DESIGN AND CONSTRUCTION OF A 50W FREQUENCY MODULATION TRANSMITTER FOR THE TRAINING RADIO AT THE FEDERAL UNIVERSITY OYE EKITI, IKOLE CAMPUS

BY

AYEORIBE OLAREWAJU PETER
PGD/EEE/2019/002

A REPORT PROJECT SUBMITTED TO

THE DEPARTMENT OF ELECTRICAL/ELECTRONICS ENGINEERING, FACULTY OF ENGINEERING, FEDERAL UNIVERSITY OYE-EKITI, EKITI STATE, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POST GRADUATE DIPLOMA IN ELECTRICAL AND ELECTRONICS ENGINEERING.

Supervisor: Prof. O. Akinsanmi
Co-supervisor: Dr . A. Oluwole

Febuary, 2020

Table of Content

ABSTRACT

- This project presents the design and construction of a 50 W frequency modulation transmitter for the Federal University Oye-Ekiti, Ikole campus training radio, as a means of providing more practical knowledge on the communication aspects of electrical and electronics engineering. The FM transmitter was achieved with the help of the combination of the digital and the analog components arranged on two circuit boards. The modulation scheme used a direct setup of the intermediate carrier established at 88.1 MHz and the transmission carrier at 88.1 MHz. Using a 150W DC power supply, the transmitter output of a 50-watt signal was achieved at a bandwidth of 88 MHz to 108 MHz. This receptivity level translates to successful audio reception at a distance of 5 km from the transmitting antenna. This project provides a useful tool and practical knowledge for communication engineering in the Ikole Campus of the Federal University, Oye-Ekiti.

Background of study

- The Campus FM Radio transmitter is a widely used medium of communication, which has been improving ever since its discovery in 1986. A rapidly growing demand for the training of FM transmitters exists among individuals and institutions, from which the Federal University Oye-Ekiti, Ikole campus is not exempt. For example, universities and other tertiary institutions need to broadcast educational, entertainment, and even news programs that are particularly designed for campus audiences. FM transmitters are also required in the laboratories for practical and hands-on teaching of students who have an interest in communications. Hence, the need for training on the FM transmitter system cannot be overemphasized at the Federal University Oye-Ekiti, Ikole Campus. Because of this training purpose, there is a need to provide more practical knowledge on the communication aspects of electrical and electronics engineering by the design and construction of a 50 W frequency modulation transmitter for the Federal University Oye-Ekiti, Ikole Campus.

Motivation

- The motivation behind this project was the mission of providing training radio for the Federal University Oye-Ekiti, Ikole Campus, as a means of providing more practical knowledge on the communication aspects of electrical and electronics engineering in the faculty of engineering. The search for knowledge was also a motivation behind this project, as many skills and new ideas will be acquired during the making of the project. More also to build our practical experience so we can practice as successful engineers or problem solvers in the future.

Significance of the Study

- The importance of the study is to provide a device (transmitter) that will allow music or other audio content from a portable media player, CD player, or other portable audio system to be played through a nearby FM radio. It can either be a capability built into a portable media player or a portable appliance that plugs into the headphone jack or proprietary output port of a portable media player or video device. The sound is then broadcast through the transmitter on an FM broadcast band frequency and picked up by the receiver. This technology allows users to enjoy their favorite music or podcasts without needing to connect their devices directly to the radio, providing greater flexibility and convenience. Additionally, it opens up possibilities for sharing audio with a larger audience, making it ideal for gatherings or outdoor events.

Aim of study

The aim of this project is to design and construct of 50w Frequency Modulation Transmitter for the Federal University OyeEkiti, Ikole campus training radio, as a means of providing a more practical knowledge on the communication aspects of Electrical and Electronics Engineering.

Objectives of Study

- —To design a 50-watt FM transmitter that will be used as a training radio for Federal University Oye Ekiti, Ikole Campus, faculty of engineering workshop building.
- —To explicate the FM transmitter, which transmits a frequency-modulated signal to an FM radio up to a distance of 5 km.

Scope of the Project

- The scope of the project involves using an RF transistor and integrated circuits to generate an oscillating signal, which is modulated by a modulator module and then finally amplified and filtered by a low-pass filter to remove the harmonic frequencies. This process ensures that the output signal is clean and suitable for transmission. The successful implementation of these components will enhance the overall performance and reliability of the communication system. The design also incorporates an antenna made of galvanized dipole elements that radiate the RF signal, which covers 5000 meters.

Research Gap

- **Research Gap**

Although frequency modulation (FM) transmitters are widely studied and implemented globally, **there exists a significant gap in the development of low-cost, locally constructed FM transmitters specifically tailored to educational and training purposes in Nigerian universities.** Most campus radio stations in Nigeria either rely on commercial equipment or face operational limitations due to cost, technical know-how, or infrastructural challenges.

Moreover, **few documented projects focus on transmitter designs that are optimized for mid-range power output (around 50W)** — a power range that is suitable for campus-wide or community-based broadcasting. Additionally, **there is limited practical literature or case studies** demonstrating the design, construction, and testing of such transmitters within the context of Nigerian institutions, particularly with consideration for:

Local component availability

Energy efficiency in low-resource environments

Integration with academic training curricula

Compliance with Nigerian Broadcasting Commission (NBC) standards

This project therefore aims to fill this gap by designing and constructing a **functional, efficient, and replicable 50W FM transmitter**, explicitly for the **Training Radio Station at FUOYE Ikole Campus**, thereby contributing to both academic learning and technical capacity development within the institution.

Summary of Literature Review

NAME	YEAR	Author	TECHNIQUE	LIMITATIONS
Examine DTT in Ghana	2013	Ebenezer Malcalm* and Bernice Abena Darkoah Agyemang Gh	The study examined the state of art technology of digital television transmission and assessed Ghana readiness for DTT.	Unavailable of constant power supply to the transition sites.

Summary Literature Review contd.

Investigation for path losses and propagation in DTT	2017	Akinsanmi Akinbolati	The Received Signal Strength (RSS) of the DTTBS was measured at intervals along selected routes around the stations using a digital signal strength meter.	Results for all the routes and seasons revealed that path loss increases with increase in trans-receiver distances.

Summary Literature Review contd.

