***Project Report***

*on*

FREQUENCY MODULATION Tx-Rx USING USRP

*Submitted in partial fulfilment of the requirements for the award of the degree*

*of*

**Bachelor of Technology**

in

**Electronics and Communication Engineering**

by

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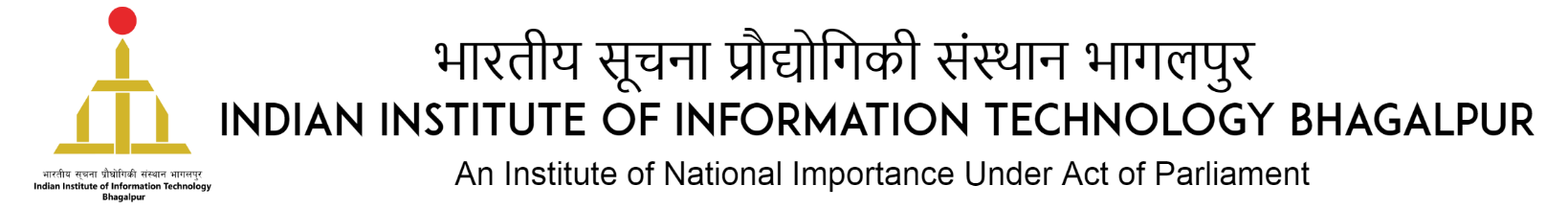
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**Dec, 2024**



# 

# DECLARATION

We hereby declare that the work reported in this project on the topic “***Frequency Modulation Tx-Rx using USRP***” is original and has been carried out by us independently in the **Department of Electronics and Communication Engineering, IIIT Bhagalpur** under the supervision of **Dr. Prakash Ranjan,** Assistant professor, IIIT Bhagalpur. We also declare that this work has not formed the basis for the award of any other Degree, Diploma, or similar title of any university or institution.

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# Home

# CERTIFICATE

This is to certify that the project entitled “***Frequency Modulation Tx-Rx using USRP***” is carried out by

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, B. Tech. students of IIIT Bhagalpur, under my supervision and guidance. This project has been submitted in partial fulfillment for the award of “***Bachelor of Technology”*** degreein ***Electronics and Communication Engineering*** at ***Indian Institute of Information Technology Bhagalpur***.

No part of this project has been submitted for the award of any previous degree to the best of my knowledge.

|  |  |
| --- | --- |
| **(Supervisor)**  **Dr. Prakash Ranjan**  Assistant Professor  Dept. of Electronics and Communication Engineering | **(Head)**  **Dr. Dhrubajyoti Bhattacharya**  Assistant Professor  Dept. of Electronics and Communication Engineering |

# Acknowledgement

With great pleasure we express our cordial thanks and indebtedness to our admirable Guide, *Dr. Prakash Ranjan,*Assistant Professor, Department of Electronics and Communication Engineering***.*** His vast knowledge, expert supervision and enthusiasm continuously challenged and motivated us to achieve my goal. We will be eternally grateful to him for allowing us the opportunity to work on this project.

We express our sincere gratitude to Dr. Dhrubajyoti Bhattacharya, Assistant Professor and Head of Department for his valuable help providing me all the relevant facilities that have made the work completed in time.

During the course of this Project Report preparation, we have received lot of support, encouragement, advice and assistance from many people and to this end we are deeply grateful to them all.

We have great pleasure in expressing my sincere gratitude and thanks to the *Prof. P.K.Jain****,*** *Director,*Indian Institute of Information technology Bhagalpur for his constant encouragement for innovation and hard work.

We would take this opportunity thank all faculty members of department of Electronics and Communication Engineering, IIIT Bhagalpur for their persistence in academic excellence throughout the years.

The present work certainly would not have been possible without the help of our friends, and also the blessings of our parents.

Kummari Siddartha Ramavath Adithya Vechalapu Uday Kiran Yata Rupesh

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# Abstract

This paper investigates the implementation of Frequency Modulation (FM) transmission and reception using Universal Software Radio Peripheral (USRP) devices in conjunction with MATLAB and the USRP Hardware Driver (UHD). FM is a widely adopted modulation technique in communication systems due to its robustness against noise and interference. The combination of USRP hardware and MATLAB provides a flexible and powerful solution for developing and testing radio frequency (RF) applications.

In this study, we design, implement, and evaluate an FM transmitter and receiver system using USRP hardware and MATLAB's UHD support. The transmitter modulates an audio signal onto a carrier wave by varying the frequency of the carrier in accordance with the amplitude of the audio signal. The modulated signal is then transmitted over the air. On the receiver side, the USRP captures the transmitted signal, and MATLAB processes it to demodulate and retrieve the original audio signal.

Key components of the system include:

1. **MATLAB**: Utilized for developing the algorithms for FM modulation and demodulation, and interfacing with USRP hardware through UHD.
2. **USRP Hardware**: Employed for transmitting and receiving the RF signals.
3. **Audio Processing**: Managed by both the USRP hardware and MATLAB software to ensure high-quality signal transmission and reception.

