying out your work.

PRECAUTION TAKEN DURING SOLDERING

- ✔ We always ensure that adequate metallic contact was made between the components leads and the copper coatings of the cero-board.

- ✔ We prepared the surface to be soldered by removing all oxidation, greases adhesives and particles Secured in fixed position the surface to be soldered together.
- ✔ We heated the surface to be soldered for a few seconds with a heated soldering iron holding the iron in place.
- ✔ We touched the end of a length of solder to the heated junction. Allowed the solder to melt and flow through.
- ✔ We avoided heating components, especially ICs and transistors, directly to avoid thermal runaway by using IC socket.

HOW TO TROUBLESHOOT THE SYSTEM

What if the transmitter does not work? Take the following steps while troubleshooting:

- ✔ Check the work for possible dry joints bridges across adjacent tracks or soldering flux residues that usually cause problems.
- ✔ Check again all the external connections to and from the circuit to see if there is a mistake there.
- ✔ See that there are no component missing or inserted in wrong places.
- ✔ Make sure that all the polarized components have been soldered the right way.
- ✔ Make sure that the supply has the correct voltage and is connected the right way in the circuit.
- ✔ Check for damaged components.
- ✔ Contact your data sheet or component retailer.

This miniature transmitter is relatively not too hard to construct and its transmissions can be picked up on any standard FM transceiver set. It has an expected range of up to 5 meters or more depending on the line- of-sight, obstructions by large buildings, etc. It is highly efficient for room monitoring, baby listening, nature research, conferencing lecture hall, intra- community communicating (broadcasting) since it is highly directive.

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