Research Article / Review Article FUPRE JOURNAL 9(3):227-235(2025)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Development of a Cellular Radio Frequency Modulation Transmitter-Receiver System

OTAVBORUO, E. E.[1,*]

[1]*Department of Electrical and Electronic Engineering, Federal University of Petroleum Resources, Effurun, Delta State*

ARTICLE INFO

Received: 12/07/2025
Accepted: 30/09/2025

Keywords

Cellular FM, Cellular radio, Frequency modulation, Receiver, Transmitter

ABSTRACT

Frequency Modulated (FM) signal transmitter is a device for transmitting Frequency Modulated signal over short range. The project is aimed at designing independent transmitter-receiver system suitable for FUPRE academic environment with extension to industrial, scientific and medical spheres. This document outlines a straight forward and cost-effective design technique for constructing a FM transmitter using simple electronic components like resistor, capacitor, inductor etc. The transmitter was tuned to 101.0 MHZ at open space as well as building, and trees while the FM receiver as well cellular FM radio receivers were located at a radius of about 300m from the transmitting point. The system was also tested at the lecture theater one auditorium close to the library, and Tetfund one building (old Tetfund) at Federal University of Petroleum Resources, Effurun, Delta State. A clear voice signal was received at these locations.

1. INTRODUCTION

A transmitter is defined as an electronic device that can propagate an electromagnetic signal with the aid of an antenna (Iskam, 2022). Whereas frequency-modulated (FM) transmitter generates an FM waves using a frequency carrier or an oscillator while the signal output is transferred through the antenna which interfaced with the electromagnetic medium. Most FM transmitters utilized in Nigeria are made outside the shore of the country and therefore conform to actual demands on Nigeria university campuses. This study, therefore, demonstrate that FM can be locally designed to meet the needs of students, teaching staff and the university community in terms of academic news broadcast, research and entertainment on the campus. The FM transmitters are commonly used for communication and broadcasting purposes. Compared to amplitude modulation (AM), FM signals are less susceptible to interference and noise due to their higher bandwidth (Braga, 2001; Boylesta, 2007). However, the transmitted signal from FM devices have limited reception range. This, of course is dependent on the distance between the transmitter and receiver as well as the design parameters deployed. During transmission, the modulated signal encounters mix noises emanating from buildings, trees, and other before it is transferred to the receiver. Transmitters are typically powered by 9V DC batteries which can last for approximately six hours before

*Corresponding author, e-mail: otavboruo.ericsson@fupre.edu.ng

they discharge (Lathi, 1998). This study uses communication principles and theories to explain radio transmission. In principle the modulating signal is then mixed with a carrier radio frequency (RF), a process known as frequency modulation. FM transmission is achieved by varying the frequency of the carrier wave in accordance with the encoded the modulating signal. This project is geared towards developing an FM system which aid clear, and efficient communication. The variation of the carrier wave's frequency in accordance with modulating signal contributes significantly resistance to physical interference encountered in the atmospheric. The same process is applied in the digital or discrete sense, where the frequency shift-key (FSK) is used to replace the analog FM. Digital techniques gives rise to the proliferations of modern communication systems by providing higher data rates as well as removing noise from radio communication system. Digital modulation schemes are in general used for effective long-distance communication. *(*Basu and Bhowmik, 2020). To implement FM system, the following components used are: (i) KT0803 (FM transmitter) (ii) RDA5807 (FM receiver) (iii) microcontroller powered by a rechargeable 9V battery, (iv) LCD screen.

The aim of this project is to improve on the one way traditional FM system transmission by interfacing developed FM system with mobile phones devices. This could be applied in mitigating distance barrier experienced by the overcrowded classes as the FM design incorporates transmitting modules which operate in the industrial, scientific medical (ISM) band.

Specifically, the primary goals of the project are to:

- Design and construct an independent frequency modulation transmitter-receiver system that also connects the cellular FM receiver system
- Mitigate subscription fees charged by Network operators
- Enhance the dissemination of academic lectures using radio broadcasting beyond the limited and overcrowded hall.