The implementation is tested under various conditions to evaluate performance metrics such as signal-to-noise ratio (SNR), bit error rate (BER), and audio quality. The results demonstrate the feasibility and efficiency of using MATLAB UHD with USRP for FM transmission and reception, highlighting the flexibility and capability of this setup for educational purposes, prototyping, and research in wireless communication.

This work underscores the potential of combining USRP hardware with MATLAB for handling different modulation schemes and its significance in modern communication system research and development. Future work will explore the integration of more advanced signal processing algorithms and modulation techniques to further enhance.

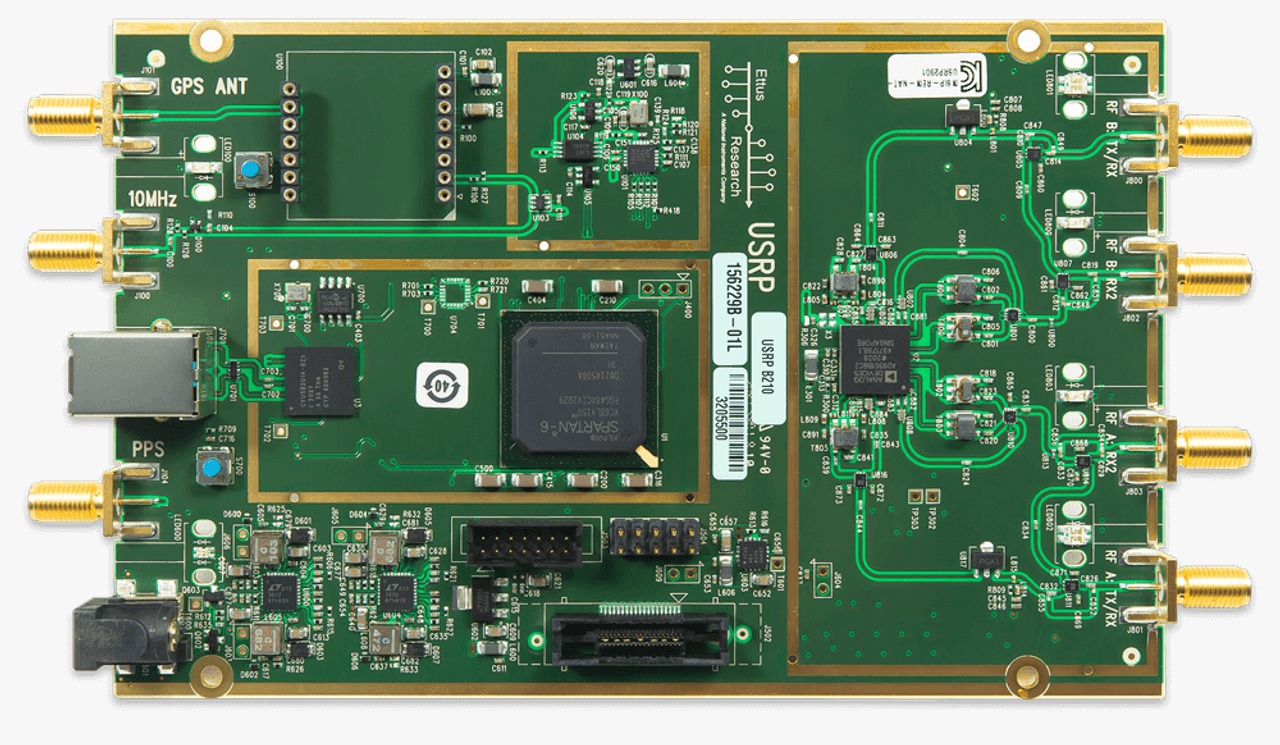
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# Chapter 1: Introduction To FM Tx-Rx Using USRP

Frequency Modulation (FM) is widely used in communication systems for its robustness against noise and interference, making it ideal for high-fidelity audio broadcasting and two-way radio communications. The Universal Software Radio Peripheral (USRP), a popular Software Defined Radio (SDR) platform, combined with MATLAB and the USRP Hardware Driver (UHD), provides a powerful framework for developing and testing RF communication systems.

This paper presents the implementation of an FM transmitter and receiver using USRP hardware and MATLAB. The project involves designing FM modulation and demodulation schemes, configuring the USRP hardware for real-time signal transmission and reception, and evaluating system performance through metrics like signal-to-noise ratio (SNR) and audio quality.

By leveraging the extensive signal processing capabilities of MATLAB and the flexibility of USRP, this study demonstrates the practical utility of these tools in FM communication. The results highlight the potential of the USRP-MATLAB platform for educational purposes, prototyping, and advanced research in wireless communication.



