iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** V **Month of publication:** May 2024

DOI: https://doi.org/10.22214/ijraset.2024.62951

Advanced SDR Solutions for VHF and UHF Interoperability in Disaster Response

Mohit Judge[1], Rajesh Bhatt[2]
[1, 2]*Faculty of Communication Engineering, Military College of Telecommunication Engineering*

Abstract: Effective disaster management requires robust communication systems that can seamlessly operate across various radio sets and frequencies. This paper presents the development of a Universal Software Defined Radio (SDR) aimed at improving communication interoperability during disaster response efforts, with a particular focus on integration with Very High Frequency (VHF) and Ultra High Frequency (UHF) radios. The technical aspects of the papaer are explored, emphasizing the use of open-source solutions and highlighting global applications of SDR technology in disaster management scenarios.
Keywords: Software Defined Radio (SDR), Multi Communicator SDR(MC-SDR), Digital Signal Processing (DSP), Cognitive Radio, Multiple Input Multiple Output (MIMO), Machine Learning (ML), Artificial Intelligence (AI).

I. INTRODUCTION

In any disaster management situation, establishing clear and efficient communication channels is vital for effective response and coordination. The electromagnetic spectrum is the backbone of these communications and achieving interoperability across various radio sets used by different agencies presents a significant challenge. This paper introduces a noble initiative — the development of a Universal Software Defined Radio (SDR) — designed to communicate with VHF and UHF radio sets utilized in disaster response operations. The paper adopts an inclusive approach, leveraging insights from open-source solutions and self-conducted experiments with SDR technology. By delving into the technical intricacies of waveform design, modulation schemes, and interoperability frameworks, this paper aims to contribute to the advancement of interoperability issues.

II. BACKGROUND

Modern radio operations demand a sophisticated communication infrastructure capable of overcoming the challenges posed by diverse terrains, varied operational scenarios and the proliferation of heterogeneous communication systems. Traditional radio technologies, while proven, face limitations in interoperability and adaptability to the dynamic nature of any disaster management operation where different agencies communicate with each other with radio communications as their main mode of communication.

In response to these challenges, there has been a paradigm shift in radio communications towards Software Defined Ra- dios (SDRs). Unlike conventional radios with fixed hardware configurations, SDRs enable reconfigurability through soft- ware, allowing for adaptability to different frequency bands, modulation schemes, and waveform requirements.

III.METHODOLOGY

Designing such a Multi-Communicator Software Defined Radio (*MC-SDR*) for the radio operations necessitates a meticulous methodology, taking into account the complex requirements of communication to VHF and UHF radio sets. The following detailed approach outlines specific components, configurations, and considerations for each phase of the design process.

A. System Requirements

In the initial phase of System Requirements Analysis, it is essential to establish the frequency range specifications for both VHF and UHF bands, ensuring compatibility with widely used radio sets such as Tadiran, Kenwood, Motorola, and Yaesu. This foundational step is critical as it informs all subsequent design decisions and ensures the system meets operational needs.

B. Equipment Selection

The key components have to be meticulously chosen to ensure optimal performance. The BladeRF 2.0 micro xA4, known for its wideband capabilities, is selected as the reconfigurable RF front-end, providing the flexibility needed for communication.

C. Waveform Development Platform

Choosing a suitable Software Framework is critical. GNU Radio is the preferred choice for its open-source nature, providing a robust platform for signal processing and modulation. Python scripts are crafted for waveform customization, and a user-friendly GUI is implemented using Qt toolkit.

D. Interconnectivity

Designing an MC-SDR to communicate with VHF and UHF sets involves designing software-defined inter-faces adhering to SCA compliance standards.

E. Large-Scale Development Considerations

Addressing Large-Scale Development Considerations involves optimizing hardware for cost-effective production, utilizing PCB design tools for efficiency, adhering to ISO 9001 standards, and con- sidering collaboration with established defense contractors like Lockheed Martin, ADTL, Astra Rafael or Rod and Shwartz for mass production.