Overall, the project highlights how the FM technology could be combined with a digital microprocessor to provisioning an effective and inclusive academic lectures to students within Federal University of Petroleum Recourses, Effurun, Delta State.

2. LITERATURE REVIEW

The primary function of an FM transmitter circuit is to perform frequency modulation and amplify FM signals for long-range communication, utilizing a simple single-transistor setup. In frequency modulation (FM), the frequency of a carrier wave is altered in accordance with the fluctuations of the modulating signal, which contains the intended information. FM transmitters typically operate within the very high frequency (VHF) range, spanning from 87.5 MHz to 108.0 MHz in the electromagnetic spectrum. The prototype of the smart FM transmitter used in this research achieves excellent transmission range while consuming minimal power. The efficiency and operation of the wireless audio transmitter are largely influenced by electrical elements such as the induction coil and the variable capacitor. Essential elements of the FM transmitter include an antenna, RF amplifier, modulator, audio pre-amplifier, and microphone. The RF signal required for transmission is generated by an oscillator within the FM transmitter. A 9 V power source is sufficient to operate the circuit, which consists of various components such as capacitors, inductors, resistors, a trimmer capacitor, microphone, antenna, and transmitter section. The microphone, equipped with a capacitive sensor, captures sound by detecting changes in air pressure, which are then converted into AC signals. The KT0803 transmitter module is employed to create the oscillating tank circuit, comprising an inductor and a variable capacitor. This general-purpose module is to amplify the signal. As current flows through the phase lock loop circuit, the circuit resonates at a frequency matching that of the modulated AC signal.

2.1 Review of Related Research Works

This chapter provides an overview of previous research and design efforts related to FM transmitter systems, highlighting different methods used to achieve similar objectives. Studies have explored frequency modulation and radio transmitter design, and some of the works relevant to this studies are summarized below.

The design and construction of an FM transmitter was undertaken by a research study with the sole aim of illustrating design and construction in details the capability of FM signal operations (Iskam, et al, 2022). The FM transmitter was constructed using a designed circuit diagram consisting of the BC547 NPN transistor, resistors, coil, capacitors, power supply, and a microphone. The practical design worked well at a frequency of 89.7 MHz and covers a distance of 10 m.

Raghu et al. (2021) designed a basic FM transmitter aimed at producing a noise-free signal over a short distance, with potential applications in security and surveillance. The design followed a four-stage methodology which include the input, amplification, resonance, and output. The circuit included components such as resistors, capacitors, inductors, a 2N2222 transistor, a microphone, an antenna, and a 5V power source. The project successfully met its objective of delivering clear signal transmission within the limited 200 meters using a simple and efficient circuit.

Investigation was carried out on optimizing random FM radar waveforms to enhance spectral efficiency and system performance (Mohr and Blunt, 2020). The study utilized Gaussian and super-Gaussian spectral templates and employed the Temporal Template Error (TTE) method to fine-tune the waveform shape. This technique minimized deviations from target spectral characteristics, resulting in improved spectral containment and waveform performance.

A study developed a wireless FM transmitter intended for long-distance communication (Deboris et al. 2020). That project centered on building a prototype capable of transmitting high-definition audio using FM technology over a considerable range. Key components in the design includes audio pre-amplifier, FM modulator and the RC unit used for unwanted noise cancellation. The project utilized bit hardware and NI Multisim Student Edition 14 software. The circuit include a three stage single ended Class A amplifier, stage two and three consist of two thank capacitor units used for the output signals and minimizing the signal distortions. The circuit incorporated the class A amplifier and the tank circuit. The transmitter is operated across the FM band (88 – 108) MHz. The prototype transmitted an input audio signal at the input of the microphone and a mobile phone received a clear audio signal at 100 meters from the transmitter unit outside the range outside the FM range.

Mbagwu et al. (2020) designed and constructed a low-power digital FM transmitter based on an existing circuit. The system, powered by a safe 9V DC supply, incorporated a 2N3904 transistor in its low-output stage. However, the output power

(2.52×10^{-5} mW) was insufficient for practical broadcasting. The project involved recalculations and experimentations aimed at improving output efficiency. Despite successful testing, the transmitter failed to deliver optimal clarity or extended range.