* 1. **Overview**

This paper investigates the implementation of an FM transmission and reception system using USRP hardware and MATLAB with the USRP Hardware Driver (UHD). FM is selected for its robustness against noise and interference. The project involves using MATLAB to modulate audio signals onto a carrier wave and USRP hardware to transmit the signal. On the receiver side, the USRP captures the transmitted signal, and MATLAB demodulates it to retrieve the original audio. The study aims to design and implement FM modulation and demodulation schemes, utilize USRP for real-time communication, and evaluate the system's performance based on metrics like signal-to-noise ratio (SNR). The results demonstrate the effectiveness of the USRP-MATLAB combination for FM communication, highlighting its potential for educational, prototyping, and research applications. This work showcases the flexibility and capability of the USRP-MATLAB platform in developing modern communication systems**.**

* 1. **Literature Survey**

FM is a robust modulation technique commonly used in communication systems due to its resistance to noise and interference. The integration of SDR platforms like USRP with MATLAB and UHD provides a flexible and efficient environment for real-time implementation of FM modulation and demodulation. This combination allows researchers and engineers to develop, test, and experiment with communication systems effectively. USRP and MATLAB are widely used in both research and educational settings for exploring various modulation techniques and evaluating system performance. Studies show that FM systems using USRP and MATLAB perform well, with minimal signal errors even in noisy environments, making them ideal for practical communication system design and testing.

* 1. **Motivation**

The motivation for implementing an FM transmission and reception system using USRP and MATLAB lies in the need for a flexible, cost-effective platform for real-time communication system design and testing. Traditional hardware-based systems are limited in customization and scalability, while USRP and MATLAB provide a versatile environment for experimenting with various modulation techniques, including FM. This approach allows for rapid prototyping, system optimization, and advanced signal processing, making it ideal for research, education, and development of modern communication systems. It enhances learning and accelerates the exploration of next-generation communication technologies.

* 1. **Objective**

The objective of this study is to design and implement an FM transmission and reception system using USRP hardware and MATLAB. The goals are to develop FM modulation and demodulation schemes, utilize USRP for real-time signal transmission and reception, and evaluate system performance based on metrics like signal-to-noise ratio (SNR) and audio quality. This study aims to demonstrate the effectiveness of USRP and MATLAB for real-time communication system development, with a focus on research and educational applications.

* 1. **Project Layout**

The project is structured into several key phases to ensure a systematic approach to the design, implementation, and evaluation of the FM transmission and reception system using USRP and MATLAB. The layout is as follows:

1. **Introduction and Background**:
   * Overview of Frequency Modulation (FM) and its applications.
   * Introduction to Software Defined Radio (SDR) and the USRP platform.
   * Brief on MATLAB’s role in signal processing and communication system design.
2. **Literature Survey**:
   * Review of previous work on FM communication systems, SDR platforms, and the integration of USRP with MATLAB.
   * Discussion of existing FM system implementations, performance evaluations, and challenges.
3. **Motivation and Objectives**:
   * Explanation of the motivation for using USRP and MATLAB for FM transmission and reception.
   * Clear statement of the project’s objectives, focusing on real-time signal processing and system evaluation.
4. **System Design and Implementation**:
   * **FM Modulation and Demodulation**: Design the modulation and demodulation algorithms using MATLAB.
   * **USRP Setup**: Configure USRP hardware for real-time signal transmission and reception.
   * **Integration**: Implement the system by combining MATLAB scripts with USRP hardware.
5. **Testing and Evaluation**:
   * Test the FM system by transmitting audio signals and receiving them through USRP.
   * Evaluate system performance using metrics such as signal-to-noise ratio (SNR), bit error rate (BER), and audio quality.
6. **Results and Discussion**:
   * Present the results from testing and performance evaluation.
   * Analyse the effectiveness of the FM transmission and reception system.
   * Compare the results with theoretical expectations and real-world performance.
7. **Conclusion and Future Work**:
   * Summarize the findings of the project.
   * Discuss potential improvements and the scope for further research in FM systems and communication technologies.

This layout provides a structured approach to developing and testing the FM communication system, ensuring clarity and a comprehensive evaluation of the system’s performance.



# Chapter 2: Frequency Modulation Tx-Rx Using USRP

The **FM Transmission and Reception System using USRP and MATLAB with UHD** offers a versatile platform for building real-time communication systems. This setup allows researchers and engineers to implement and experiment with FM modulation and demodulation schemes, while leveraging the capabilities of Software Defined Radio (SDR) and USRP hardware. Below, we delve deeper into the working of this system, offering more information about each part of the process and expanding on the code and considerations for both the transmitter (Tx) and receiver (Rx).

* 1. **System Overview**

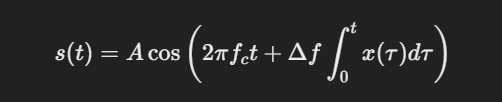
FM (Frequency Modulation) is a popular modulation technique used in radio communication because of its resilience to noise and ability to transmit high-fidelity audio. In this system:

1. **FM Transmitter (Tx)**: The audio signal, such as a sine wave or pre-recorded audio, is modulated onto a carrier signal using frequency modulation.
2. **FM Receiver (Rx)**: The FM-modulated signal is captured by USRP, and the receiver demodulates the signal to recover the audio signal.

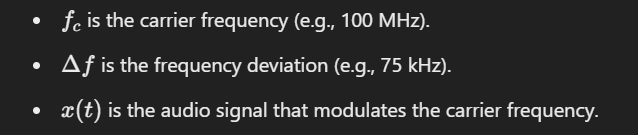
The real-time performance of this system is achieved using **USRP hardware** (Universal Software Radio Peripheral), which allows for the transmission and reception of RF signals. The USRP is controlled using **MATLAB and the UHD API**, which offers a seamless connection between the hardware and signal processing algorithms.

