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DESIGN AND CONSTRUCTION OF A DEPARTMENTAL MINI-RADIO STATION AT THE FACULTY OF ENGINEERING CARITAS UNIVERSITY ENUGU

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Abstract

The "Design and Construction of a Departmental Mini-Radio Station in the Faculty of Engineering" focuses on creating a functional radio broadcasting system for educational purposes. These radio waves are a type of electromagnetic wave with frequencies ranging from about 3 KHz to 300 GHz. The mini-radio station encompasses the design and assembly of essential components, including a low-power FM transmitter, an antenna system, and audio processing equipment. The project follows a systematic approach, beginning with a comprehensive analysis of the requirements, followed by the selection of appropriate hardware, circuit design, and implementation. The goal is to ensure reliable signal transmission within a limited range while adhering to regulatory standards. The test result of this research work revealed the successful achievement of the primary objective; the design and construction of Mini-Radio station in faculty of Engineering Caritas University Enugu (Transmitter Part) with Audio Console Using Frequency Modulation (FM) With Power Rating of 20 Watt of appreciable range operating on 9v power supply. This system has been implemented with the locally source material in our electronic markets and used to implement the system using the necessary rudiment usually employed in electronic system implementation from the above stated results. The constructed radio station will serve as a valuable educational tool; provide students with practical experience and understanding of radio frequency principles, signal propagation, and broadcast engineering.

Keywords: ***Unmanned vehicles (UVs), Flight Control, Payload capacity, Navigation, Drone delivery system and photography***

1.0. Introduction

The design mini-radio (communication) station within the faculty of Engineering, Caritas University is the transmission and reception of information using radio waves which will serve as a broadcasting house in the faculty where mostly audio content and programming are produced and transmitted over broadcasting spectrum or frequency. Radio waves are a type of electromagnetic wave with frequencies ranging from about 3 kHz to 300 GHz. This technology is widely used in various applications, from broadcasting audio and video to facilitating two-way communication in various fields.

The world has developed to an era of information when electronics communication systems influence most of human activities. These electronics communication systems consist of three main components: The transmitter also known as the source, the channel and the receiver. A transmitter is an electronics device, which, with the aid of an antenna, propagates an electromagnetic signal such as radio, television or other telecommunications. In the previous years, signal energy was generated in transmitting plants using arcs or mechanical alternators. Presently, a transmitter usually has a power supply, an oscillator, a modulator and amplifiers for audio frequency (AF), intermediate frequency (IF) and radio frequency (RF). Transmitters are sometimes classified according to the signal information they process and radiate. Television transmitter's processes sounds and picture signal while radio transmitter processes only sound the research dealt with the production of an FM transmitter of appreciable range for practical application, (Chandra et al, 2023).

1.1. Transmitter

The "transmitter segment "of the radio station, (commonly called a radio transmitter) is an electronic device capable of producing radio waves with the help of an antenna. The transmitter produces a high-frequency electrical current, which is then sent to the antenna. This current energizes the antenna, causing it to emit radio waves. The term "transmitter" often specifically refers to a device used for broadcasting, such as an FM radio transmitter, which typically includes the transmission device, antenna, and sometimes the entire building that houses it. 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 transmitters. In a frequency modulation (FM) transmitter, it is added by varying the radio signal's frequency slightly. Many other types of modulation are used. 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. Information transmission is very vital to human life just as the early men used sticks to produce sound which indicates the location of each other as they wander about also down to the middle era when town crises come into play for the same information propagation to be transmitted from one point to another with the aid of radio communication which necessities the application of radio transmitter and receiver.

1.2. Receiver

The receiving part of the radio station (commonly called a radio receiver) which is an electronic device that receives radio waves and converts the information carried by them to a usable form. It is used with an antenna. The antenna intercepts radio waves (electromagnetic waves) and converts them to tiny alternating currents which are applied to the receiver, and the receiver extracts the desired information. The receiver uses electronic filters to separate the desired radio frequency signal from all the other signals picked up by the antenna, an electronic amplifier to increase the power of the signal for further processing, and finally recovers the desired information through demodulation. The information produced by the receiver may be in the form of sound. A radio receiver may be a separate piece of electronic equipment, or an electronic circuit within another device. In consumer electronics, the terms FM receiver are often used specifically for receivers designed to reproduce the audio (sound) signals transmitted by radio broadcasting stations.

