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Bridging Radio Diversity Using Software Defined Radio

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ABSTRACT

Ensuring effective communication in joint radio operations is paramount for coordinating response efforts across various agencies. This paper introduces "InterComm SDR," a Universal Software Defined Radio (SDR) solution designed to bridge the gap between different radio systems, facilitating seamless interoperability between Very High Frequency (VHF) and Ultra High Frequency (UHF) radios. The technical details of a successfully executed waveform are discussed, with a focus on leveraging open-source technologies and drawing from global implementations of SDR technology to electromagnetic spectrum operations.

Keywords: - *Software Defined Radio (SDR), Intercomn SDR (IC-SDR), Digital Signal Processing (DSP), Electromagnetic Spectrum Operations (EMSO), Artificial Intelligence (AI), BladeRF, Universal Serial Radio Peripheral (USRP), Very High Frequency (VHF), Ultra High Frequency (UHF).*

1. Introduction

In situations like rescue missions, military operations, humanitarian aid efforts, law enforcement containment situations, or flood relief situations, establishing clear and efficient communication channels is vital for effective coordination and mission success. In the absence of mobile connectivity, when radio communications are prevalent, the electromagnetic spectrum becomes the backbone of these communications. Achieving interoperability across various radio sets used by different agencies becomes a significant challenge. This paper introduces a Bridge Software Defined Radio (SDR) solution designed to facilitate seamless communication between VHF and UHF radio sets.

2. Background

During the 2010 Haiti earthquake relief operations, the international response included military, governmental, and non-governmental organizations from various countries and agencies. The lack of interoperability among different radio communication systems led to significant challenges in coordinating relief efforts effectively. A similar situation arose during the Hurricane Katrina relief operations in 2005 in New Orleans. Many examples can be cited where radio operations were of paramount importance but had inherent challenges due to the vast diversity of spectrum and radio sets. In any joint operations scenario, where multiple agencies have to communicate using radio communications as the mainstay, a suitable method is required to tackle interoperability issues in the VHF and UHF range. This is because a multitude of Radio sets work in these bands. Thus, a suggested solution is the *Intercomm* SDR.

3. Methodology

To design such a bridging radio repeater that has the potential to make radio sets of different frequency bands intercommunicate irrespective of different make and model, extensive testing and trials were required. The Intercomm SDR has the capability to achieve spectrum convergence across the VHF and UHF spectrums. The design of such a solution 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: -

3.1 Design Considerations

In the first phase of System Requirements Analysis, the frequency range in which the communication is to be established by the *Intercomm* SDR was done. The VHF and the UHF were the most widely used short to medium-range frequency bands in which radio communications are prevalent. Also most widely used brands Tadiran, Kenwood, Motorola, and Yaesu are being used in these frequency bands. This foundational step was critical to finalize the type of equipment required based on their characteristics.

3.2 Selected Hardware

The key components have to be meticulously chosen to ensure optimal performance. The BladeRF 2.0 micro xA4, known for its wideband capabilities, was selected as the reconfigurable RF front-end. The working frequency of the BladeRF is from 47MHz to 6GHz. The BladeRF xA4 was the best choice for the experiment due to its wider frequency range, higher transmit power output and two antenna ports. None of the commercially available SDRs work on all required bands with 2×2 MIMO streaming. Either, they have Receive-only (no transmission capability) or Lower TX power output, limited to one antenna port. A medium-performance computing device was selected having specifications such as 12th Gen Intel(R) Core (TM) i5-12450H 2.00 GHz processor, 16Gb RAM, and a Geforce RTX GPU.

3.3 Selected Software Platform

GNU Radio Companion (GRC) was chosen as the selected waveform development platform. Its open-source nature, customizable solutions, comprehensive toolkit, and a variety of built-in signal processing blocks were the main reasons for its selection. The intuitive graphical user interface of GRC simplifies the design and real-time debugging of signal processing flowgraphs. It is compatible with a wide range of hardware, including BladeRF 2.0 micro xA4, and support for Python scripting further enhances its flexibility. Additionally, GRC benefits from an active community and extensive documentation, ensuring robust support and continuous improvement. The details of the hardware equipment and the software required have been tabulated for easy assimilation in Table 1.

Table 1: COMPONENTS SUGGESTED FOR MC-SDR

Ser.No.	**Appearance (in Times 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

4. EXPERIMENTAL SETUP & RESULT

The experiment was carried out in lab conditions with all the equipment assembled together. The experiment required extensive testing and trials to get the optimized results for VHF and UHF. The experiment has been done using Narrow Band Frequency Modulation (NBFM).