* 1. **FM Transmitter (Tx)**

FM modulation involves varying the carrier frequency in accordance with the amplitude of the audio signal. The carrier signal's frequency deviation is proportional to the amplitude of the input audio. The FM equation is:



Where:



FM modulation can be performed using MATLAB’s fmmod() function. The audio signal modulates the carrier by changing its instantaneous frequency based on the amplitude of the audio signal.

**2.2.1 FM Demodulation (Rx Side)**

FM demodulation is the reverse process where the receiver detects changes in frequency of the incoming signal. The demodulation process calculates the instantaneous frequency of the received signal and recovers the original audio.

One common method of FM demodulation involves differentiating the phase of the received signal, which allows extraction of the instantaneous frequency.

**2.2.2 Detailed Transmitter (Tx) Code Explanation**

The transmitter code involves:

* **Audio Signal Generation**: You can generate a sine wave or load an audio file (e.g., a music clip).
* **FM Modulation**: The audio signal is FM-modulated onto a carrier.
* **Signal Transmission**: The modulated signal is transmitted via the USRP.

**2.2.3 CODE FOR Tx-**

% Transmitter Code using USRP B210

% Define the audio sample rate and samples per frame

audioSampleRate = 200e3; % Higher sample rate for FM transmission (200 kHz)

samplesPerFrame = 1024; % Number of samples per frame for live audio

% Create an audioDeviceReader object to capture live audio

audioReader = audioDeviceReader('SampleRate', audioSampleRate, 'SamplesPerFrame', samplesPerFrame);

% Create a figure for live plotting

figure;

hPlot = plot(zeros(samplesPerFrame, 1)); % Initialize the plot with zeroed data

ylim([-1, 1]); % Set amplitude limits for the plot

xlabel('Sample Number');

ylabel('Amplitude');

title('Live Audio Data (Voice)');

% USRP B210 Serial Number (replace with your actual serial number)

usrpSerialNumber = '3166CCB'; % Replace with your actual serial number

% Set FM transmission frequency (choose a valid FM frequency within the range)

fmFrequency = 88.9e6; % FM frequency (e.g., 98.3 MHz for Radio Mirchi)

% Set initial MasterClockRate and calculate InterpolationFactor

masterClockRate = 20e6; % Use 20 MHz master clock rate for both transmitter and receiver

interpolationFactor = round(masterClockRate / audioSampleRate); % Round to nearest integer

% Adjust MasterClockRate if necessary to ensure a valid InterpolationFactor

while (interpolationFactor > 512 || interpolationFactor < 1) && masterClockRate > 5e6

masterClockRate = masterClockRate - 1e6; % Reduce clock rate step-by-step

interpolationFactor = round(masterClockRate / audioSampleRate); % Recalculate factor

end

% Create a USRP B210 transmitter object

usrp = comm.SDRuTransmitter(...

'Platform', 'B210', ...

'SerialNum', usrpSerialNumber, ... % USRP serial number

'CenterFrequency', fmFrequency, ... % Set FM center frequency (98.3 MHz)

'Gain', 30, ... % Transmission gain

'MasterClockRate', masterClockRate, ... % Set same master clock rate for both transmitter and receiver

'InterpolationFactor', interpolationFactor); % Use rounded interpolation factor

% Create FM modulator for audio (Remove Stereo property)

fmModulator = comm.FMModulator(...

'SampleRate', audioSampleRate, ... % Audio sample rate

'FrequencyDeviation', 75e3); % Frequency deviation for FM radio (standard 75 kHz)

% Start the timer

disp('Starting live voice transmission...');

startTime = tic; % Record the starting time

% Transmit for 30 seconds

transmitDuration = 30; % Transmission duration in seconds

try

while toc(startTime) < transmitDuration

% Read audio data from the microphone

audioData = audioReader();

% Update the plot with live audio data

set(hPlot, 'YData', audioData);

drawnow; % Refresh the plot immediately

% FM modulate the audio data

fmSignal = fmModulator(audioData);

% Transmit the FM modulated signal via USRP

usrp(fmSignal);

end

catch ME

% Display error message in case of failure

disp('An error occurred during transmission:');

disp(ME.message);

end

% Release system resources

release(audioReader);

release(fmModulator);

release(usrp);