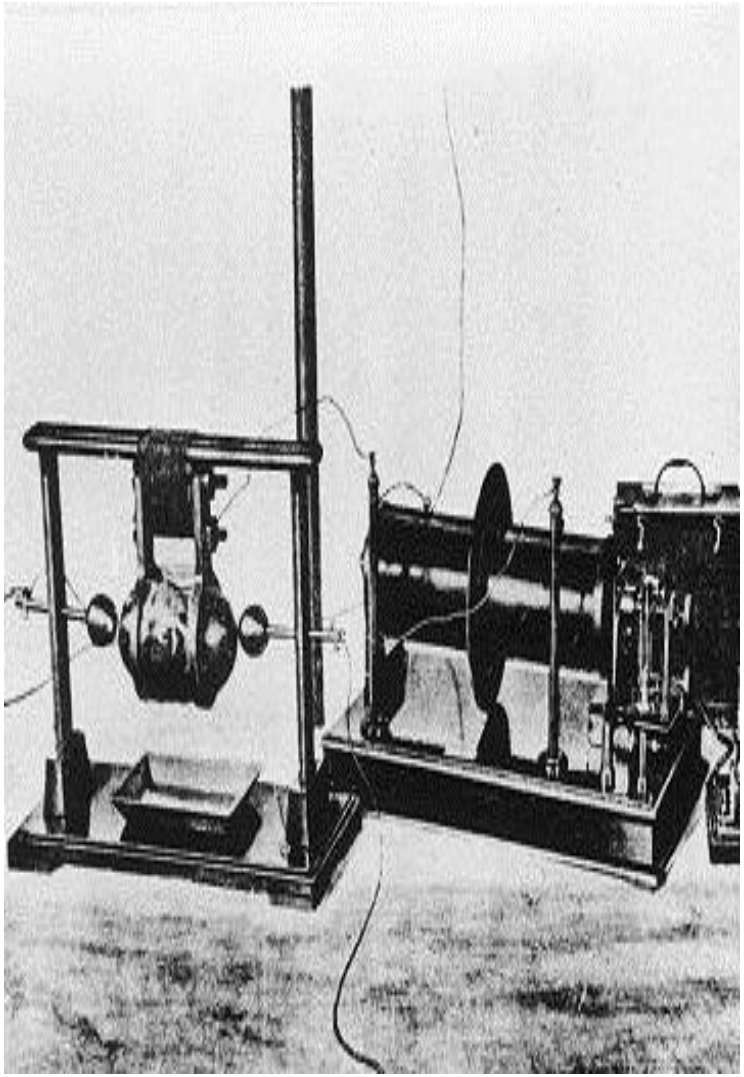
Implications of DTT failure in Nigeria	2016	Gloria Eneh Omale1 , Daniel Ofomegbe Ekhaerafo2 , and Coleman Fidelis Essien3	Digitization puts in the conversion of analogue information in any form so that the information can be processed, stored and transmitted through digital circuits, equipment and networks.	Lack of digital empowerment in Nigeria

Summary Literature Review contd.

Analysis of a propagation modal	2020	Gavilanes, J. J	A propagation model is able to predict the trajectory loss of a radio frequency signal between the base station and the receiver.	Lack of signal strength.

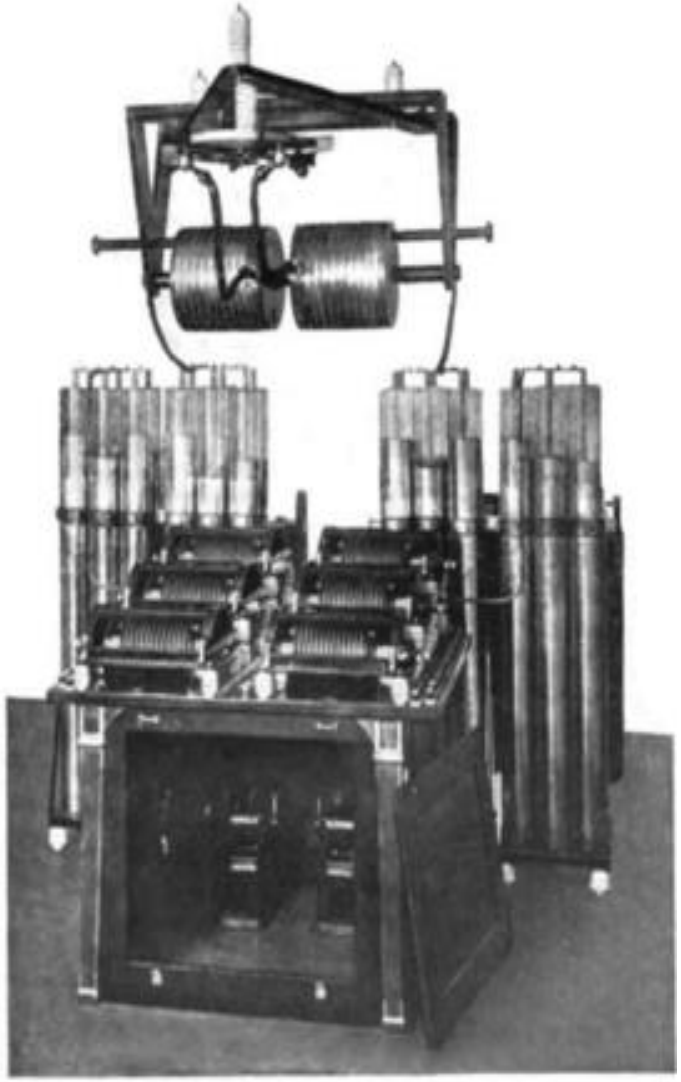
Review of Literatures on the past works - "Guglielmo Marconi's spark gap transmitter"

Spark, 1887 designed a transmitter but his transmitter could not transmit audio (sound) and instead transmitted information by radiotelegraphy. But, FUOYE training FM Radio transmitted audio developed a practical tool for the training of the communication aspect of Electrical and Electronic Engineering.



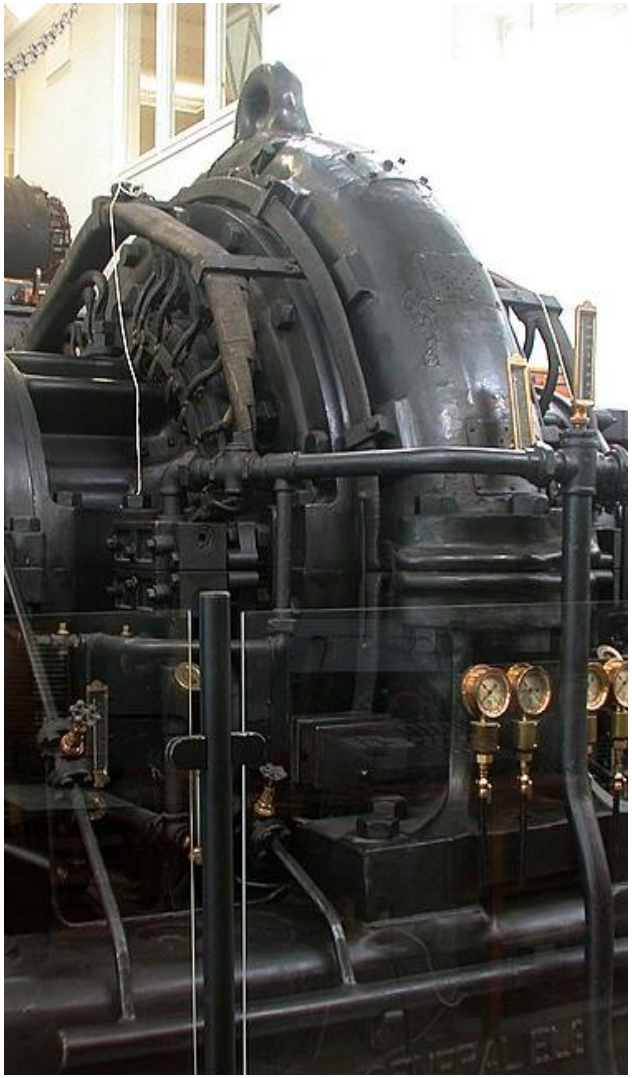
Review of Literatures on the past works - "Navy Poulsen FM MW arc transmitter"

Navy Poulsen ,1903 designed a transmitter which generated continuous waves using an electric arc in a magnetic field. The drawback of Navy's transmitter was low power 10Watts despite its huge size. However, this FUOYE training FM Radio transmitted higher power also developed a campus training radio through which information on academic and social activities could be spread in the Ikole campus of the university.