TABLE I
COMPONENTS SUGGESTED FOR MC-SDR

Ser. No.	Appearance (in Time New Roman or Times)		
	Item	Model	Make
1	SDR Board	BladeRF 2.0 micro xA4	Nuand
2	ADC/DAC	AD9361	Analog Devices
3	FPGA	Cyclone IV EP4CE40F	Intel
4	Antennas	VHF/UHF antenna	Various Manufacturers
5	Simulation Software	GNU Radio Companion	Open Source
6	Computer	HP Victus(any model)	Custom Build

IV. EXPERIMENTAL SETUP & RESULT

A. Setup

While setting up the experimental setup, I found that there are various radio sets that operate in the VHF and UHF band of 3-30 Mhz and 30-300 Mhz range. The idea here is to design a universal SDR that operates with radio sets of both VHF and UHF radio sets. This can also be further enhanced to HF sets. The experimental setup consists of a RF front end (For my experiment BladeRF 2.0 micro SDR has been used) connected to a laptop/PC and radio sets (of VHF and/or UHF Bands). One radio set is successfully able to communicate with the SDR in transmitter-receiver mode using this reference flowgraph and can be modified and utilized based on the type of SDR used and the Radio set parameters such as sampling rate and modulation scheme.

B. Two-way Communication

The sub- flowgraph for transmitter side (SDR setup to radio set) will contain ’Audio Source (Microphone of the PC/Laptop)’ and ’osmocom sink’ (can be used for any SDR being used) for transmission. The receiver side (radio set to laptop) will have the ’osmocom Source’ and ’Audio Sink (Speaker)’. The transceiver will consist of both these sub-flowgraphs as part of a single one for transmitting and receiving VHF/UHF signals. The flowgraph for NBFM has been demonstrated in figure 1 and 2.