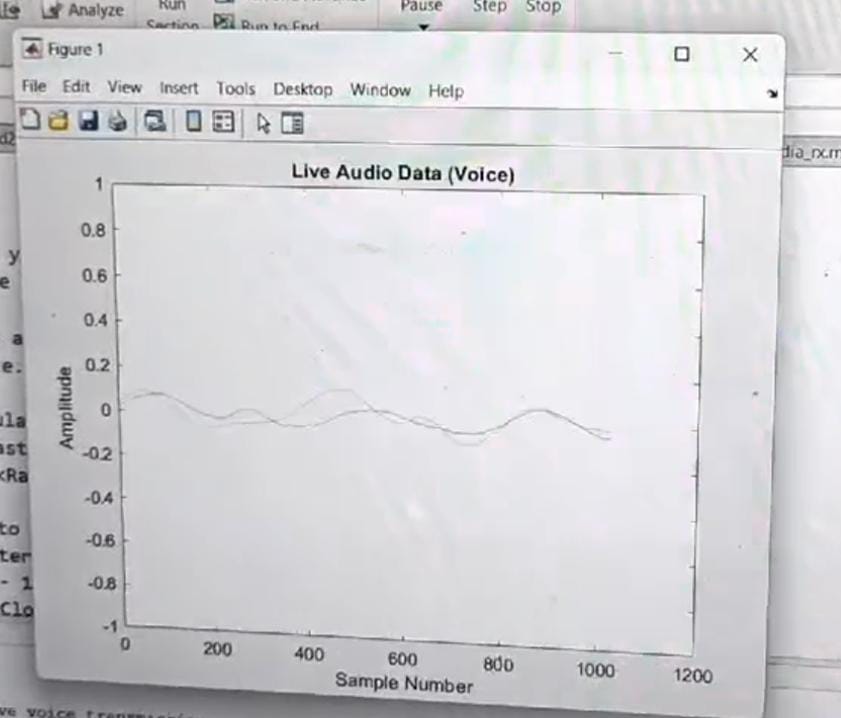
% Display total time elapsed

disp(['Total time elapsed: ', num2str(toc(startTime), '%.2f'), ' seconds']);

disp('Live voice transmission finished.');