Review of literatures on the past works – "Alexanderson alternator Transmitter"

Alexanderson, 1910 designed his transmitter with alternator, a huge rotating machine used as a radio transmitter at very low frequency The drawback of Alexanderson's transmitter was a low transition frequency, while, FUOYE training FM Radio transmitted a high frequency and developed a practical tool for the training of the communication aspect of Electrical and Electronic Engineering.



FM Transmitter Types

FM signals can be produced by either directly varying the frequency of the carrier oscillator or by converting phases modulation to frequency modulation (indirect method). Depending on the method employed, FM transmitters are classified into 2 types: Direct and Indirect frequency modulation transmitter.

Direct FM Transmitter

The frequency modulation is achieved by direct variation of the carrier signal by the modulating signal. The Direct frequency modulation is commonly achieving during the transistor reactance modulator or the varactor diode modulator approach. The transistor reactance modulator comprise an active device (transistor) and a RC network in parallel with a resonant tank circuit. The RC network causes the transistor to present a capacitive or inductive effect at its output which is a function of the transconductance (gm) of the transistor.

Advantages and Disadvantages of Direct FM

Advantages of Direct FM

It is easier to obtain high frequency deviation It requires simpler circuitry.

Disadvantages of Direct FM

Additional circuitry (i.e. Automatic Frequency Control loop) is required to achieve good frequency stability. Requires a Pre-emphasis stage to reduce hiss and high frequency noise.

Indirect FM Transmitter

Indirect FM transmitters produce the FM signal whose phase deviation is directly proportional to the amplitude of the modulating signal. With this method the phase angle is varied while the frequency and amplitude remain constant. i.e. phase modulation. In order to achieve frequency modulation from phase modulation, the modulating signal must be of the same frequency as the carrier frequency.

This is commonly achieved by first amplitude modulating the modulating signal in order to produce a constant frequency signal with varying amplitude.

Advantage and Disadvantage of Indirect FM

Advantage of Indirect FM

The crystal oscillator can be used; hence there is better frequency stability.

Disadvantage of Indirect FM

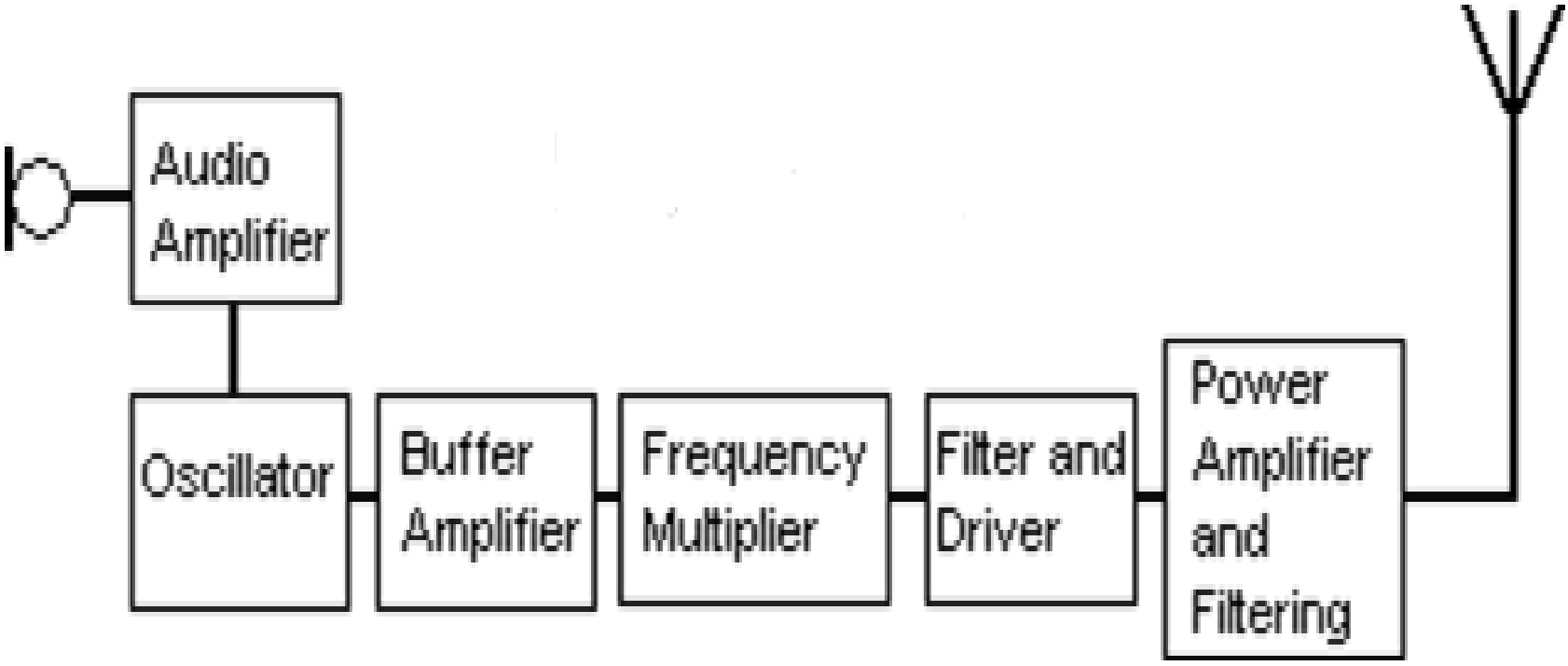
There is limited phase deviation; hence low modulation index.

Electroacoustic Transducers (Microphones)

A transducer is a device that converts energy from one form to another form. Transducers in terms of electro acoustic converts sound wave energy to electrical signal energy and vice versa. Transducer that converts changes in air pressure into corresponding changes in electrical signals is called microphone. Several varieties of microphones exist which may be classified according to the basic principle of operation. These include its resistance, moving coil induction, and capacitance and piezoelectric effect property.

Methodology-The Transmitter design

The design procedure and the analytical description of the transmitter to be developed have been described in this chapter. One of the main highlights of this chapter was the design of the required to construct antenna and 50W-Power Amplifier module of the FM Transmitter. The design consists of the following sections: audio amplifier, oscillator, frequency multiplier, buffer amplifier, filter and drive and power amplifier and filtering. These sections work in perfect synergy to bring about the overall functionality of the device.



Methodology Continued

In the above Figure shown block diagram, an Audio signal was fed into audio amplifier module that increases the power of an electrical signal whose vibrations are confined to the audio frequency range 30 Hz to 20 kHz such a range that can be perceived by the human ear. This was further amplified in buffer amplifier module. The voltage used to power the modules was 12 V DC (Direct Current). Therefore, a 9 V, 1.2 Ampere DC battery was used as the DC source. The signal was later fed into oscillator which produced a continuous, repeated, alternating waveform without any input. The Oscillator basically converted unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components. Frequency multiplier here was used as electronics circuit that generated the output signal whose output frequency was a harmonic (multiple) of carrier input frequency.