A project designs and constructs a low cost and low power FM transmitter using locally sourced materials for the purpose broadcasting news programmes and entertainment in the university space (Onah et al, 2019). The design employed three stages which includes, breadboard, vero-board construction, and printed circuit board constructions. Signals from a microphone is amplified and modulated using proteus software, tested with a printed circuit board before being constructed on a vero-board.

Shrivastava et al. (2017) designed a short-range FM transmitter powered by a 9V DC battery with a lifespan of about six hours. The system modulated audio signals, such as those from a microphone, with the RF carrier signal. The project detailed the components used to including a microphone, transistor, capacitors, and an inductor. The circuit operated in four main stages: audio input, signal amplification, modulation through an LC oscillator, and RF transmission through an antenna. A circuit diagram and explanation of each component's role were provided. The system was simulated using NI Multisim 10 to verify the design and analyze the waveform and frequency spectrum. Practical testing on a breadboard at 97.1 MHz demonstrated clear voice transmission within a 20-meter radius, with noticeable noise beyond that range. The study concluded that extending the transmission range and improving performance could be achieved by adding more amplification stages and optimizing the power supply.

Ranjana et al. (2013) conducted a project at the Raj Kumar Goel Institute of Technology for Women in Ghaziabad. Their objective was to design a compact, low-power FM transmitter suitable for applications like hearing aids, security, and entertainment. The project emphasized the advantages of FM technology, particularly its resistance to noise and the capture effect that allows the strongest signal to prevail.

Ahmed (2012) designed and implemented a low power FM transmitter operated at 106 MHz to be implemented on a local area network for local entertainment on a campus. The design of the final circuit of the transmitter was focused on the parameterization of the directivity, pre-emphasis, Oscillator which is obtained from bipolar junction transistor (BC239BP), modulator and antenna. All devices used in the designed was sourced locally. There was no demonstration of the practical transmitter that determines if it meets the specifications for which it was designed.

3. MATERIAL AND METHODOLOGY

This project was accomplished through the help of and adoption of existing FM transmitters approaches past works. Theoretical background from textbook form the basic concept for actualizing the empirical transmitter receiver system projected in this study. Theoretically, the frequency modulated signal is expressed by Dunlop and Smith, (1994) as shown in Equations (3.1) to (3.4). By applying half-angle trigonometry functions and series expansion of cosine and sine to Equation (3.2) while assuming that $\beta \ll 1$, produced the narrowband theoretical formulation of the frequency modulated signal conveniently approximated as shown in Equation (3.3). Equation (3.3) was rewritten using Fourier series while specifying Bessel function for of the first kind for the coefficient C_n for various values of n as shown in Equation (3.4). Theoretical bandwidth (B) of an FM system is expressed utilizing Carson's rule for both large and small β as shown in Equation (3.5).

$$V_{fm} = A\cos\left(2\pi f_c + \frac{K_2 a}{f_m}\sin(2\pi f_m t)\right) \tag{3.1}$$

$$V_{fm} = A\cos(2\pi f_c + \beta\sin(2\pi f_m t)) \tag{3.2}$$

$$V_{fm} = A\left(\cos(2\pi f_c t) + \frac{\beta}{2}\cos\{2\pi(f_c - f_m)t\} + \frac{\beta}{2}\cos\{2\pi(f_c + f_m)t\}\right) \tag{3.3}$$

$$\begin{aligned} V_{fm} = {} & J_0(\beta)\cos(2\pi f_c t) - J_1(\beta)[\cos\{2\pi(f_c - f_m)t\} - \cos\{2\pi(f_c + f_m)t\}] + \\ & J_2(\beta)[\cos\{2\pi(f_c - 2f_m)t\} - \cos\{2\pi(f_c + 2f_m)t\}] + \\ & J_3(\beta)[\cos\{2\pi(f_c - 3f_m)t\} - \cos\{2\pi(f_c + 3f_m)t\}] + \ldots \end{aligned} \tag{3.4}$$

$$B = 2f_m(1+\beta) \tag{3.5}$$

$$B = 2f_m\beta = 2\Delta f_c \qquad when\ \beta >> 1$$
$$B = 2f_m \qquad when\ \beta << 1$$