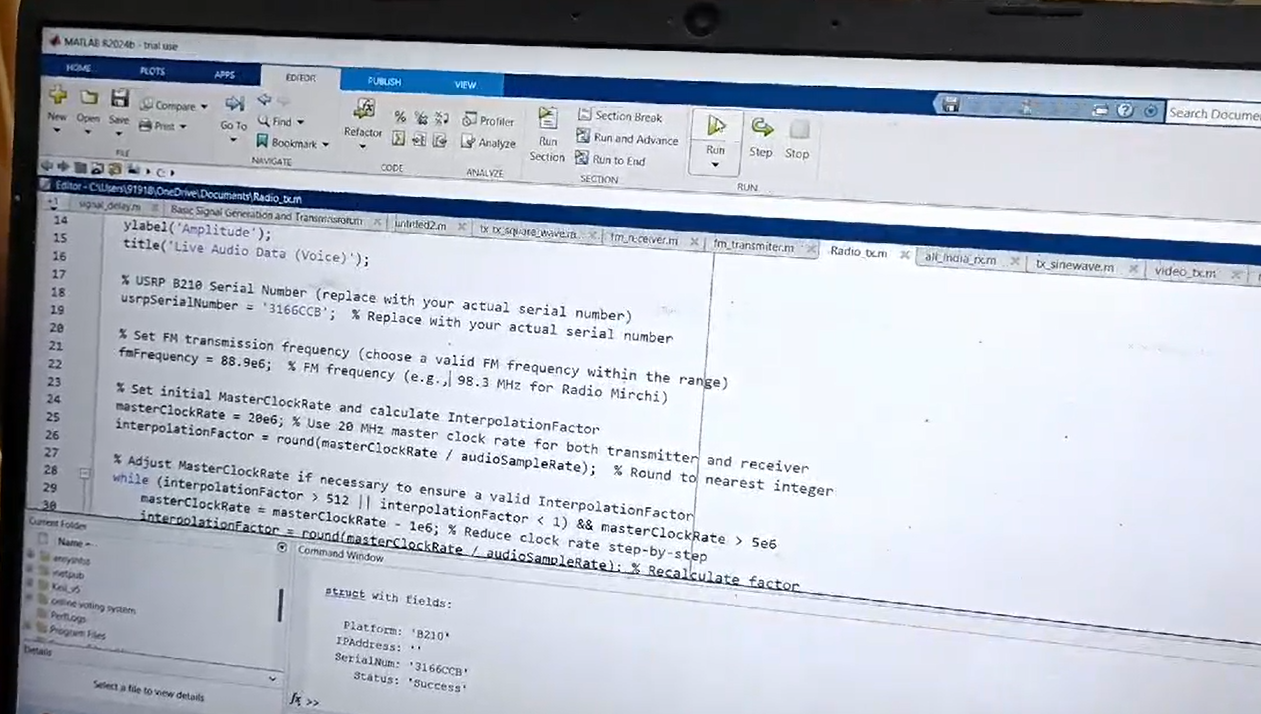


**Input Audio Signal**



* 1. **FM Receiver Rx-**

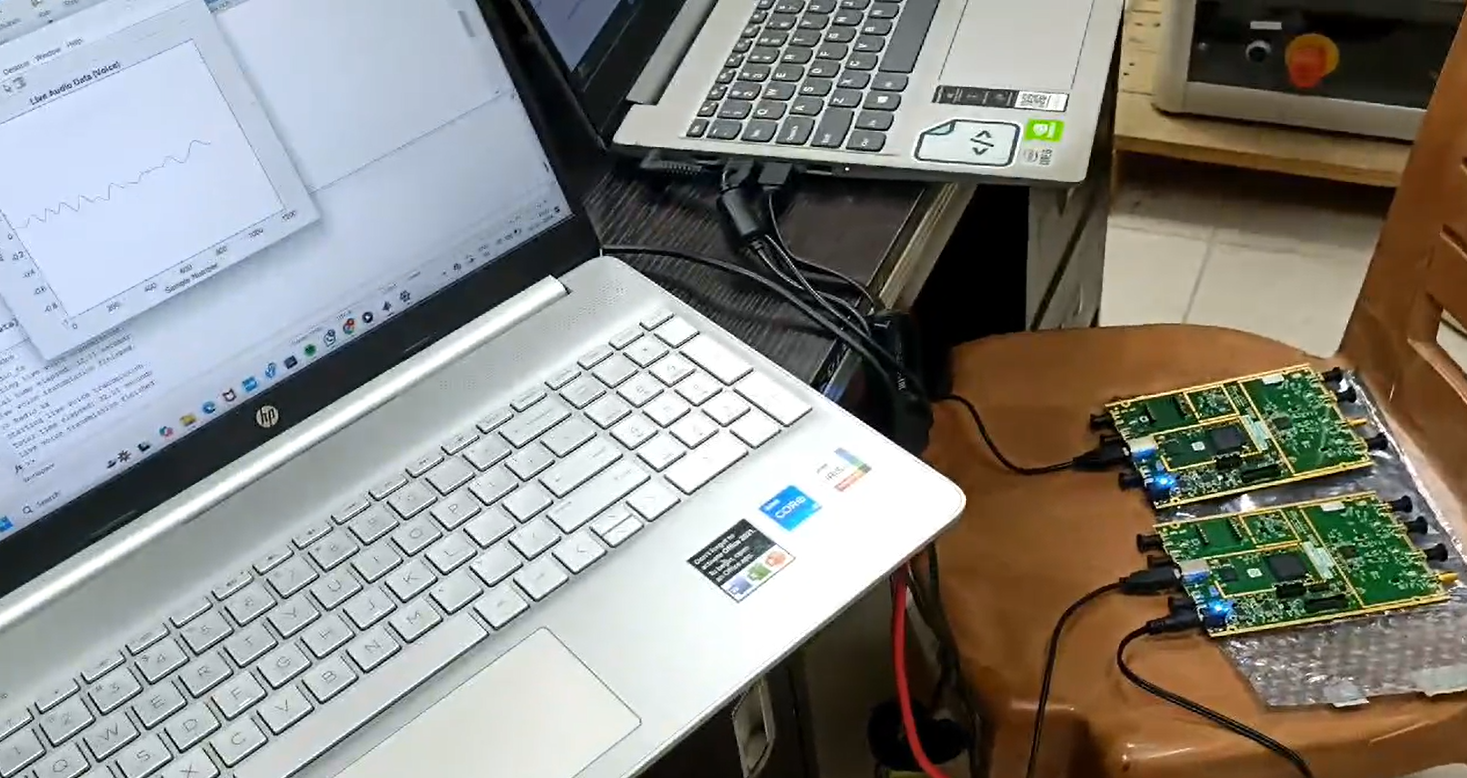
To implement an **FM Receiver (Rx) using USRP and the UHD (USRP Hardware Driver)** in MATLAB, you'll need to set up the system to receive an FM-modulated signal, demodulate it, and extract the original audio or message signal.Below is a step-by-step guide and MATLAB code that demonstrates how to set up the receiver to capture and demodulate an FM signal using USRP hardware and the UHD API.

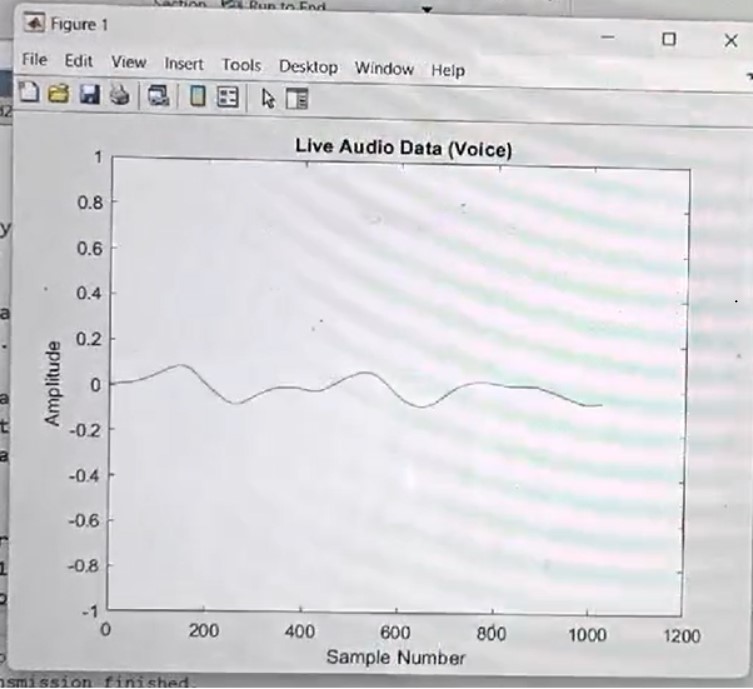


**2.3.1 System Overview**

The FM Receiver system works by:

1. Receiving the FM Signal: The USRP hardware receives the FM-modulated signal, typically transmitted by an FM transmitter.
2. FM Demodulation: The received signal is demodulated to extract the original message (such as an audio signal) that was encoded using FM modulation.
3. Audio Playback or Signal Processing: The demodulated signal is typically played back as audio or processed further, depending on the application.