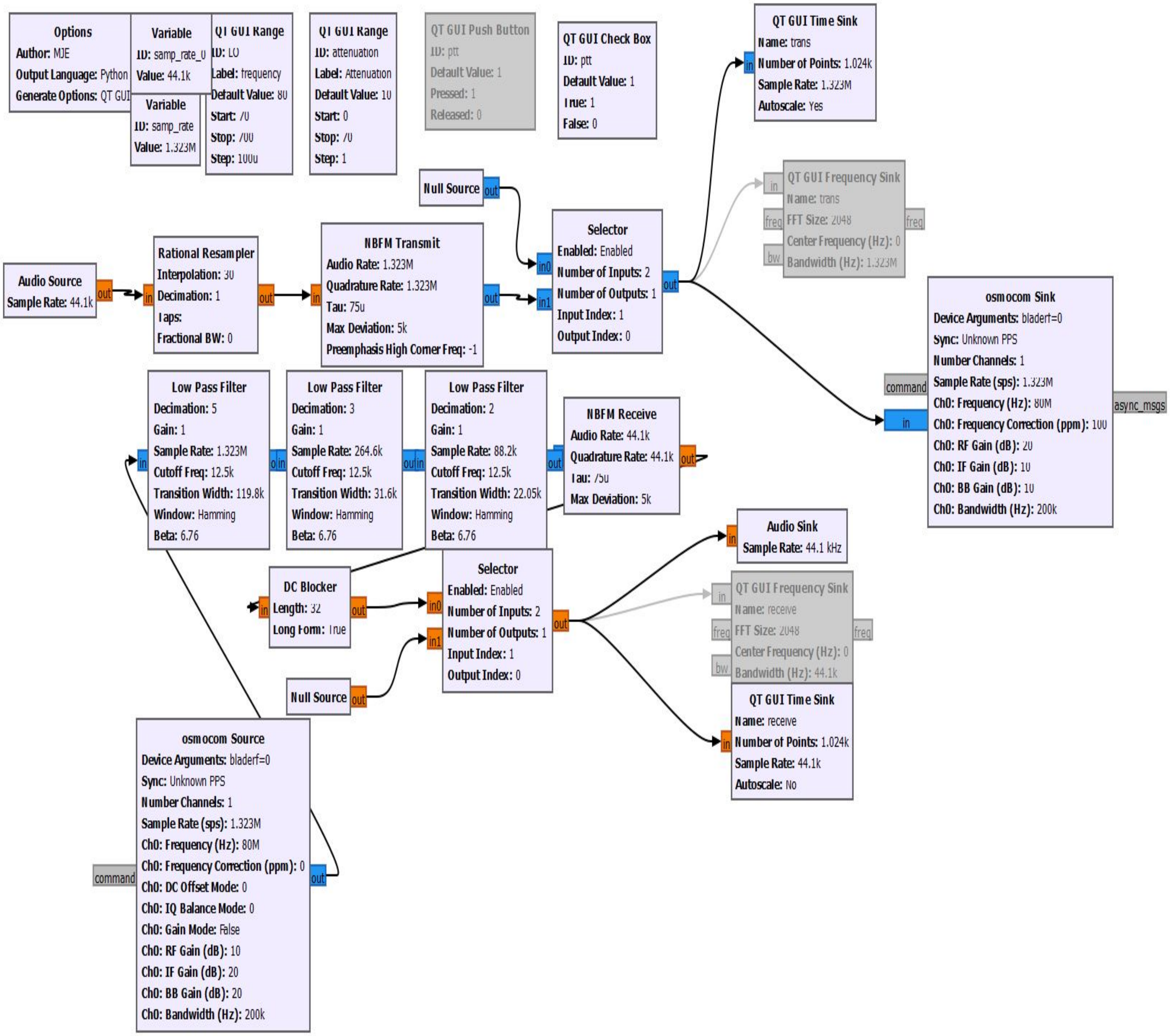


Fig. 1 A Two-way Communication Flowgraph for Communication using NBFM

C. Modulation

It is important to note the type of Modulation and Demodulation blocks being used i.e. WBFM/NBFM receive/transmit blocks that modulate or demodulate the signal. There is also a need to appropriately set the frequencies, gains, and modulation/demodulation settings in the BladeRF (or any SDR being used) blocks to match your radio sets' specifications. Additionally, we have to consider adding filters and signal processing blocks as needed to improve signal quality and avoid interference.

D. Flexibility

The MC-SDR can work with any Radio set based in the reference model described above. With the Osmocom Sink Block we can also configure the trans-receiver too work with a multitude of SDRs. The wider the frequency range of the SDR the more flexible the MC-SDR will become.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