Methodology Continued

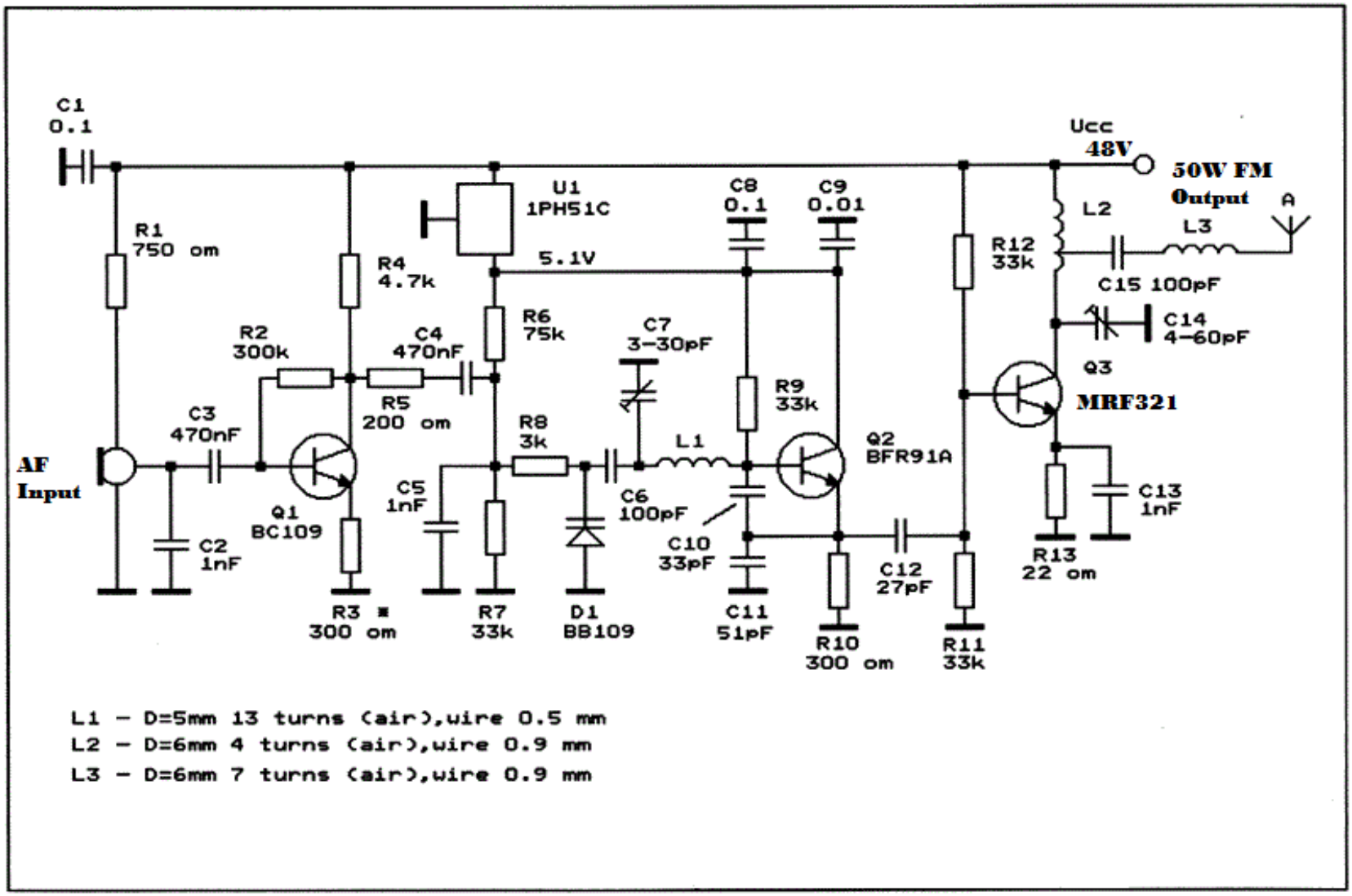
A subsequent band pass filter selects the desired harmonic frequency and removes the unwanted fundamental and other harmonics from the output. Buffer amplifier was one that provided electrical impedance transformation from one circuit to another, with the aim of preventing the signal source from being affected by whatever currents that the load may be produced with. Filter drivers are optional drivers that add value to or modify the behavior of a device. A filter driver can service one or more devices.

System Design

A good design is required for engineering project to be implemented. Mathematical and engineering calculations and derivations are mostly the process which this project undergone.

All communication electronic system including this FM Radio Transmitter entails forward radiation propagation of RF Wave through air, likewise voltage dropped at some points. Hence, various law and principles that deal with radio frequency was used for the design. Since ideal conditions are not always obtainable, some assumptions necessary for optimum performance of the system were made in the design of this project.

Schematic Diagram of the 50W FM Transmitter



Calculations

Transmitter Distance (d)

From the Global Positioning System (GPS), using the fields Area measurement software, a total distance of 1.375km=1375m was obtained as the total range to be covered by the transmitter.

The required output power P_t of the radio transmitter

Using the formula $P_t = \frac{E_2 \times d_2}{30}$

Where $E = 20\mu v = 20 \times 10{-}6v$, $d = 1375m$

- $P_t = \frac{(20\times10-6)^2\times(1375)^2}{30}$
- $\therefore P_t = 2.52 \times 10-5mw$
- When measuring a transmitter output, the measurements must be made in the far field; the power received per unit area from an isotropic antenna is calculated from the following equation.
- $Pr = P_t\ (4\pi d_2)$
- Where Pr= received power
- P_t=transmitted power
- d=distance from transmitter in meters
- $P_t = 2.52 \times 10-5mw$, d=1375m

- $Pr = \frac{2.52 \times 10-5}{(4\pi \times (1375)2)}$
-
- $Pr = \frac{2.52 \times 10-5}{2.375 \times 107}$
- $Pr = 1.06 \times 10-12mw$
- ∴1.06×10-12mw is the received power from the transmitter.
- $E = \frac{\sqrt{(30P_t)}\ d}{d}$
- Where $E$is the field strength in v/m,

P_t is the transmitted power and $d$is the distance from transmitter in meters.

P_t = 2.52 × 10−5mw, d = 1375m

Let E be the field strength

$$E = \frac{\sqrt{(30 \times 2.52 \times 10-5)}}{1375}$$

$$E = \frac{\sqrt{7.56 \times 10-4}}{1375}$$

E = 1.99 × 10−5 v/m

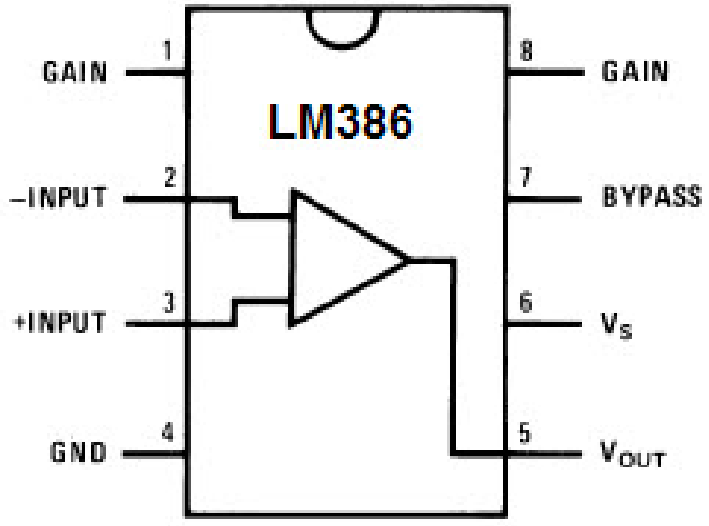
∴ 1.99 × 10−5 v/m is the field strength in the transmitter.