****



**2.3.2 Receiver (Rx) Code Explanation:**

The FM receiver code using USRP and UHD in MATLAB involves several key steps to receive and demodulate an FM signal. First, the receiver parameters are defined, including the carrier frequency (100 MHz), sample rate (1 Msps), and gain (30 dB). The USRP hardware is initialized and configured with these parameters, tuning to the specified frequency and sample rate. The receive() function is then used to capture the FM-modulated signal, which is stored in the received\_signal variable. Optionally, the real part of the signal can be plotted for visualization. The received signal is then demodulated using MATLAB’s fmdemod() function, which extracts the audio signal by detecting frequency deviations in the FM signal. Finally, the demodulated audio signal is played back using the sound() function, or it can be saved as a WAV file for further analysis. This process demonstrates how FM signals can be received, demodulated**,** and analyzed in real-time using USRP hardware and MATLAB.

**Code For Rx-**

% Parameters

serialNumber = '3166CFB'; % Replace with your USRP B210 serial number

sampleRate = 200e3; % Sampling rate (200 kHz typical for FM)

audioSampleRate = 48e3; % Audio playback rate

frameDuration = 0.1; % Frame duration (in seconds)

centerFrequency = 88.9e6; % Replace with your desired station frequency (e.g., 98.3 MHz for Radio Mirchi)

% Derived parameters

samplesPerFrame = sampleRate \* frameDuration;

% Verify USRP availability

try

% Create USRP receiver object

radio = comm.SDRuReceiver(...

'Platform', 'B210', ...

'SerialNum', serialNumber, ...

'MasterClockRate', 20e6, ...

'DecimationFactor', round(20e6 / sampleRate), ...

'Gain', 30, ...

'SamplesPerFrame', samplesPerFrame, ...

'CenterFrequency', centerFrequency); % Set the specific station frequency

catch ME

disp('Error initializing USRP Receiver:');

disp(ME.message);

return;

end

% Create audio player

audioPlayer = audioDeviceWriter('SampleRate', audioSampleRate);

% FM demodulator

fmDemod = comm.FMDemodulator(...

'SampleRate', sampleRate, ...

'FrequencyDeviation', 75e3);

disp(['Listening to live radio at ', num2str(centerFrequency / 1e6), ' MHz...']);

% Start the reception

try

while true % Continuous listening

% Receive data from the USRP

rxData = radio();

if ~isempty(rxData)

% Convert to floating-point

rxDataFloat = double(rxData); % Ensure data is in floating-point format

% FM Demodulation

demodulatedSignal = fmDemod(rxDataFloat);

% Resample to match audio playback rate

audioSignal = resample(demodulatedSignal, audioSampleRate, sampleRate);

% Play audio

audioPlayer(audioSignal);

else

disp('No data received. Adjust antenna or gain settings.');

end

end

catch ME

disp('An error occurred during FM reception:');

disp(ME.message);

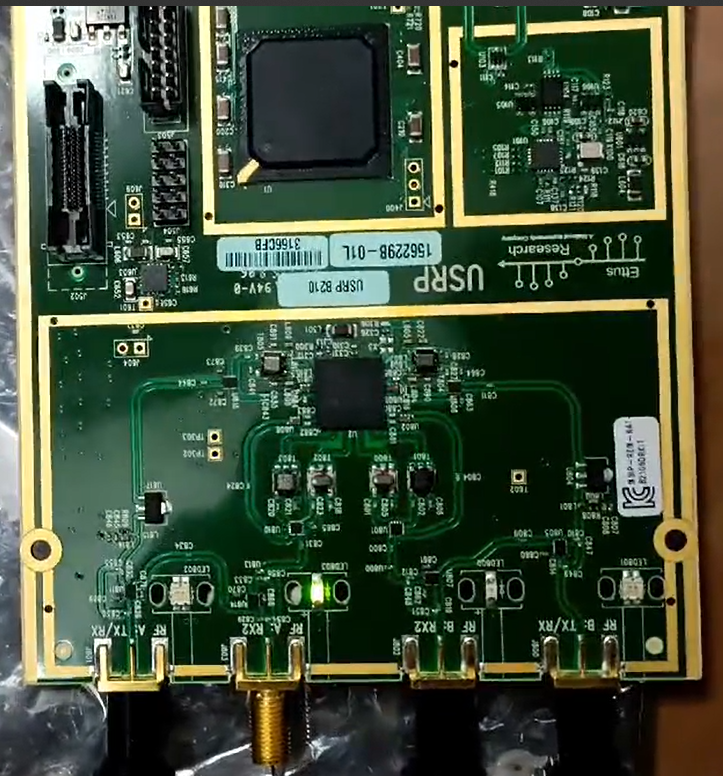
end

% Release resources

release(radio);

release(audioPlayer);

disp('FM Radio reception finished.');



**Chapter 3: Motive to use Portable BTS using USRP**

Using a portable Base Transceiver Station (BTS) with a Universal Software Radio Peripheral (USRP) has several compelling motives, especially in fields such as telecommunications, research, emergency response, and education. Here are some key reasons:

**3.1 Research and Development:**

* + **Flexibility:** USRPs are highly configurable, allowing researchers to experiment with different frequencies, protocols, and network configurations.
  + **Cost-Effective:** Compared to commercial BTS equipment, USRPs are relatively inexpensive, making them accessible for academic and small-scale industrial research.
  + **Rapid Prototyping:** Researchers can quickly implement and test new algorithms, protocols, and technologies without needing to build hardware from scratch.



* 1. **Education:**
  + **Hands-On Learning:** Using portable BTS setups with USRPs provides students with practical, hands-on experience in telecommunications.
  + **Accessible Demonstrations:** Educators can easily demonstrate concepts such as signal processing, modulation, and network configuration in a real-world setting.

**3.3 Emergency and Disaster Response:**

* + Deployability: Portable BTS units can be rapidly deployed in disaster-stricken areas to restore communication networks.
  + Network Restoration: In emergencies, they can be used to set up temporary communication networks, providing essential connectivity for rescue operations and coordination.



**3.4 Coverage in Remote Areas:**

* + Rural and Remote Deployment: Portable BTS setups can be used to provide coverage in rural or remote areas where traditional network infrastructure is not feasible.



* + Pop-Up Networks: They can be employed for events or temporary setups where network coverage is required for a short duration.
  1. **Security and Surveillance:**
  + Network Monitoring: Portable BTS can be used for monitoring and analyzing wireless communication in specific areas.
  + Interception: Law enforcement agencies may use them to intercept and monitor communication under legal frameworks.



**3.6 Customization and Control:**

* + Tailored Solutions: Users have complete control over the network parameters, allowing for customized solutions tailored to specific needs.
  + Protocol Testing: Developers can test new communication protocols and ensure compatibility with existing networks.

**3.7 IoT and Smart Applications:**

* + Testing IoT Devices: Portable BTS units can be used to test and develop Internet of Things (IoT) devices and applications in controlled environments.
  + Smart City Implementations: They can be part of smart city infrastructure, providing connectivity for sensors and other smart devices.



**Example Applications:**

* Academic Research: Universities and research institutions using USRPs to study next-generation wireless technologies like 5G and beyond.
* Emergency Services: Quick deployment of communication networks in areas hit by natural disasters to aid in rescue and coordination efforts.
* Rural Connectivity Projects: Providing internet and mobile connectivity to remote villages and underserved areas.
* Telecommunication Companies: Testing new network configurations and services before large-scale deployment.

In summary, the portability, flexibility, and cost-effectiveness of BTS using USRP make it an invaluable tool across various domains, providing a versatile platform for innovation and practical applications

**Chapter 4: Conclusion And Future Scope**

**4.1 Conclusion**

The implementation of FM transmission and reception using **USRP hardware** and **MATLAB with UHD** provides a versatile and powerful platform for real-time communication systems. In this setup, the FM transmitter modulates an audio signal onto a carrier frequency, and the FM receiver captures the modulated signal using USRP hardware, performing FM demodulation to recover the original audio signal. The use of UHD and MATLAB facilitates seamless integration of software-defined radio (SDR) with hardware, enabling easy experimentation with different communication techniques. The flexibility of USRP allows for high-quality signal processing and real-time control over parameters such as frequency, gain, and sample rate. This system can be applied to various practical applications, including amateur radio, communication research, and educational purposes, providing insights into the working of FM systems.

**4.2 Future Scope**

The future scope of FM transmission and reception using USRP in MATLAB is vast and offers numerous possibilities for enhancement and expansion. Some potential areas for future work include:

1. Improved Signal Quality: Advanced techniques like adaptive filtering, noise reduction, and interference mitigation can be incorporated to enhance the quality of the received signal in real-world environments with high noise levels.
2. Broadband FM Systems: Moving from narrowband FM to broadband FM (wideband FM) could enable the transmission of higher fidelity signals, including stereo audio or video, by increasing bandwidth and sample rates.
3. Digital Audio Transmission: Future work can focus on integrating digital audio formats or even data transmission alongside audio in the FM signal, making it more versatile for modern communication systems.



1. Multiple Channel Reception: Extending the system to receive multiple FM channels simultaneously using multiple USRP devices or advanced signal processing techniques could open doors to multi-channel audio broadcasting systems.
2. Adaptive Transmitter Design: Implementing adaptive modulation schemes for the transmitter that can automatically adjust frequency deviation based on the channel conditions or signal strength would increase system robustness.



1. Integration with Other Modulation Techniques: Exploring hybrid systems that combine FM with other modulation techniques, such as AM or QAM, could lead to more complex communication systems, enabling greater data throughput.

Overall, FM transmission and reception using USRP in MATLAB UHD offers a robust platform for exploring various aspects of communication systems, with significant potential for growth in both educational and practical applications.

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