4.1 Experimental Setup

During the experimental setup, I found that maximum medium to short-range radio sets operate in the VHF and UHF bands of 3-30 Mhz and 30-300 Mhz range. Also, while designing flowgraphs it was to be found that each radio set has its own Modulation scheme and Sampling Rate. These parameters may or may not be common for different radio sets. The idea here is to design the *Intercomm* SDR that operates with radio sets of both VHF and UHF. This can also be further enhanced to HF sets based on the SDR working frequency capabilities and suitable modifications in the GNU Radio Companion Flowgraphs. The experimental setup consisted of a RF front end (For my experiment BladeRF 2.0 micro SDR has been used) connected to a laptop/PC and a UHF radio set on one end and a VHF set on the other. The requirement is that the radio set will first receive the signal from radio set A,(UHF) demodulate it, get the baseband signal, then re-modulate it and send it for transmission to Radio Set B(VHF).

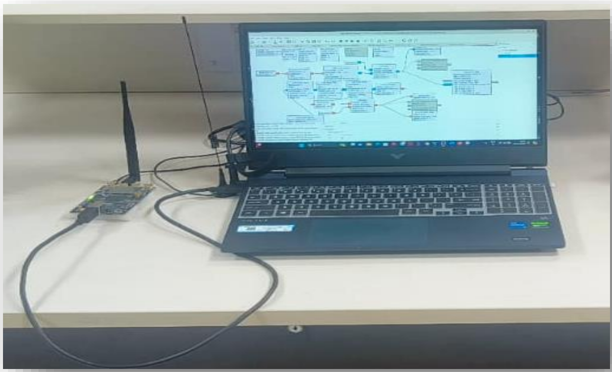

Figure -1: Experimental Setup

4.2 Signal Processing

The flowgraphs have been configured in GNU radio companion for both transmitter and receiver modules. SDR setup will be in between the two radio sets acting as a repeater. It will first receive and demodulate the received signal. Then the SDR will re-modulate and transmit the signal at the desired frequency to the other radio set. The flowgraph will contain both ’osmocom source’ and ’osmocom sink’ along with other blocks as shown in figure 2 and 3. Note the type of modulation and Demodulation blocks being used i.e. NBFM receive and 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 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.

4.3 Results

After deliberate testing and trials, the results were successful and radio set A was able to communicate with radio set B with the SDR setup in the middle thus providing the necessary proof of concept for the *Intercomm* SDR. The Flowgraph and the output graph have been depicted in Figures 2 and 3. It was concluded that the VHF and UHF sets mostly work on the NBFM/WBFM scheme with a sampling rate of up to 1.323 Million Samples Per Second.

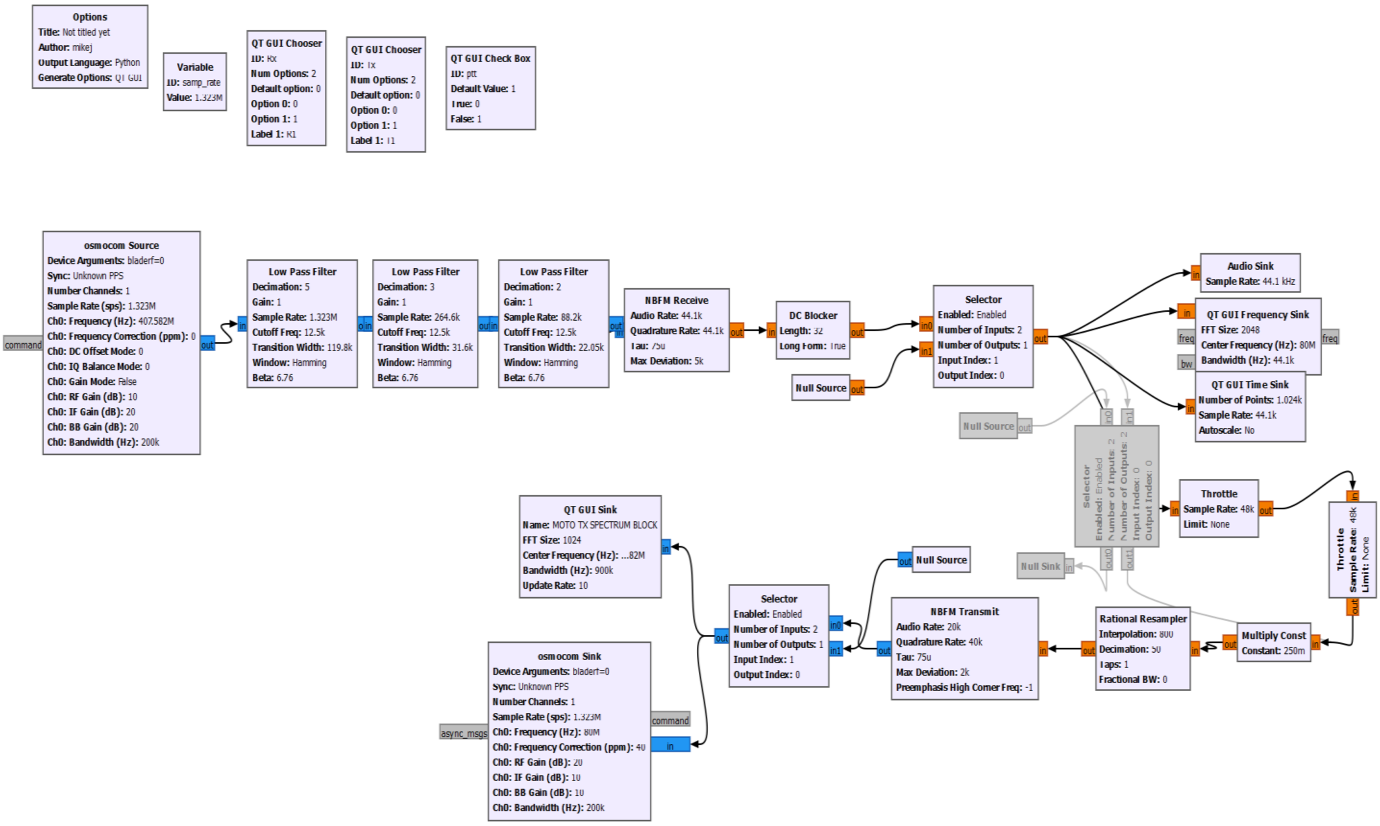

Figure -2: Flowgraph for Bridge Mode using GNU Radio Companion for NBFM Communications