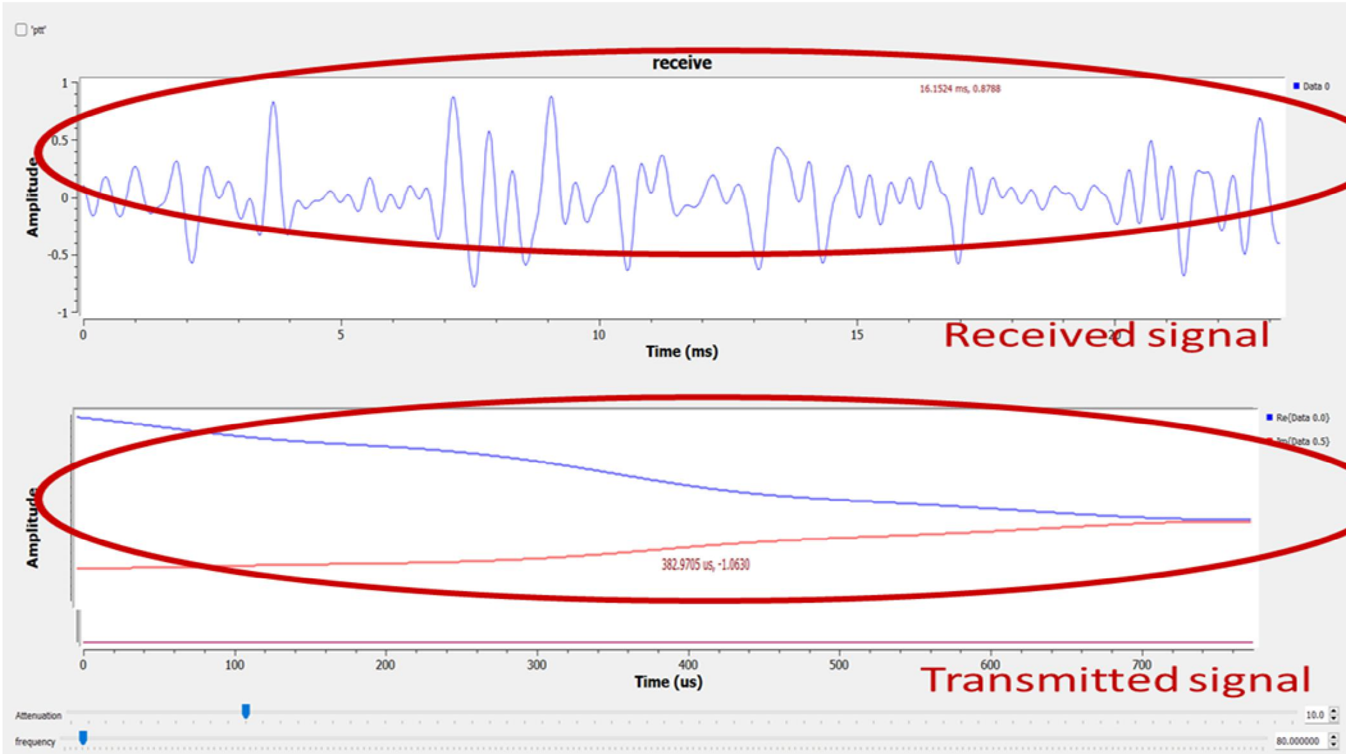


Fig. 2 Output Graph NBFM

E. Parameter Differences Between Radio Sets

There is another important point to consider – different radios will have different flowgraphs even though they work in the same frequency band but of different make and model. These differences can affect how they interact with an SDR system like the one here. Here are some key differences:

1) *Different Modulation and Demodulation schemes*: Radio sets within the same frequency band may utilize different modulation and demodulation techniques. For instance, one set might use Wide Band Frequency Modulation (WBFM), while another uses Narrow Band Frequency Modulation (NBFM). This requires customizing the modulation/demodulation blocks in GNU Radio Companion to meet each radio set's specifications.
2) *Signal Processing Requirements:* Radio sets can have distinct signal processing needs, such as filtering, amplification, and noise reduction. These requirements necessitate varying configurations of GNU Radio Companion flowgraphs to ensure compatibility and optimal performance for each radio set.
3) *Interface Variations:* The interfaces (e.g., connectors, protocols) employed by different radio sets can differ significantly, requiring different setups or adapters to connect them to the SDR system. Ensuring seamless integration across diverse equipment is essential. The interfaces (e.g., connectors, protocols) used by different radio sets may vary, requiring different configurations or adapters to connect them to the SDR system.
4) *Frequency Offset and Calibration:* Even within the same frequency band, different radio sets may have slight frequency offsets or require different calibration procedures. GNU Radio Companion flowgraphs may need to be modified for these differences to ensure accurate communication.

V. USE CASES

A. Cognitive Adaptability in Future Rescue Operations

In Rescue operations, inspired by the principles laid out by Mitola III and Maguire Jr., MC-SDR equipped teams could autonomously identify and select optimal frequencies, waveforms and modulation schemes. This dynamic adaptability would prove crucial in mitigating the challenges posed by spectrum congestion, providing disaster recovery teams with a technological advantage that enhances communication capability.