2.0 CONCEPTUAL THEORY

In the modern era, radio communication remains one of the most effective and widespread means of disseminating information. Establishing a departmental mini-radio station within the Faculty of Engineering, Caritas University Enugu, is driven by the need to create a functional, practical platform for educational broadcasting, engineering communication experiments, and real-time information sharing. The conceptualization of this project blends communication engineering principles, electronic circuit design, audio processing, and antenna technology to achieve a low-power FM (Frequency

Modulated) broadcasting system suitable for departmental purposes. The conceptual theory behind the design and construction of a departmental mini-radio station at Caritas University Enugu is rooted in the synergy of communication technology, electronic design, and educational utility. By adopting robust engineering principles and innovative design strategies, the project aims to deliver a sustainable, functional, and educationally beneficial radio

2.1. *Theoretical Framework*

The design and construction of a departmental mini-radio station are rooted in several communication theories and engineering principles that guide the effective transmission and reception of information via radio waves. This theoretical framework provides the foundation for understanding the processes, systems, and technologies involved in setting up a functional radio broadcasting unit within an academic environment such as the Faculty of Engineering, Caritas University, Amorji -Nike Emene, Enugu

2.2. Review of the Related Work

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". 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, (Onah *et al*, 2018) Radio waves were first generated by German physicist Heinrich Hertz in 1887, who used micrometer spark gaps attached to dipole and loop antennas to detect them. However, these primitive devices are more accurately described as radio wave sensors, not "receivers", as they could only detect radio waves within about 100 feet of the transmitter, and were not used for communication.

Mbagwu *et al*, 2020 presented a study on design, construction and testing of JP mini radio broadcast transmitter and audio console. The study was to design and construct a power rating of 20-watt Frequency Modulation (FM) transmitter to be received at a range of 100 meters. The transmitter has an audio jack port which picks up very weak sound signals, a transistor, resistors, inductor, and capacitors. This project is aimed at serving a community using a small radio broadcasting equipment with a power rating of 20 watts. A community of 100 meters in radius should be covered comfortably. The design procedure involves the modification of an output of the transmitter. Based on the procedures adopted, and the tests carried out, the specific findings include a range of 98.5MHz of transmission from a 9V DC battery. The work indicated that the practical frequency modulated (FM) transmitter requiring a low power of 20 Watt can be designed and constructed effectively.

David Chen (2024) presented a study on Design and Construction of FM Transmitter and Receiver which was built with discrete analog components and integrated on two circuit boards. The modulation scheme uses a super-heterodyne setup, in which the intermediate carrier is at 300-kHz and the transmission carrier is at 24.3-MHz. Using 711-mW of DC power, the transmitter outputs a 5-dBm signal centered at 24.3-MHz with 100-kHz bandwidth. Using about half as much power, around 342-mW, the receiver can detect incoming signals at powers as low as -110 dBm. This receptivity level translates to successful audio reception at distances of almost 2-km from the transmitting antenna atop Packard.

EFY Bureau (August 16, 2023), present a study on Designing Simple FM Radio Receiver Circuit. In their work, the receiver uses electronic filters to separate the desired signal from all the other signals picked up by the antenna, and an electronic amplifier to increase the power of the signal for further processing, and finally recovers the desired information through demodulation. Onah *et al*, 2018 presented a study on Design and Implementation of a Mini Radio Transmitter on a Locally Made PCB. There 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.

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 minimizing power usage and optimizing transmission and signal strength. It also differs from ours as we try implementing using audio console to control the input and output signal.

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.

3.0. Methodology

The research methodology is tailored towards design and construction of a departmental mini-radio station at the caritas university faculty of engineering for educational purposes, utilizing radio waves with frequencies between 3 kHz and 300 GHz.

3.1. Material Used

The materials used in construction of the circuit (drone) are:

i. Elcetronic components which includes Resistors, Capacitors, Inductors, Microphone for transmission, Transisitors, and LED
ii. Project Board: This is a white electronic kit, which is used to test and construct electronic circuit without soldering the components. It provides room for circuit modification if need be.
iii. Connecting Wires: These are tiny pieces of copper wires about $0.2mm$ 2 in diameter. They are used to assemble components together on the project board.
iv. Battery: The source dc supply is 9volts high watt battery.
v. Cutter: This is to cut connecting wires and components to size.
vi. Digital Multi-meter: This is a multipurpose electrical measuring instrument use to test for various parameters in an electrical circuit.
vii. Insulation Tape vii. Complete Pliers Set
viii. Screw driver
ix. and Others

3.2. Basic of FM (Frequency Modulation) Transmitters and Receivers

An FM (Frequency Modulation) transmitter is a device that uses frequency modulation to transmit audio signals over radio waves. The primary purpose of an FM transmitter is to encode information, such as music or voice, into a carrier wave and broadcast it to a receiver tuned to the same frequency. While an FM (Frequency Modulation) receiver is a device that captures FM radio signals and converts them into audio signals that can be heard through speakers or headphones. The primary function of an FM receiver is to detect the frequency-modulated signals, demodulate them to extract the audio information, and amplify this audio signal for playback.