Where,

$$K_2 a = \Delta f_c$$

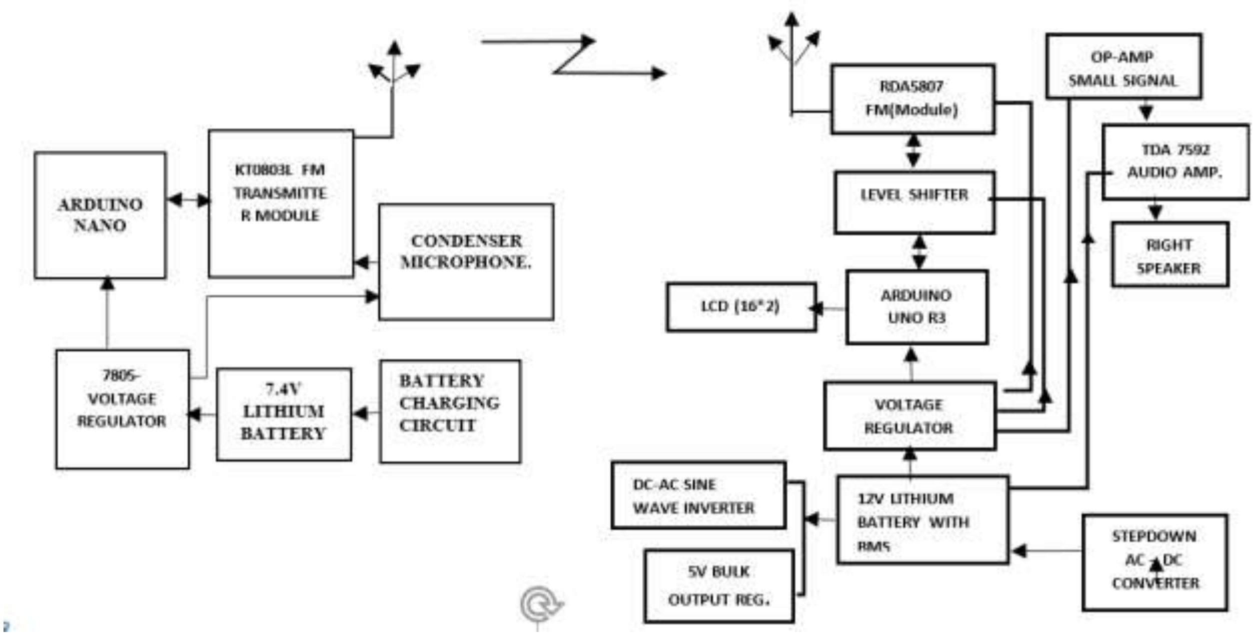
$$\beta = \frac{\Delta f_c}{f_m}$$

3.1 Frequency Modulation Transmitter and Receiver Circuit Design

The transmitter and receiver architecture is depicted in Figure 3.1 it consists of the transmitter and receiver modules. The transmitter device is designed with the following components KT0803 FM Transmitter module, condenser microphone, switch, Arduino Nano interfacing together powered by battery. Arduino Nano serve as processing interface which helps in creating a medium of communication signal from the KT0803L FM transmitter module and condenser microphone. A 7805-voltage regulator connected to the Arduino board to deliver a working voltage for the entire operation. Figure 3.1 (a) is the architecture of the FM transmitter.

The architecture and modules of the receiver comprise the RDA5807, level shifter, Arduino Uno R3, lithium battery, operational amplifier, DC-AC sine wave inverter. Stepdown AC-DC converter, 5 V bulk output and LCD linked as shown in Figure 3.1 (b). The FM receiver circuit functions by using the antenna to capture FM signals from the electromagnetic medium, which is then processed by the RDA5807 module. This module locks onto the 101 MHz FM transmitter, demodulates the FM signal, and delivers stereo audio output through the left right channels. At the heart of the receiver circuit is the Arduino Uno R3, which controls operations such as frequency tuning and station switching by communicating with the RDA5807 module. It also handles input from control uplink and downlink channels. A logic level shifter is used to bridge the voltage difference between the Arduino's 5V output and the 3.3V input required by the RDA5807.The audio output from the RDA5807 is amplified using a TDA7297 amplifier module, which drives stereo speakers (LS1 and RS1) to produce clear audio output. A 16x2 LCD, managed by the Arduino, displays information like the current station or frequency. A potentiometer (RV2) is used to adjust the display contrast.