B. Machine Learning and Artificial Intelligence enables SDRs

Imagine a scenario where a disaster relief team is able to identify and communicate with other teams of different agencies seamlessly without the knowledge of the RF spectrum and type of radio sets. This involves the integration of Machine Learning (ML) and Artificial Intelligence (AI) algorithms into SDR systems. A future where SDRs learn and predict communication patterns based on historical data, allowing them to dynamically optimize settings for different operational scenarios is not so far away. ML algorithms could analyze real- time signal conditions, predict disruptions, and autonomously implement adaptive modulation schemes.

C. Flood Relief Scenarios

An essential application of Universal SDR technology lies in spectrum efficiency and resource optimization. Envision a scenario where flood relief columns, equipped with MC-SDRs, can dynamically allocate and reallocate spectrum resources based on priorities. This ensures optimal utilization of available frequencies and bandwidth, reducing the likelihood of signal interference and enhancing overall communication reliability. The teams can then prioritize the locations that require immediate support and home on to the frequencies and radio sets being used.

D. Global Interoperability

In the future landscape of disaster recovery and rescue operations, Universal SDRs play a pivotal role in achieving global interoperability. As rescue teams from different countries collaborate on joint missions, the adaptability and reconfigurability of SDRs enable seamless communication across diverse radio sets and frequencies. This ensures effective coordination, information sharing, and interoperability, overcoming the limitations associated with traditional fixed-frequency radios. Universal SDRs contribute to fostering stronger alliances and cooperative efforts on a global scale.

VI. WAY AHEAD

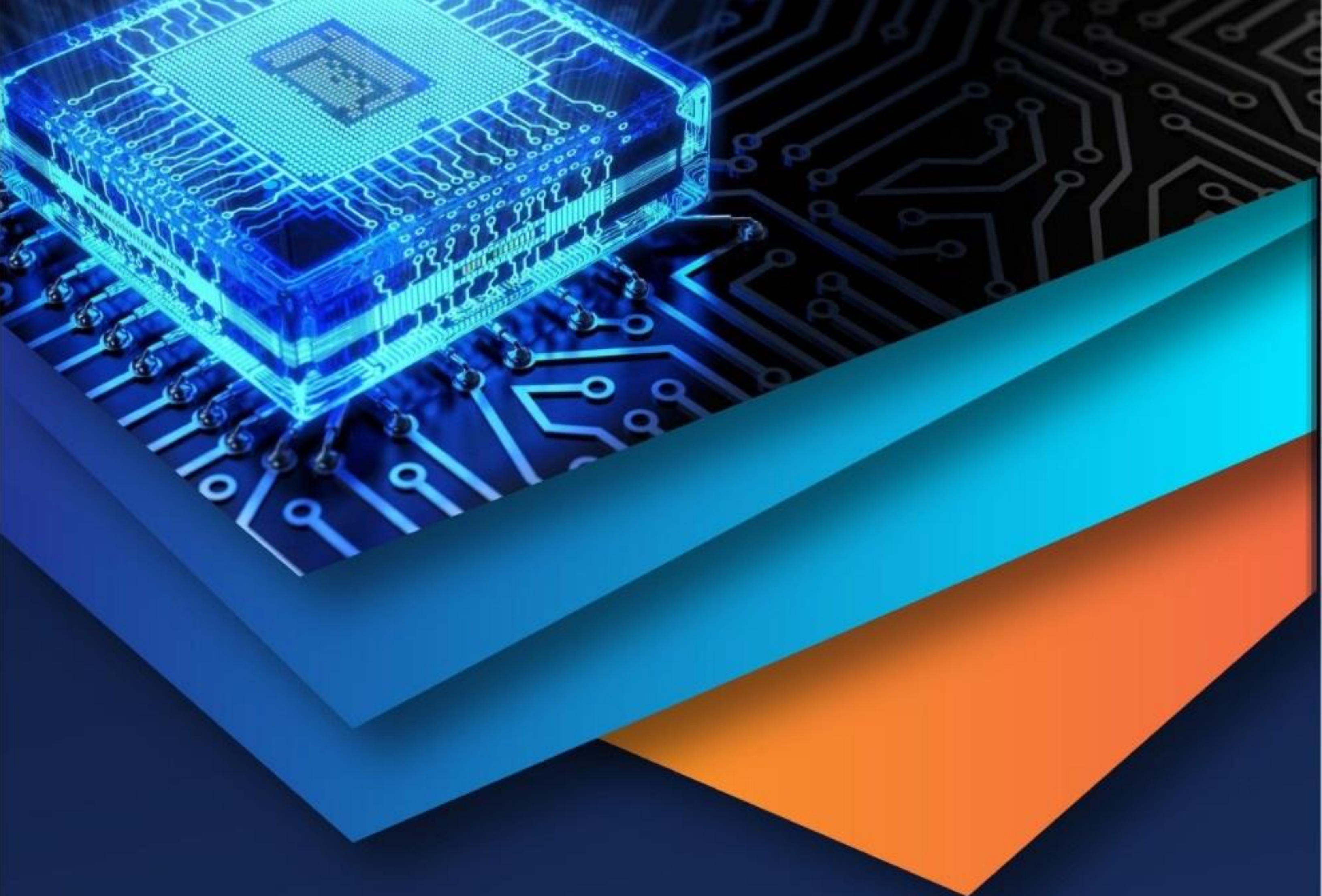
Continued and joint efforts between governments, contractors and research institutions to refine and optimize the proposed *MC-SDR*. Continued research and development will be crucial in addressing new challenges and expanding the communication capabilities. Furthermore, the integration of cutting-edge technologies such as Machine Learning (ML) and Artificial Intelligence (AI) into SDR systems could further enhance their adaptability and responsiveness. As nations embark on the journey of modernizing the infrastructure for enhanced electro-magnetic operations, the commit- ment to innovation and collaboration will play a pivotal role in shaping the future landscape of Software Defined Radios in radio disaster management operations.