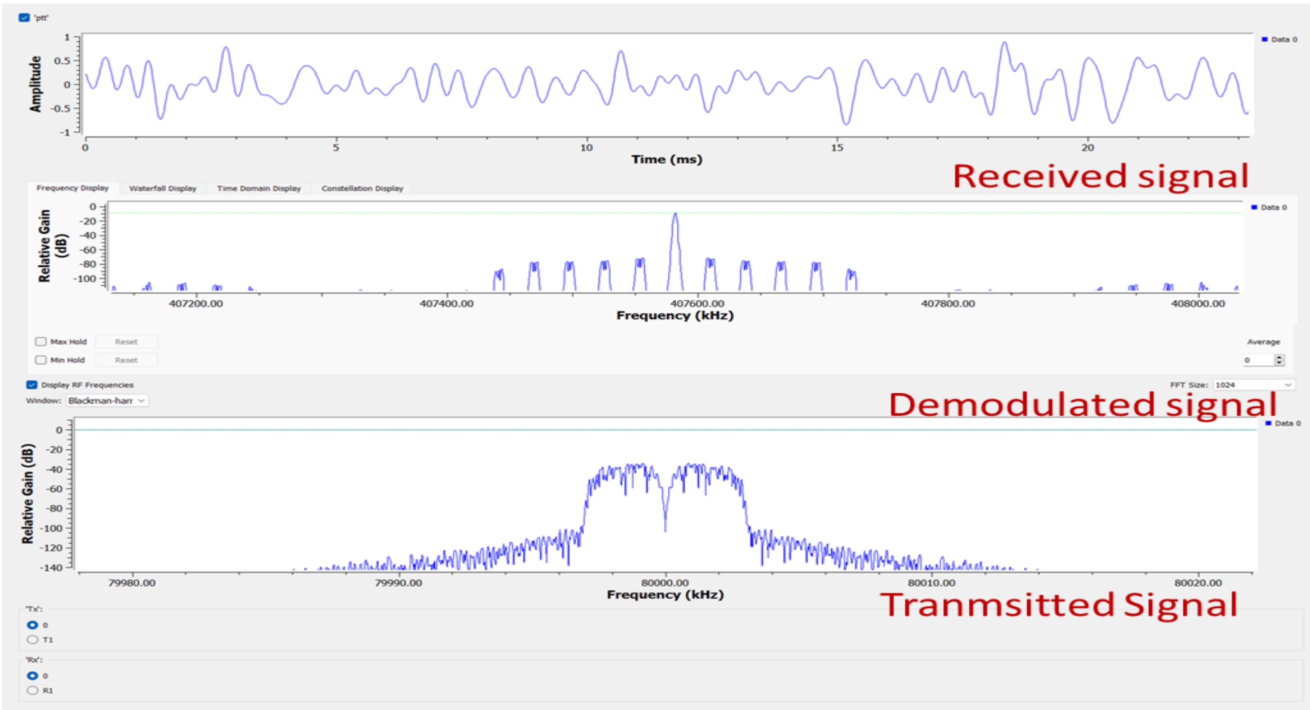

Figure -3: Output for Bridge Mode using GNU Radio Companion

5. Applications

The *Intercomm* SDR is designed to act as a bridge between different radio systems, allowing communication across VHF and UHF bands. The SDR's flexibility in software reconfiguration makes it an ideal candidate for this role. The system can dynamically adapt to different frequencies, modulation schemes, and protocols, ensuring seamless interoperability. Some applications where these can be used are: -

5.1 Disaster Management

During natural disasters, various agencies such as fire services, medical teams, and law enforcement need to coordinate efficiently. *Intercomm* SDR can facilitate communication across different radio systems used by these agencies, ensuring timely and effective responses.

5.2 Public Safety and Emergency Services

For large public events or emergencies, seamless communication between police, emergency medical services, and security personnel is crucial. This can ensure that all units remain in constant communication, improving safety and response times.

5.3 Military Operations

In joint military operations involving different branches or allied forces, *Intercomm* SDR can bridge the communication gap between different radio systems, enhancing operational coordination and mission success.

5.4 Commercial and Industrial Use

In industries like oil and gas, transportation, and mining, effective communication between different units is critical for operational efficiency. *Intercomm* SDR can integrate various communication systems, enhancing overall productivity.

6. Challenges

There are multiple challenges in designing the *Intercomm* SDR for radio interoperability. A few of them have been enumerated below: -

6.1 Secrecy

This project is being developed for radio interoperability and is just the first step towards developing an indigenous waveform-based SDR with secure communication as its main feature. This would require the specifications of the security protocols currently used in radio sets to be made available to the R&D team.

6.2 Standardization

The lack of standardization is one of the main issues. Multiple vendors have SDRs but with the lack of a standard waveform. key components have to be meticulously chosen to ensure optimal performance.

6.3 Trained Manpower

The trained manpower is another area that requires dedicated efforts in terms of training and a basic understanding of how the SDR will work.

6.4 Design Complexity

It was found that the development of two flowgraphs one each for transmission and one for reception then combining them and configuring the same in a single flowgraph required knowledge, research, and extensive trials and testing. However it

7. Way Ahead

After the proof of concept, the *Intercom* SDR will be a stepping stone for a secure and robust solution for many electromagnetic spectrum operations. The future advancement will depend on research and development, technical feasibility, and rigorous trials and testing in the subject. Some of the points for future advancements have been enumerated below: -

7.1 Indigenous Waveform

To ensure the continued advancement of Universal SDR, the focusing of finalizing the waveform and enhancing its capabilities to support more flowgraphs and standards, conducting rigorous interoperability testing, and integrating trial feedback for improved functionality.

7.2 Artificial Intelligence

The introduction of machine learning and artificial intelligence to automatically detect and home to the active frequencies during live operations will further enhance its capability.

7.3 Secrecy

Security will have to be bolstered with advanced encryption and authentication protocols. The aim should be to achieve a secure and robust waveform.

7.4 Collaborative Research

Collaborative research with industry and academia will drive innovation. Comprehensive training for military personnel and efforts towards a standardized waveform-based SDR will further ensure effective and seamless communication in diverse operational scenarios.

8. Conclusion

In conclusion, the *Intercomm* SDR project aims to enhance communication interoperability in joint operations. By ensuring seamless communication across various radio brands, we can significantly improve coordination and effectiveness. The future prospects of this technology are promising, with the potential to impact radio communications positively.

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