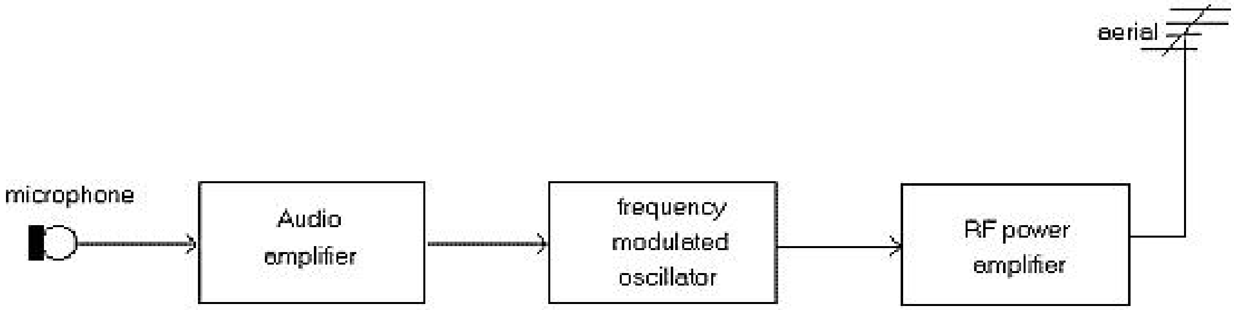

Figure 1: Block Diagram of an FM Transmitter

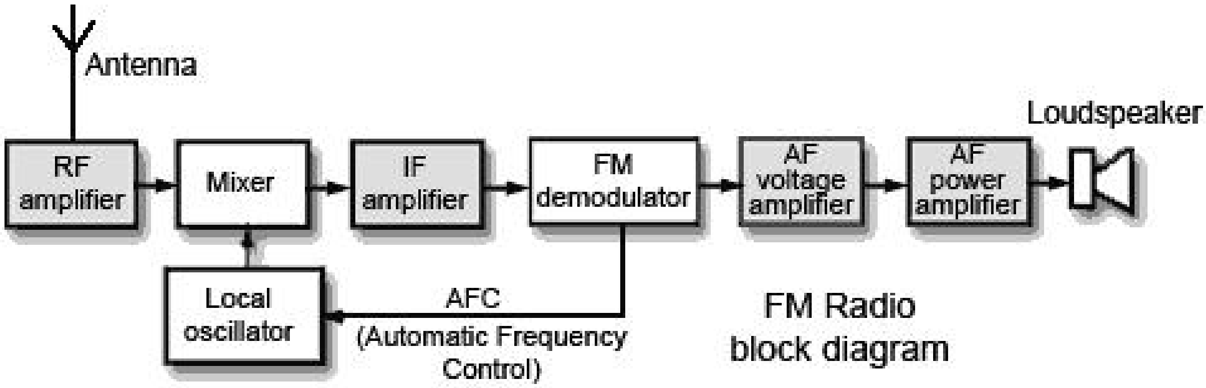

Figure 2: Block Diagram of an FM Receiver

In summary, an FM transmitter modulates a carrier wave with an audio signal by varying the frequency of the carrier in accordance with the audio signal's amplitude. This modulated signal is then amplified and transmitted through an antenna to be received by FM receivers tuned to the same frequency. While an FM receiver captures FM signals, amplifies and tunes them, converts the RF signals to a fixed intermediate frequency, demodulates the audio information, and finally amplifies the audio signal for playback. The combination of these components and processes enables the clear reception of high-quality audio from FM broadcasts. Here are the key components and principles of an FM Transmitter and receiver:

Audio Source: The input audio signal can come from various sources such as a microphone, a music player, or any other audio device and the weak signal will be amplified at this stage. **Microphone (Optional):** Converts sound waves into electrical signals if the audio source is live sound.
Antenna: Converts the amplified electrical signals into electromagnetic waves and radiates them into the air and also in receiver, it Captures the electromagnetic waves (radio signals) transmitted by the FM transmitter. The design and length of the antenna are critical for effective transmission and reception.
RF Amplifier: Amplifies the weak radio frequency (RF) signals received by the antenna to a level suitable for further processing. It helps improve the signal-to-noise ratio.
Pre-amplifier: Amplifies the low-level audio signal from the audio source to a suitable level for modulation.
Tuner: Selects the desired frequency from the wide range of frequencies captured by the antenna. This is achieved by adjusting the resonant frequency of the tuner circuit to match the frequency of the desired FM station
Frequency generator or Oscillator: Generates a high-frequency carrier wave. The Frequency generation stage (often known as the oscillator) defines the frequency on which the transmitter will operate. The frequency of this wave is typically in the FM broadcast band (88 to 108 MHz). Incorrect

setting of this stage can easily result in operation outside of the amateur band, and hence interference to other (non-amateur) radio users.
Modulator: The heart of the FM transmitter, where the audio signal modulates the frequency of the carrier wave. This process involves varying the carrier frequency in proportion to the amplitude of the input audio signal.
Frequency Multiplier (Optional): Increases the frequency of the carrier wave to the desired broadcast frequency if the oscillator does not directly generate it.
Power Amplifier: Amplifies the modulated carrier wave to a level suitable for transmission. This ensures the signal can travel long distances without significant loss of strength. The power amplification of the radio signal is carried out in the final stage of the Transmitter block diagram. It makes the signal stronger so that it can be transmitted into the aerial. The R.F. power amplifier output must be connected to a correctly matched antenna (the "Load") to work properly. Use of the wrong antenna, or no antenna, can result in damage to the transmitter.
Mixer: Combines the RF signal from the tuner with the local oscillator signal to produce the intermediate frequency (IF). This process is called heterodyning and results in a fixed frequency that contains the same modulation as the original RF signal.
IF Amplifier: Amplifies the intermediate frequency signal. Since the IF is fixed, the amplification and filtering can be optimized for this specific frequency, improving selectivity and sensitivity.
Limiter: Removes amplitude variations in the IF signal, which helps eliminate noise and ensures that only frequency variations are passed on to the demodulator.
Demodulator: Extracts the audio signal from the frequency-modulated intermediate frequency signal. The most common demodulation method for FM is the use of a frequency discriminator or phase-locked loop (PLL).
Audio Amplifier: Amplifies the demodulated audio signal to a level suitable for driving speakers or headphones.
Speaker or Headphones: Converts the amplified audio signal into sound waves that can be heard by the listener.

3.4. Design Calculation

3.4.1 Transmitter Distance (D)

From the Global Positioning System (GPS), using the fields Area measurement software, a total population distance of the transmission of $35777 km = 35.777 \times 103 m$ was obtained as the total range to be covered by the transmitter.
The population distance of the transmission $\mathbf{d_{pt}}$
Using the formula $\mathbf{d}_{pt} = \sqrt{2hR}$……………………………………………(I) .

Where:
$\mathbf{d}_{pt}$ = be the population distance of the transmission.
h = height of tower (100 meters) R = 6400 km = $6.4 \times 106m$
R = Radius of the earth Population density (P) = 500 per square kilometer.
R = Radius of the earth
Population density (**P**) = 500 per square kilometer.
$\mathbf{d_{pt}} = \sqrt{2x100x6.4x10^6}$
$\mathbf{d_{pt}}$ = 35777 km 9 050 966 799
$\therefore \mathbf{d}_{pt} = 35.77 \times 10^3 m$
Area reach (A) = πd^2 …………………………………………………….(II)

$\pi = 3.142$
$d_{pt} = 35.77 \times 103m$

$Ar = 3.142 \times (35.77)^2$
$\therefore Ar = 4020$ square kilometer
Let population reach be P, Area reach be Ar and Population density be P_d.
$Pr = A_r \times P_d$ .... (III)

$Ar = 4020$ square kilometer,
$P_d = 500$ per square kilometer
$P_r = 4020 \times 500$
$P_r = 2010000$
$\therefore P_r = 2.01 \times 106$or 2.01 million
$\therefore$ Coverage range $(C_r) = 35.777$ Population reach $(P_r) = 2.01$ million
When measuring a transmitter output, the measurements must be made in the "far field". In the far field, the power received per unit area from an isotropic antenna is calculated from the following equation:

Using $P_r = \frac{Pt}{4\pi d2}$ .... (IV)