Power to the circuit is provided through several L2596 DC-DC buck converters, which step down voltage to appropriate levels: 12V for the audio amplifier and 5V or 3.3V for other components such as the Arduino and the FM module. Resistors are used throughout the circuit to manage current flow and maintain stability. Altogether, this setup enables efficient FM signal reception with stereo audio output, while offering user-friendly controls for tuning and station selection. Figure 3.2 shows the practical circuit realization of the FM transmitter-receiver system.



(a) FM transmitter system (b) FM Receiver system

Figure 3. 1: Schema presentation of FM transmitter and receiver system.

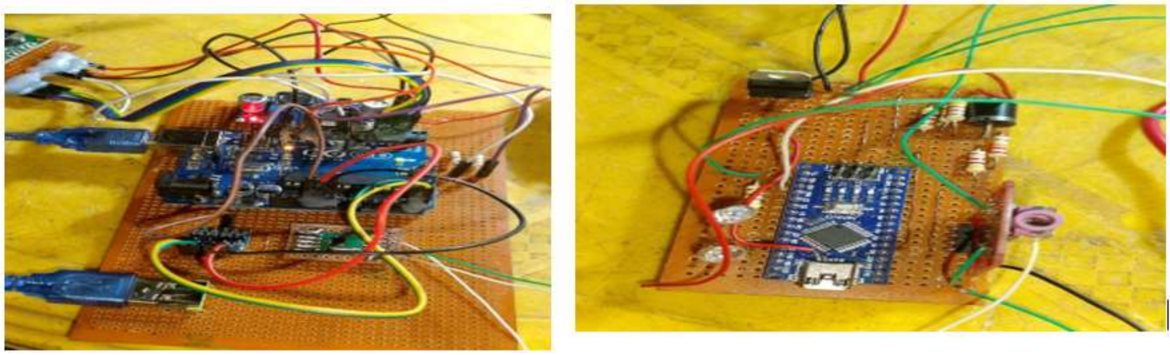


Figure 3.2: Practical circuit representation of the FM transmitter-receiver system.

For 88 -108 MHz, the total channel width of a station is 150 kHz + 2(25) kHz = 200kHz, and only alternate channels can be allocated within a geographical area. In accordance with the Federal Communication Commission (FCC), the maximum limit of the frequency of the modulating signal ($f_{a, max}$) for both commercial television and FM broadcast band is 15kHz, while the maximum deviation for FM and Television are 75 kHz and 25 kHz, respectively (Dunlop and Smith, 1994).

3.2 Frequency specification of FM transmitter

The frequency of the FM transmitter is radio system presented as shown in Equation (3.6).

$$F_{tx} = F_{ref} \times \frac{N}{R} \qquad (3.6)$$

Where:

F_{tx}: desired frequency for transmission
F_{ref}: reference frequency= 32.768kHz (from the datasheet)
N: multiplier {synthesized frequency control value} = 3080.078
R: Divider = 1

$$F_{tx} = \frac{32768 \times 3080.078}{1}$$

$$\approx 101 \times 10^{6}\text{Hz} = 101\text{MHz}$$

Instantaneous frequency calculation is represented by Equation (3.7).

$$F_t = F_c + \Delta F \, sin 2\pi f_m t \qquad (3.7)$$

Where,

F_c = Carrier frequency (101MHz)
ΔF = Peak frequency deviation

Fm = Modulating frequency

F_t= 101MHz $\pm$ 75kHz

The instantaneous frequency varies between 101.075MHz and 100.925MH, it given by s Equation (3.8)

$$\text{Channel code} = \frac{F_{tx} - F_{start}}{step\ size} \tag{3.8}$$

Where,

F_{tx} = 101MHz

F_{start} = 76MHz

step size = 50kHz

$$\text{Channel code} = \frac{101-76}{0.05} = 500$$

500_{10}= 11110100_2

The channel code was used to program the frequency, which is distributed across the following registers as shown below.