Specifications of the System

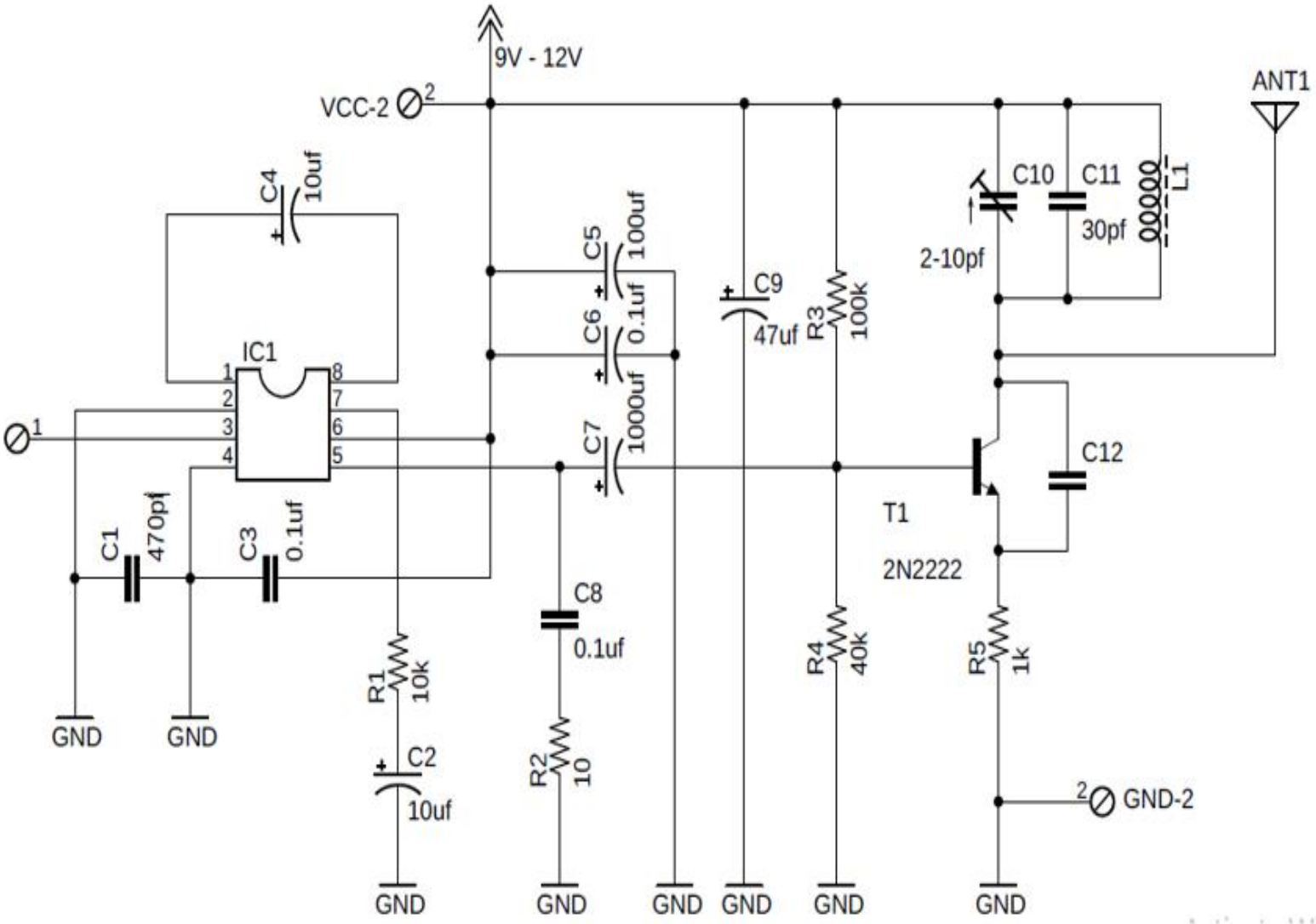
- Input power = Output power = 3000W
- Input Voltge = 220VAC
- Frequency of transmission: 88.3MHz (Bandwidth 88-108MHz)
- Effective Output Power: 50W
- Apparent Output Power: 100W
- Coverage Distance = 5KM radius

Block Diagram of Pre-Amp Audio Amplifier LM386

- Pin 2 and 3 are the sound input pins and by using these pins we could place the sound and we could amplify (Figure 3.2).
- Pin 4 is the GND terminal.
- Pin 5 is the output of the amplifier.
- Pin 6 is the terminal which receives the positive DC voltage, so that the op-amp amplifies the signals.
- Pin 7 is the bypass terminal, it can bypass 15kohm resistors. This pin was usually wired to ground or left open.



Schematic Diagram of the Audio Amplifier



Explanation on Schematic Diagram

A potentiometer, which was used as a volume control for the audio signal. To make the LM 386 more flexible, two pins (1and 8) of the audio amplifier are provided for gain control and gain adjustments. When the pins 1 and 8 open, the 1.35 kW internal resistances set the gain at 20 (26 dB). When we connected capacitor and placed from pin 1 to 8, bypassing the 1.35 kW internal resistors, the gain was go up to 200 (46 dB)

For us to get desired gain, we selected one of the above external parts and could connect between the parts mentioned below. By selecting circuit we got amplification of 200, circuit Figure 3.2.1 would give a gain of 50, circuit 3.22 would raise the bass level about 5dB, and this was connected in between 1 and 5 pins.

Testing and Construction

Construction implies the physical implementation of the designed work. It was carried out after a very careful and considerable arrangement has given to the work. Also the electrical connection of all the components in the respective units of our design in order to achieve the desired purpose was done here. It was full of challenges, which were resolved out God's grace. Also our practical experience came into play here

Testing and Construction Continued

The first step was that the calculated values of all the associated components were sought and gathered. Then the project was constructed on the project broad. This has the advantage of components to be easily fixed in and removed at will without damaging them. At point extreme care was taken not to break the terminals of the components used there was this tendency for fixing and removing them in order to sit the made design and more importantly achieve the design expected output

Testing and Construction Continued

Wires were used to interconnect the components where necessary. It should also be noted that working either the breadboard as shown below in Figure 4.1 enabled us to carry out all necessary modifications in order to obtain the desired response.

The circuit was then transferred to the Vero-board as shown below in Figure 4.2 for permanent. The wiring involved the joining of the components legs onto each other by the binding force of the hot flux emanating from a piece of melted solder that have been subjected to the heat energy developed at the bit of an electric soldering iron.