Where:
$P_r = Received\ power\ in\ watt(s).$
$P_t = Transmitter\ power\ in\ watt(s)$
$d = distance\ from\ transmitter\ in\ meter(s)$
$P_r =?\ ,\ P_t = 20\ watt\ and\ d = 1000\ meters$

$$P_r = \frac{20}{4\pi X(1000)2}$$
$$P_r = \frac{20}{4\pi\ X10000}$$
$$P_r = \frac{20}{12566.37}$$
$P_r = 1.57 \times 10^{-4}$w
$P_r = 1.57 \times 10^{-4}$w
$\therefore = P_r = 1.57 \times 10^{-4}$w is the received power from the transmitter.
This equation (iv) is also referred to as the inverse square law, since doubling the distance gives a fourfold reduction in signal power. Many radio receivers have a manual which includes a specification sheet.

3.4.2 Antenna Length

The antenna either with a piece of solid strand 22-gauge wire 30 inches long or used a telescopically extendable antenna. Its length should be approximately 1/4 the FM wavelength; recall that multiplying frequency and wavelength equals the speed of light. It's most probably be operating the transmitter near 108 MHz, as such:
Speed of light = frequency x wavelength = 300 000 km/sec

$$\text{Wave length} = \frac{300\,000\frac{km}{s}}{108\ MHZ} = 2.78\ meters$$

Antenna Length = 0.25 x wavelength = 0.69 meters
Thus, antenna should be 27.3 inches

3.4.3 The Sensitivity of Radio Receiver

If a radio receiver is quoted as having a sensitivity of $20\mu V/m$ then this is the weakest signal that the particular receiver can ''hear''. To receive signals or stations weaker than this, then a high gain antenna or preamplifier is required. The problem with amplifying weak signals is that you also amplify the inherent background noise that is present. For example, Caritas FM 98.5MHz broadcasts a signal with a 20Watts transmitter then what is the field strength at a distance of 1000 meters.

Using $E_{fs} = \frac{\sqrt{30Pt}}{\text{d}}$ ………………………………………………………….. (V)

Where: E_{fs}= is the field strength in v/m
d_t = is the distance covered by the transmitter in meters.
P_t = transmitter power in watts
$P_t = 20\ watt\ and\ dt = 1000\ meters$
$E = \frac{\sqrt{30X20}}{1000}$
$E = \frac{\sqrt{600}}{1000}$
$\therefore E = 0.0244\ v/m$
$\therefore$ 0.0244 $v\ m\ is\ the\ field\ strength\ in\ the$ transmitter

It should be noted that equation (iv) assumes 100% energy is transferred from the transmitter to the antenna, and that the antenna has unity gain (a dipole). In practice, there are losses in coupling the signal from transmitter to antenna, and also losses in the antenna itself. The formula in equation (1) assumes that all energy leaving the transmitter is converted to Radio Frequency (RF) energy; there are no losses in the transmitting or receiving antenna and no loss in the path from transmitter (TX) to receiver (RX). In all cases these conditions are never met. There are losses in the receiving and transmitting antenna, and the signal is attenuated on its way to the receiver (RX). Tress, buildings, hills all reduce radio waves before they reach the receiver

4. Results

The design and construction of the departmental mini-radio station at the Faculty of Engineering, Caritas University, Enugu, were successfully completed and tested. The system was able to transmit clear audio signals within the intended coverage area, effectively broadcasting departmental information, educational programs, and announcements to students and staff.
The radio station, operating on a low-power FM frequency, demonstrated stable transmission with minimal interference and good sound quality. All major components—including the audio input system (microphone and mixer), RF transmitter, power supply, and antenna—functioned efficiently and as expected.
Upon testing, the radio station achieved:

- A transmission range of approximately 500 meters to 1 kilometer, adequate for covering the faculty premises.
- Clear and distortion-free audio output within the coverage area.
- Seamless operation of both live broadcasts and pre-recorded audio content.

The successful implementation of the project proved the feasibility of establishing a functional, low-cost, and localized radio station for academic communication within a university setting, serving as a practical model for future enhancements and expansions.

More so, the voice input of the system was power by a simplified interface of an android microphone setup within a radio transmitter system which is show in the figure 4.4 below. The Android microphone in a cell phone captures sound and converts it into an electrical signal. This signal is then digitized, processed, encoded, modulated, and transmitted via the phone's radio transmitter to a cell tower. Each step ensures that the captured audio is transmitted clearly and efficiently over the cellular network. These steps, including sound capture, signal processing, and modulation for transmission.