Register 0×01: CHSEL[11.9] bits 2.0

Register 0×00: CHSEL[8.1] bits 7.0

Register 0×02: CHSEL[0] bits 7

4. RESULT AND DISCUSSION

After completing the project design, it was tested at the Federal University of Petroleum Resources, Effurun, Delta State gather observations. The project was thoroughly inspected to ensure all components were intact and functioning, and was properly packaged. The transmitting frequency was tuned to 101.0 MHZ at open space as well as building, and trees while the cellular FM radio receiver was located at a radius of about 300m from the transmitting point. The system was also tested at the lecture theater one auditorium close to the library and Tetfund one building (old Tetfund) at Federal University of Petroleum Resources, Effurun, Delta State. Clear voice signals were received at these locations.

5. CONCLUSION

This system introduces a new and improved method of transmitting audio signals through frequency modulation using a well digitized Arduino module. The receiver system was enhanced by incorporating into it is a lithium inverter BMS and charging ports used for recharging phones, batteries of the transmitter, powering 5 V Light emitting diode, etc.

6.0ACKNOWLEDGEMENT

I thank God who has made this research a reality. I also acknowledge the Department of Electrical and Electronics Engineering as well the COET and FUPRE for giving me the platform/laboratory to realizing the research.

REFERENCES

Ahmed M. M. S., (2012). Design and Implementation of low Power FM Transmitter, School of Computing and Electrical Engineering, Bahir Dar University, 1 – 42.

Basu, D., and Bhowmik, A., (2020). Design and implementation of a smart and portable wireless FM transmitter for wide range communication. Journal of Engineering Research and Reports, 15(2), 2582–2926.

Boylestad R.L., (2007). Introductory Circuit Analysis, Eleventh Edition, Prentice Hall.

Braga N., (2001). Pirate Radio and Video: Experimental Transmitter Projects, Newnes Butterworth-Heinemann Publishing.

Deborsi B. and Bhowmik A., (2020). Design and Implementation of a Smart and Portable Wireless FM Transmitter for Wide Range Communication. Journal of Engineering Research and Reports, 15(2), 2582-2926.

Donlop J and D.G., (1994). Telecommunications Engineering (3ed.) Chapman and Hall, 59 – 63.

Iskam M. A, et al., (2022). Design and Construction of FM Transmitter. Department of ICT, Camilla University, 1-25. https://www.researchgate.net/publication/367117863_DESIGN_AND_CONSTRUCTION_OF_FM_TRANMITTER.

Lathi. B.P., (1998). Modern Analog and Digital Communication Systems, Third edition, Oxford University Press.

Mbagwu J. C, Ezike C. F, J, Ozuomba J.O., (2020). Design Construction and Testing of a Low Energy Digital Frequency Modulation (FM) Transmitter. IJSER 11(1)

Mohr C. A, and Blunt S. D., (2021). Designing Random FM RADR Waveforms with Compact Spectrum. International Conference on Acoustics Speech and Signal Processing. 1-5. DOI:10.1109/ICASSP39728.2021.9414020

Onah N, Ezike A, and Udechukwu F., (2019). Design and Implementation of a Mini Radio Transmitter on a Locally made PCB. 1-9. https://www.scribd.com/document/635161948/ONAH-MC-MINIRADIOTX.

Raghu, B. T., Krishna, R., and Praveen, A., (2021). Design and construction of a simple and cost-effective frequency modulated transmitter of the range 100 meters. International Journal of Research Publication and Reviews, 2(7), 1665–1657.

Ranjana S. and Nidhi, (2013). Design and Working of FM Transmitter. International Journal of Advance Research in Science and Engineering, 2(10), 39-44. http://www.ijarse.com

Shrivastava, A., (2017). Design and development of low-range frequency modulated signal (FM) transmitter. BIBECHANA. A Multidisciplinary Journal of Science, Technology and Mathematics, 15(0), 30–36. https://doi.org/10.3126/bibechana.v15i0.18279