Figure 4.1-Breadboard testing

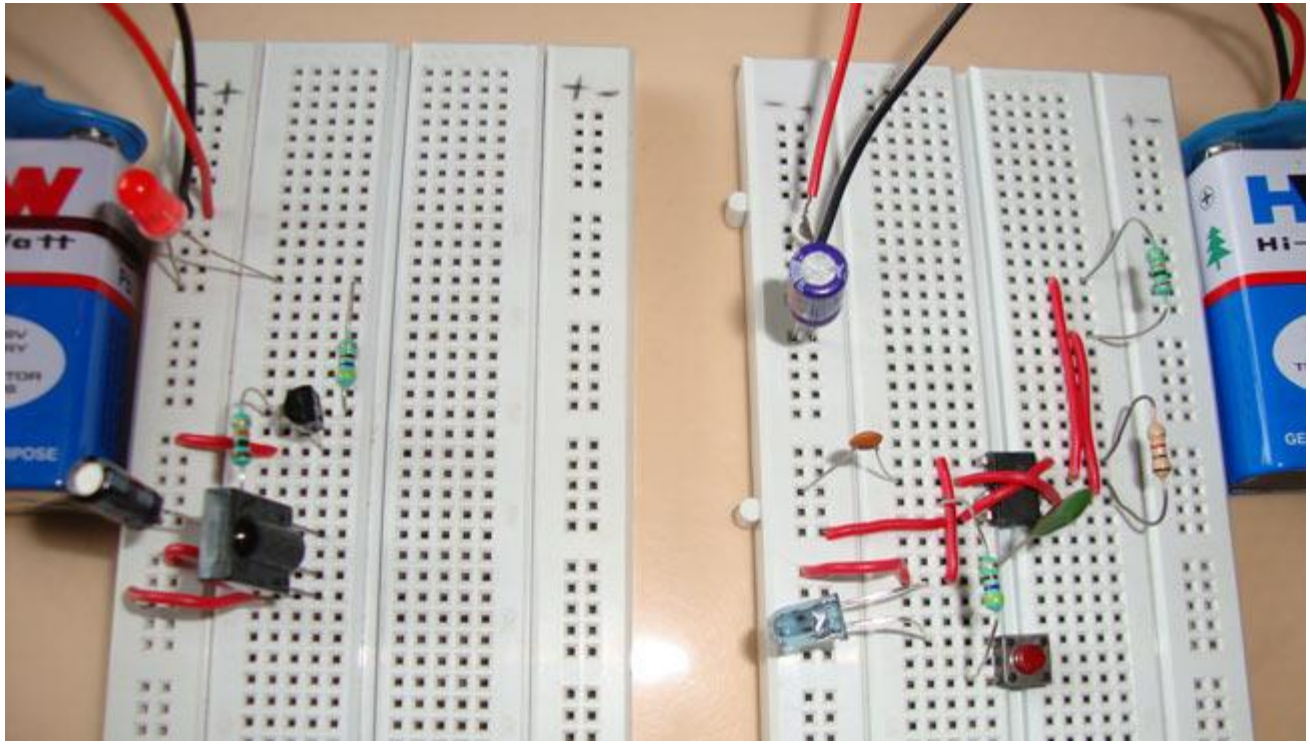
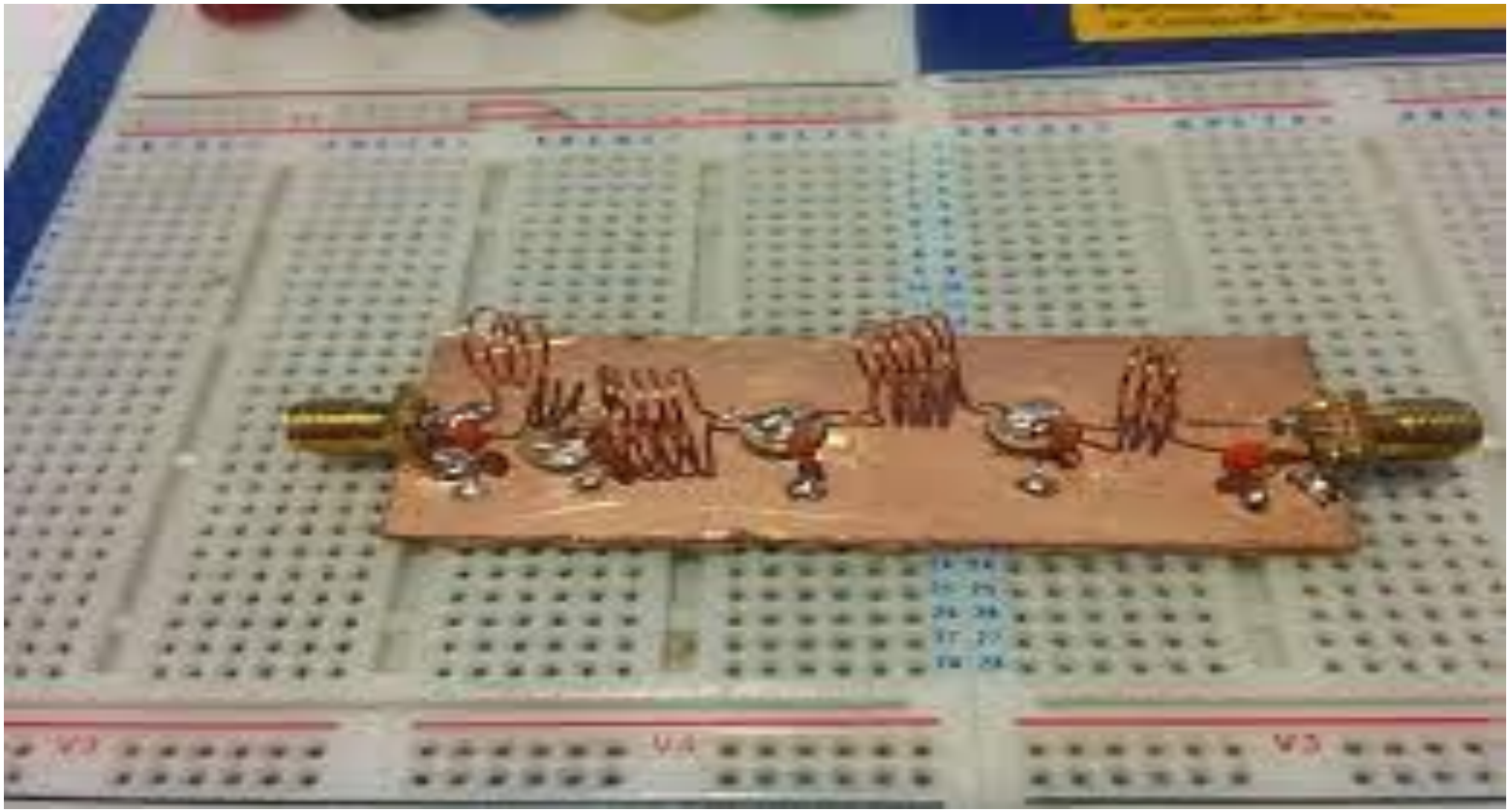


Figure 4.2-Breadboard testing



Testing Tools

The following components were fixed to the FM transmitter unit:

- RF Forward Meter: Digital RF Power Meter is connected to the front of the transmitter to display the forward transmitting power to the antenna in Watt(s).
- RF Reflected Meter: Digital RF reflected Meter is connected to the front of the transmitter to display the reverse transmitting power from the antenna in Watt(s).
- Switch: A switch is connected to the transmitter unit. This red switch controls the AC voltage input to the transmitter.

Materials Used in Testing the Circuit

- **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.
- **Bench power supply:** this was used to supply voltage to the various stages of the circuit during the breadboard test before soldering. Also, during the soldering of the project, the power supply was used to test various stages before they were finally soldered.

Materials Used in Testing the Circuit Continued

Oscilloscope: this was used to observe the oscillator waveform output to ensure the waveforms were correct and180degrees out of phase.

Connecting Wires: These are tiny pieces of copper wires about 0.2mm2 in diameter. They are used to assemble components together on the project board.

Cutter: This is to cut connecting wires and components to size.

Digital Multi-meter: This is a multipurpose electrical measuring instrument use to test for various parameters in an electrical circuit.

Insulation Tape

Complete Pliers Set

Screw driver

Figure 4.3 - Testing of FUOYE 50-Watts FM Training Transmitter

Figure 4.4 - Testing of FUOYE 50-Watts FM Training Transmitter : output waveform on oscilloscope

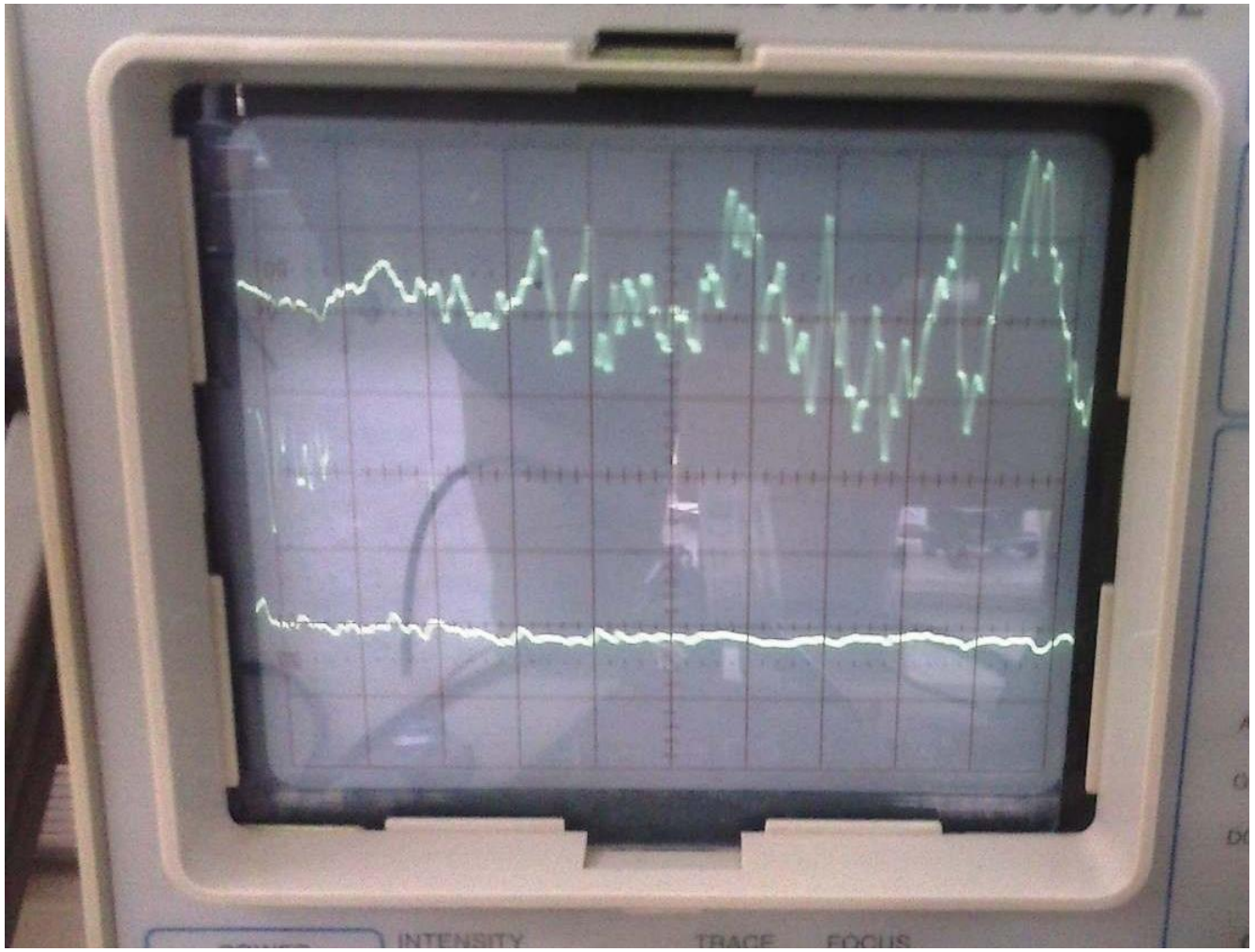


Figure 4.5 - Testing of FUOYE 50-Watts FM Training Transmitter :VSWR

Figure 4.6 - Testing of FUOYE 50-Watts FM Training Transmitter : Air conditional Force Cooling System to the transmitter

Construction of FM Dipole Antenna

The FM Dipole Antenna was constructed with galvanized iron using the same length measurement for both anode and cathode rod element figure 4.6B. 50-ohms RF cables of 30-meters were also provided for the connection of transmitter matched to the antenna. VWSR meter display the reflection status of the transmitter

Antenna Specification

- Unidirectional FM dipole antenna was used for the constructed transmitter. The specifications were:
- Height : 10m
- Impedance: 50ohm
- Cable Type: Coaxial
- Impedance of the Cable used: 50ohm

Testing of FUOYE 50-Watts FM Training Transmitter : Audio Console Installation

The Audio Console was installed very close to the transmitter in order to reduce noise along the cable line. The unit equalizes and process voice signal from microphone as well as music from various players. Figure below display the installation of the audio console at the FM studio, workshop Engineering building, Federal University Oye-Ekiti, Ikole Campus.

Testing of FUOYE 50-Watts FM Training Transmitter : Monitor with Speakers Installation

The radio monitors with the speaker were installed inside the studio and the two speakers were connected together with wire using flexible wire to monitor radio amplifier .The transmitter was connected to the mains source, 220Vac and the receiver was picked up the signal at the frequency of 88.3 MHz when the transmitter was power on.

Transmitter Radius Distance Covered Audit

The transmitter radius distance covered audit is being conducted to evaluate the efficiency and performance of the constructed 50-Watts FM Radio Transmitter. The scope of the audit includes a mobile radio receiver that we used to monitor both inside the Faculty of Engineering Federal University Oye-Ekiti Campus and the outside the school gate. The table below shows the received signal strength in dBm.

Table 4.1: Transmitter Radius Distance Covered Audit at Nominal Power 50-Watts

Location	Distance (M)	Signal Level (dBm)	Line of Sight	
Faculty of Agriculture	200	108	Plain	
Faculty of Engineering	50	113	Plain	
NNPC Filling Station	2000	65	Plain	
Oye Road	5000	60	Plain	
Omuo Road	5000	60	Plain	
FUOYE Ikole Campus School gate	600	90	Plain	

Conclusion

- The project was a 50-watt FM radio transmitter designed to provide more practical knowledge on the communication aspects of electrical and electronics engineering at the Federal University Oye-Ekiti, Ikole campus. Transmission of audio signals from different sources (phone, laptop, and also oral communication) was carried out and successfully done after going through several experiment tests. This design and construction were achieved after going through several literature reviews in which the principle of modulation was discussed and the beginning of radio transmission was also put into view.

- Transmission was possible after testing, and we got our desired result of having a crystal reception and longer transmission. The aims of the project were achieved, as the 50W FM transmitter was capable of transmitting a frequency-modulated signal to an FM radio up to a distance of 5 km. That is, a device that can broadcast signals on an FM broadcast band and be picked up by the receiver.

Limitations

- As general knowledge, no system can be 100% efficient no matter how great its design and the problem it aims to solve. Hence, the following are the limitations that should be observed in the FM radio transmitter during operation:
- Antenna loads less than 50 ohms should not be connected to the transmitter.
- The power of the transmitter should not be overdriven more than the nominal 50 watts.
- The transmitter should be used only to broadcast audio signals, not video or data signals.
- ~~T~~he power amplifier temperature should be examined constantly to avoid overheating.

Recommendation for Future Works

- The FM radio transmitter can operate safely and effectively on a plane or dry surface (within), but it must be protected from hot weather and matched properly to the dipole antenna for effective forward power and a good Voltage Standing Wave Ratio (VSWR). The following are recommended for future improvement on the project:
- The 50-watt power amplifier module can be improved to cover a greater kilometer radius distance.
- More power supplies can be added to the transmitter to increase the reach distance.
- The power of the transmitter can be improved by increasing the number of amplifiers inside the transmitter.
- The cooling system needs to be increased due to future development and maximum effective power point tracking.

Contribution to Knowledge

The project contributed to the existing knowledge as follows:

- It developed a practical tool for the training of the communication aspect of Electrical and Electronic Engineering.
- It also developed a campus training radio through which information on academic and social activities could be spread in the Ikole campus of the university.

Reference List

Andy Collinson.(1998) "Estimating Transmitter Distance." Design and Construction of a Frequency Modulation (FM) transmitter. pp.142.

Balanis, Constantine A. (2005). "Antenna theory: Analysis and Design", 3rd Ed. John Wiley and Sons. pp. 10. ISBN 9781118585733.

Balanis, Constantine A. (2005). "Antenna theory: Analysis and Design". 3rd Ed. John Wiley and Sons pp. 10. ISBN 9781118585733

Chitode J.S.. (2010). "Communication Theory". 5th ed. Technical Publications Pune. pp.21-24

Chitode.(2010). "Communication Theory, 5th ed". Technical Publications Pune,

Dale R. Patrick and Stephen W. Fardo. (2010), Electricity and Electronics Fundamentals, 2nd ed. The Fairmont Press Inc. pp.34. Dobre, Octavia A., Ali Abdi, Yeheskel Bar-Ness, and Wei Su. Communications.(2007). "Survey of automatic modulation classification techniques: classical approaches and new trends" 137–156. (2007). (PDF). pp 137–156.

Reference List Continued

Ellingson, Steven W. (2016). "Radio Systems Engineering". Cambridge University Press. pp. 16– 17. ISBN 978-1316785164.

Ellingson, Steven W. (2016). Radio Systems Engineering. Cambridge University Press. pp. 16–17. ISBN 978-1316785164.

Goh, H. S. (1998). "Antenna theory: Analysis and Design, 3rd Ed" pp. 10. ISBN 9781118585733.

Guarnieri, M. (2012). "The age of vacuum tubes: Early devices and the rise of radio communications". IEEE Ind. Electron. M.: 41–43. doi:10.1109/MIE.2012.2182822.

H. Ward Silver.(2007). "The ARRL Extra Class License Manual for Ham Radio" Halper, D. (2007). "In Search of the Truth about Fessenden". Radio World Online.

Reference List Continued

International Telecommunications Union. (2016). "Antenna theory" and "principles of Communication". Tutorial point Pvtltd. Jeffrey Wheat, Randy Hiser, Jackie Tucker, Alicia 58 Neely, and Andy McCullough, Designing a Wireless Network.syngress. ITU Rec. BS.450.

Jerry C. Whitaker.(2005)." Wireless Communication Systems: From RF Subsystems to 4G enabling Technologies". Swamy Cambridge University Press. Jones, Graham Electrical engineer (4th ed.). ISBN 9781317906834

Justesen, Don (1975). "Microwaves and Behavior". American Psychologist. Vol. 30, no. 3. Washington, D.C.: American Psychological Association. pp. 391–401..

Reference List Continued

Kellejian, Robert (2008), "Applied electronic communication: Circuits, systems, transmission. Science Research Associates. Lin, James C. (2021). "Auditory Effects of Microwave Radiation. Chicago: Springer". p. 326. ISBN 978-3030645434.

Louis F.(2016). "Principles of Electronic Communication Systems 4th edition". Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

Mary, B. Nahin, P. J. (2001). "The Science of Radio with Matlab and Electronics Workbench Demonstration, 2nd Ed". Springer Science & Business Media.

Nnolum, E and Mamah, R. (2018). "Design and implementation of a laboratory dual antenna" Ogbuanya (2017). "Design and Construction of Frequency Modulated (FM) transmitter with output power of 10 watts and range above 4KM". Department Industrial technical Education, Paul McLane, "Radio World: FM Signal Count Grew 38% in Ten Years." [Online]. Available: http://www.radioworld.com/article/fm-signal-count-grew--in-ten-years/277873.

Reference List Continued

Radio Systems Engineering. Cambridge University Press. pp. 16–17. ISBN 978-1316785164.

Ralph, B. (1992). "Newton to Einstein". The Trail of Light. Cambridge University Press. Receiver system. Department of Electronic Engineering, University of Nigeria, Nsukka. Receiver system. Department of Electronic Engineering, University of Nigeria, Nsukka. 59 Receiver. University of Malaysia, Sarawak.

Serway, Raymond. (2008). "College Physics, 8th Ed. Cengage Learning". pp. 714. ISBN 978- 0495386933

Reference List Continued

Serway, Raymond; Faughn, Jerry; Vuille, Chris. (2008). "College Physics, 8th Ed. Cengage Learning". p. 714. ISBN 978-0495386933.

Skip., Pizzi (2014). "A Broadcast Engineering Tutorial for Non-Engineers".

Storr W (2013) "Sound Transducer for Sensing and Generating Sounds" Basic Electronics Tutorials, [Online]. Available: http://www.electronics-tutorials.ws/io/io_8.html

V.K Mehta, Rohit Mehta. (2008) "Principles of Electronics". International Journal of applied Engineering research. pp.208

Zakari, A. (2009). "Design and Construction of a Long-Range FM transmitter". Department of Electronic and computer Engineering. Federal University of Technology, Minna.