Figure 3: A simplified interface of an android microphone setup

In sound capture stage, when you speak into the microphone ICON, the android microphone in a cell phone captures sound waves (acoustic energy) cause the diaphragm of the MEMS microphone to vibrate and converts it into an electrical signal. These vibrations create variations in capacitance within the microphone, generating a corresponding electrical signal that represents the sound. This signal is then digitized, processed, encoded, modulated, and transmitted via the phone's radio transmitter to a cell tower. Each step ensures that the captured audio is transmitted clearly and efficiently over the cellular network. The electrical signals produced by the microphone are typically very weak and need to be amplified. The gain control allows the user to adjust this amplification level to ensure the signal is strong enough for further processing and transmission. Setting the gain properly is crucial to ensure the audio signal is strong enough without causing distortion. In the image, the gain is set to 1.00, indicating a neutral setting.

4.1: Prototype

Having provided the casing and having finished the construction of the sections of this system, the assembling into the casing followed. The sections were properly laid out and assembled into the casing where the general coupling and linkages into the peripheral devices took place.

A case was gotten where the entire circuit was mounted follow by other external components such as Antenna, speaker, the battery leads, switch and microphone console were carefully brought out from the internal part of the casing through the holes made on the body of the casing as shown below:

Figure 4a: ***Prototype of FM Transmitter***

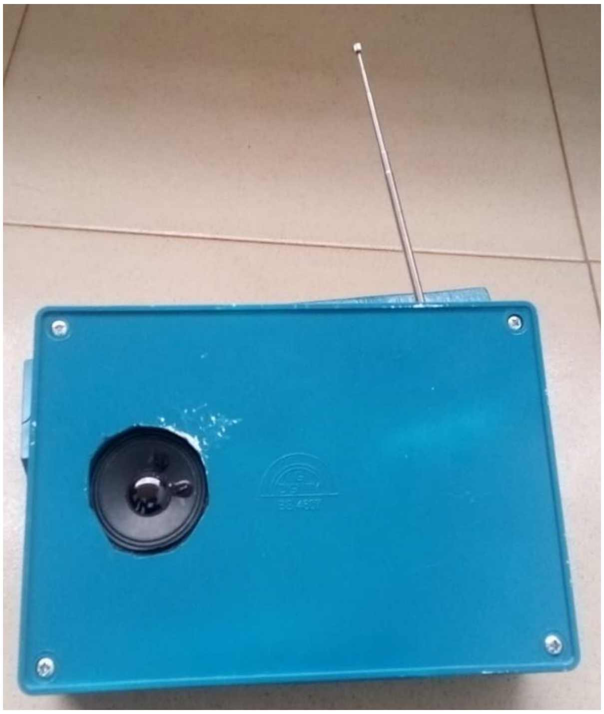

Figure 4b: ***Prototype of FM Receiver***

After the installations of the switch, antenna and speaker, indicators were firmly coupled on the body of the casing with its transformer properly guided using bolts and nut to achieve equilibrium of the system.

5. Conclusion

The test result of this research work revealed the successful achievement of the primary objective; the design and construction of Mini-Radio station in faculty of Engineering Caritas University Enugu (Transmitter Part) with Audio Console Using Frequency Modulation (FM) With Power Rating of 20 Watt of appreciable range operating on 9v power supply. Because of the impressive good result, obtained from the usability test, the Mini-Radio station is now ready for either instructional or entrepreneur purposes.

The construction and analysis of a Mini-Radio station provide significant insights into the design and operation of RF communication systems which involves a detailed understanding of radio frequency (RF) principles, careful selection of components, and precise assembly and tuning.
Finally, the findings from the construction and analysis of Mini-Radio station in faculty of Engineering Caritas University Enugu highlight the importance of careful design, quality components, and thorough testing to achieve optimal performance. By incorporating advanced features and continuously learning about new technologies, future transmitter designs can be further improved in terms of efficiency, reliability, and functionality.

5.1. Contribution to Knowledge

The successful design and construction of a departmental mini-radio station at the Faculty of Engineering, Caritas University, Enugu, contributes significantly to both academic knowledge and practical application in the following ways:

i. Development of a Low-Cost, Scalable Campus Broadcasting Model
ii. Integration of Engineering Principles into Practical Communication Solutions
iii. Enhancement of Internal Communication within the University
iv. Promotion of Research in Small-Scale Broadcasting Technologies

v. Customization of Radio Technology for Educational Purposes
vi. Foundation for Future Technological Innovations.

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