VII. CONCLUSION

In conclusion, the development of a Universal Software Defined Radio (SDR) tailored for interoperability across Very High Frequency (VHF) and Ultra High Frequency (UHF) radios represents a significant stride towards enhancing the commu- nication capabilities disaster management teams. The comprehensive approach outlined in this paper, incorporating open-source solutions, global insights, and meticulous technical considerations, underscores the commitment to addressing the complex challenges posed by diverse terrains and operational scenarios. As we look towards the future, it is imperative for nations, including India, to continuously invest in and advance SDR technologies. Embracing the principles of adaptability and interoperability, countries can forge ahead to establish more resilient and versatile communication infrastructures, thereby ensuring the effectiveness of their security forces in the face of evolving threats and technological advancements.

REFERENCES

[1] Mitola III, J., Maguire Jr., G. Q. (1999). ”Cognitive Radio: Making Software Radios More Personal.” IEEE Personal Communications, 6(4), 13-18.
[2] Sterling, C. H. (2008). ”Military Communications: From Ancient Times to the 21st Century.” ABC-CLIO.
[3] GNU Radio. (n.d.). ”GNU Radio.” Retrieved from https://www.gnuradio.org/
[4] Analog Devices. (n.d.). ”AD9361.” Retrieved from https://www.analog.com/en/products/ad9361.html
[5] Qt. (n.d.). ”Qt: A Cross-Platform Software Development Framework.” Retrieved from https://www.qt.io/
[6] NS-3. (n.d.). ”NS-3: A Discrete-Event Network Simula- tor.” Retrieved from https://www.nsnam.org/M.
[7] ADTL. (n.d.). ”ADTL - Advanced Design Technology Ltd.” Retrieved from https://www.adtlltd.com/
[8] Astra Rafael. (n.d.). Retrieved from https://www.rafael.co.il/
[9] Wyglinski, A. M., Nekovee, M., & Hou, Y. T. (Eds.). (2009). Cognitive Radio Communications and Networks: Principles and Practice. Academic Press.
[10] National Instruments. (2013). "Understanding Software Defined Radio (SDR) Technology." Available at: https://www.ni.com/en-us/innovations/white-papers/06/understanding-software-defined-radio.html



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY