Universal Waveform for SDR Based Communications

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Abstract
A Software Defined Radio is a powerful tool to make multiple communication models. It has the flexibility and adaptability to transform itself into a radio set with the right programming. We can leverage this area for developing a universal waveform for it to become truly universal in nature. This will enable effective communication that is essential in various operational scenarios, including disaster management, military operations and humanitarian aid. This paper thus introduces the concept of "Universal Waveform for SDR-Based Communications," a solution designed to enable seamless interoperability between different radio systems.

Keywords: Software Defined Radio (SDR), Universal Waveform, Digital Signal Processing (DSP), Very High Frequency (VHF), Ultra High Frequency (UHF)

1. Introduction

Effective communication is crucial in operations such as rescue operations, military scenarios, humanitarian aid, law enforcement situations and emergency coordination. When mobile connectivity is unavailable, communications rely on the electromagnetic spectrum. Achieving interoperability across different radio sets used by various agencies is challenging. This paper introduces a universal waveform for SDRs to facilitate seamless communication across VHF and UHF radios. By developing a universal waveform compatible with Very High Frequency (VHF) and Ultra High Frequency (UHF) radios, this paper aims to bridge communication gaps and enhance coordination across diverse agencies. The technical aspects of waveform development are explored, emphasizing the use of open-source technologies and highlighting potential applications in global communication operations.

2. Background

In 2005, Hurricane Katrina made its major landfall on the Gulf Coast, near the town of Buras in southeast Louisiana and devastated millions. The international response included military, governmental and non-governmental organizations from various countries and agencies. The fixed communication systems failed and mobile towers were destroyed leaving radio communications as mainstay. However, that remained a challenge due to a diverse range of radio sets being used by different aid agencies. The lack of interoperability among different radio communication systems led to significant challenges in coordinating relief efforts effectively. Thus, there was a need felt for a universal waveform-based radio that could communicate across the VHF and UHF spectrum band for short and medium range communication.

3. Methodology

To design such a universal waveform based SDR 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. A universally acceptable waveform would be required that is customizable, flexible and comprehensive in terms of radio sets it can communicate to. This waveform when configured into an SDR will have the capability the capability to achieve spectrum convergence across the VHF and UHF bands. The following detailed approach have been suggested in the paper: -

- The first phase of the waveform development would be to identify the radio sets whose conventional parameters have to be recorded in the waveform. As most of the short to medium range radio sets are working in UHF and VHF bands the widely used brands, Tadiran, Kenwood, Motorola and Yaesu sets can be selected for experiment. This foundational step was critical to finalize the type of equipment required based on their characteristics.
- The The BladeRF 2.0 micro xA4 was selected as the RF front end based on its wideband capabilities and reconfigurability. It's working frequency is from 47MHz to 6GHz which covers the VHF and the UHF spectrum. The BladeRF xA4 was the best for the experiment due to its wide 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. The computing device was selected having specifications such as 10/11/12th Gen Intel(R) Core (TM) i3/i5-12450H 2.00 GHz processor, 8/16Gb RAM and a GPU.
- The 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 simple 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. The details of the hardware equipment and the software required have been tabulated for easy assimilation in Table 1.

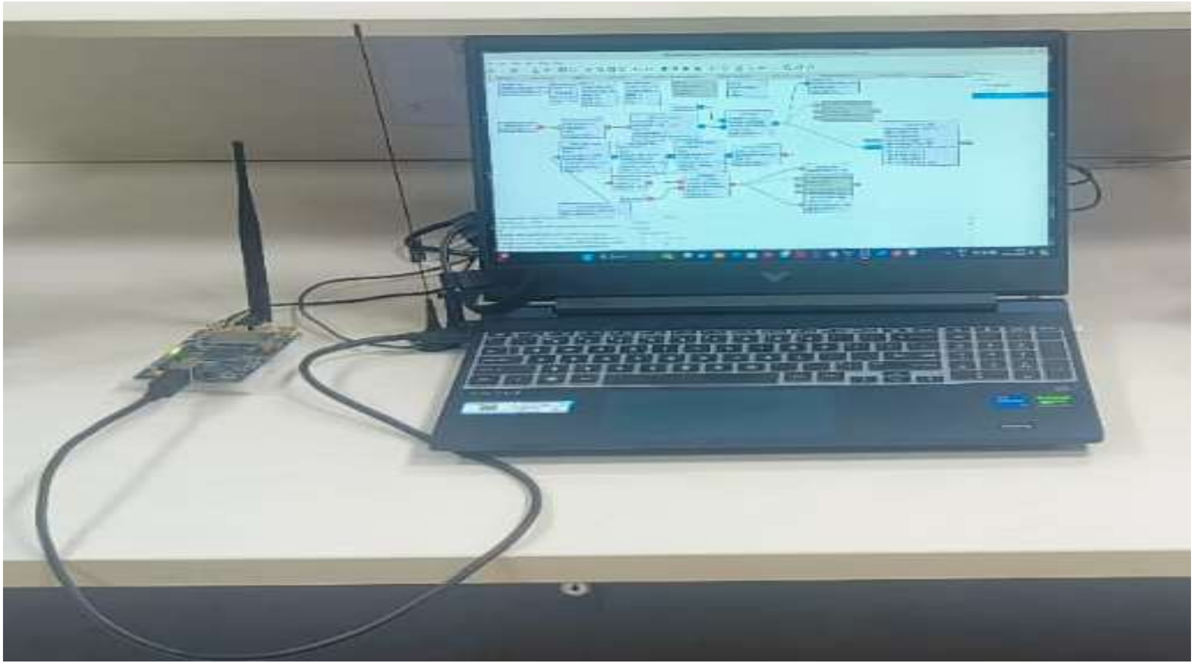
Table 1: Equipment Selection for Experiment

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

4. Experimental Setup

- The experimental setup consisted of a RF front end (BladeRF 2.0 micro SDR) connected to a laptop/PC and a UHF radio set. The requirement is that the radio set will first receive the signal from radio set demodulate it, and hear the output on laptop speaker. The laptop microphone will then be used as an audio source that will transmit signal after modulating it to back to the radio set, thus, transforming the SDR into a radio set itself. The experiment setup can be done as shown in figure 1.

Figure 1: Experiment Setup



- This needs to be done using the GNU radio companion software to develop the transmitter and receiver flowgraphs.
- During the experimental setup in lab conditions, it was found that maximum medium to short range radio sets operate in the VHF and UHF band of 3-30 Mhz and 30-300 Mhz range as mentioned above. While designing flowgraphs it was concluded that each radio set had its own Modulation scheme and Sampling Rate.
- These parameters may or may differ for different radio sets. The idea here is to design the waveforms that contains flowgraphs of radio sets of both VHF and UHF. The term waveform has been used many times. It is simply a Flowgraph that will be made in GNU Radio Companion. This flowgraph when executed should configure the SDR in such a manner that it becomes a universal SDR able to communicate with different radio sets. Thus, this waveform of complex flowgraph will transform the SDR into a radio set.
- Now which radio set is decided by the sub-flowgraph selected with the help of a simple Graphical User Interface. Therefore, this waveform will comprise of multiple smaller waveforms of all radio sets selected.
- As a proof of concept, one transmitter and receiver flowgraph was designed and implemented in GNU Radio Companion successfully. The individual UHF Transmitter and Receiver Flowgraphs have been demonstrated by the flowgraph in figure2 and 3.

Figure 2: UHF Transmitter Flowgraph

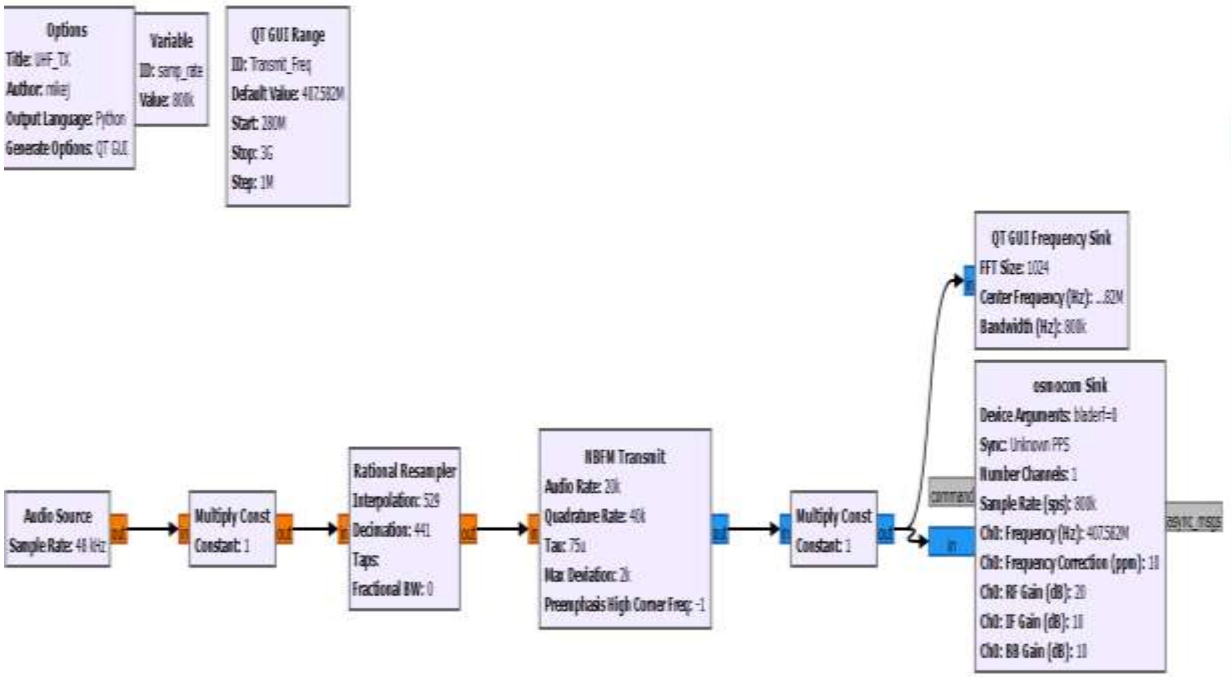
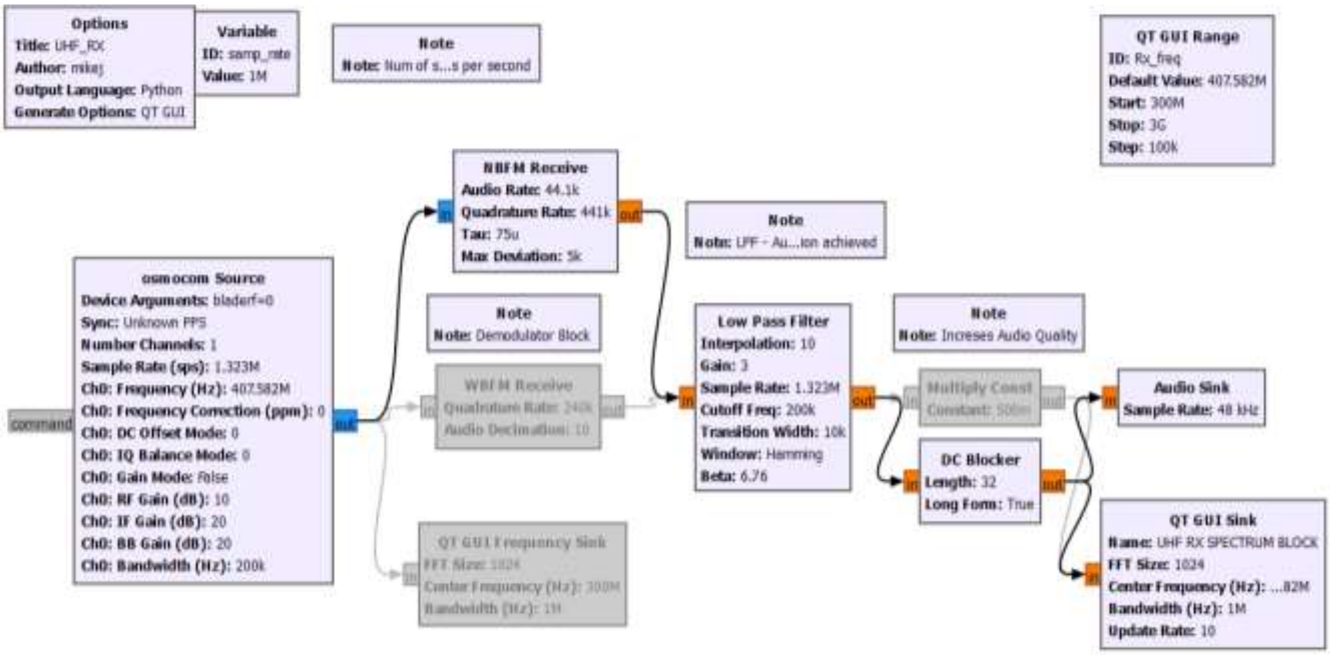
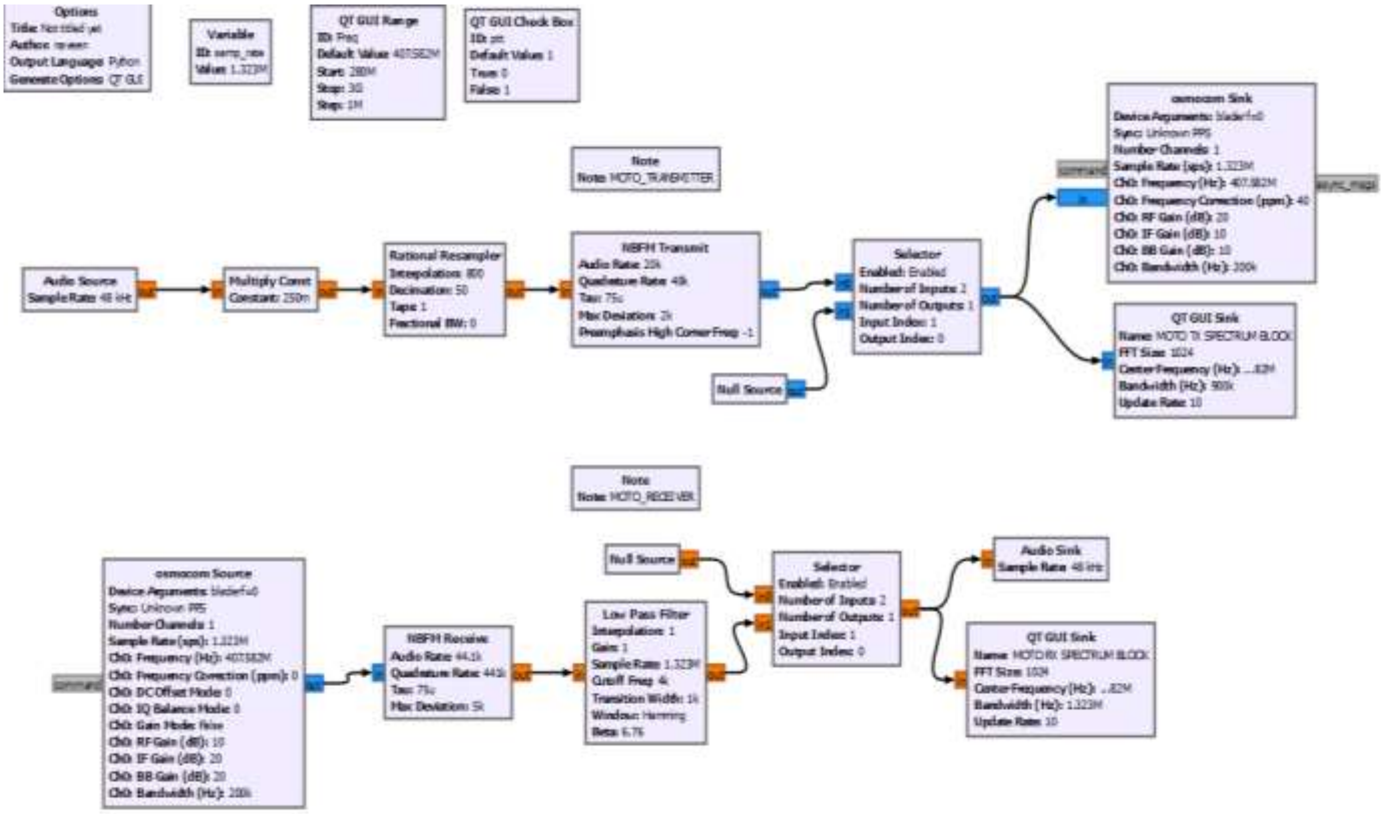


Figure 3: UHF Receiver Flowgraph



- The next step would be to combine the two flowgraphs into one Waveform. 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 SDR will consist of both these sub-flowgraphs as part of a single universal Waveform for transmitting and receiving VHF/UHF signals. This has been demonstrated by the flowgraph in figure 4.

Figure 4: UHF Transceiver Waveform



- It is important to note the type of Modulation and Demodulation blocks being used in the combined Waveform i.e. WBFM/NBFM receive/transmit blocks that modulate or demodulate the signal. There is also a need to adjust the frequencies, gains and modulation/demodulation settings in the BladeRF blocks to match your radio set specifications. We may also have to consider adding filters and signal processing blocks as needed to improve signal quality and avoid interference.

5. Application Scenarios

- The universal waveform once finalized and configured with the SDR could be used in rescue operations, where these teams equipped with the waveform enabled radio sets to communicate with other radio sets in the area, providing disaster recovery teams with a technological advantage that enhances communication capability.
- These Waveform enabled SDRs can be used in military operations for better communication, command and control. The soldier could reduce the number of radio sets carried by him to communicate with different radio sets.
- An essential application of Universal Waveform enables SDR lies in its interoperability domain. Envision a scenario where flood relief columns, equipped with such SDRs, can prioritize the locations that require immediate support and home on to the frequencies and radio sets being used.
- The Universal rnabled SDR can be made such that as when a radio set is to be added in the Waveform, a sub-flowgraph for transmission and reception can be made and added into the Waveform. This can be helpful where a in a joint operation new radio sets are introduced.

6. Challenges

- Lack of a Standardization for a single waveform development that will include SCA compliance.
- There will be a need to add robust security protocols and mechanisms to make it secure.
- Need for training and awareness about the basics of SDR technolodies to the users and researchers.
- Comprehensive trials and testing and Research and Development in the field to achive a robust and flexible waveform.

7. Conclusion

In conclusion, the development of a Universal Waveform and a Waveform enabled Software Defined Radio exclusively for interoperability across Very High Frequency (VHF) and Ultra High Frequency (UHF) radios represents a significant leap towards advanced SDR solutions for interoperability. The detailed and deliberate approach outlined in this paper, incorporating open-source solutions, global insights, and meticulous technical considerations may help us achieve a multi purpose Waveform capable of blurring the Spectrum as we see it. As we look towards the future, it is imperative for nations, including India, to continuously invest in and advance SDR technologies.

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