

# Implementation of Low Cost SDR in HF Band for Emergency Application

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## Research Article

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# Abstract

When events are uncontrolled due to hurricanes, the communication will breakdown. During this strenuous situation there is a need for reliable communication system to provide alert and emergency services. There remains a particular attention towards portability, reconfigurability, and interoperability in a communication system to reduce response time during emergencies. The real-time implementation helps to come across alternatives to overcome practical difficulties and challenges. This motivates us to implement a Relay Node in real-time using SDR, hence an experiment is carried out in order to gain first hand experience between different types of architecture of SDR i.e. VUSDR, HackRF One, and USRP. The architecture of Low-cost VUSDR and comparison between different types of SDR has been presented in this paper. Future scope and applications are presented.

## 1. Introduction

SDR was introduced by Joseph Mitola [1] that include both Analog and Digital parts of the radio. Initially, the design of SDR is to meet the requirements of the military, later it was extended to other applications like GSM, NOAA, Satellite Communication etc.

Software Defined Radio (SDR) replace a traditional hardware radio by a software one and acts as a bridge between incompatible radios [27]. It uses DSP/FPGA and computer systems with suitable software. The SDR design initiated to use programmable processing, to incorporate new coding, in order to provide secure communication with modularity and inter-operability.

Software Defined Radio comprise of generic hardware. i.e. RF FrontEnd and Open Source software which offer flexibility that in turn enables the engineers to fulfil cognitive functions. VU-SDR is a Low-Cost Transceiver developed by using open-source firmware by Amateurs Hams. This will operate in HF band through HSDR software.

During natural disaster [1] for re-establishing communication a relay node is used as temporary station to communicate to the nearby station, that help quick rescue operation. To address several issues such as interference, path loss, multi path fading, shadowing, etc, one better choice is to use SDR as a relay node. The significance of Relay can be understood by studying some similar cases and the applications of relay concept in various communication system have been discussed as follows.

### 1.1 Relay for satellite ground station:

Connection failure occurs due to the interference from adjacent frequency band congestion. This will be predominant with the reception of satellite signals and also degrade the performance at the terrestrial terminal. Hence relay is deployed for the satellite to ground signal. For implementing this testbed three USRP and GNU Radio being used in [2]. The two approaches called Amplify and

Forward relay, Decode and Forward relay has been tested using GNU Radio.

## 1.2. Cooperative Relay communication

Cooperative communication enhances link capacity and reliability and end-to-end throughput. It exploits spatial and user diversity and the signals through different paths and users are combined at the receiver node. Single relay and multi-relay cooperation test bed been evaluated using USRP and GNU Radio. This technique in [3] overcomes fading and interference and improves system performance. It requires stringent synchronization of devices at their physical layer.

## 1.3. Orbiter Spacecraft to Lander

The NASA Europa Clipper mission added the features of a relay communication system to clipper Frontier Radio, to deploy for relay communications to a lander and Earth communications in[25].

## 1.4. AF Relay for Multi user MIMO

A specially designed AF (Amplify and Forward) Transceiver been implemented as AF Relay to overcome practical issues, such as pre-synchronization for cluster transmission. Reconfigurable relays is demonstrated for the first time in a realistic indoor environment with a commercial software radio platform in[23]

## 1.5. Multimedia applications through AF and DF relay Technique

To mitigate multi path fading affects and to improve SNR, relay is used especially for multimedia applications such as Audio and Video. Basically it deploys two different cooperative relaying techniques (Amplify and Forward (AF) and Selective Decode and Forward (SDF)). the Experiment setup includes USRP and GNU Radio, and it proves that the performance of cooperative communication is better than that of direct communication presented in[22].

# 2. Keywords Used In Software Defined Radio

DDC: Digital Down Conversion-Receiver part of a direct sampling.

DDS: Direct Digital Sampling - Referring to an oscillator.

dll: Dynamic link library - reusable software block.

DUC: Digital up conversion-this unit is used in the transmitter chain

I data/stream: The non-phase shifted part of the IQ audio signal.

Q data/stream: The 90° phase shifted part of the IQ audio signal.

QSD: Quadrature Sampling Detector - Front end of the Tayloe detector.

QSE: Quadrature Sampling Exciter - Front end of SDR transmitter (often a Tayloe detector working in reverse).

PTT: Press to talk (Switch)- The TX/RX button on a microphone

NCO: Numerically Controlled Oscillator – the digital local oscillator.

The receiver chain consists of two blocks. First block is to decimate the input signal to Intermediate Frequency IF, second block is to convert from IF to baseband sample, so that it could be supported by an ADC. The DSP stage involved in the architecture to shift IF signals to baseband using a demodulator and decimator/filter is called Direct Digital Down Converter.

There are two types of SDRs namely QSD/QSE based SDR and DDC/DUC based SDR. In the QSD based SDR, RF is sampled and converted to an analog baseband AF signal in a single step. The resulting "IQ" output can be demodulated and filtered entirely within the host computer - without further hardware. DDC/DUC Radios employ FPGAs and is superior to QSD/QSE radio. The function of FPGAs is to digitize the input RF signals and process in the range MHz to GHz, and it is expensive.

High-performance SDR (HPSDR) was developed in 2005 and Flex Radio in 2006 after the introduction of the Tayloe detector in 2001. To process the signal to digital form, DSP Chip has been included between the audio amplifier and final mixer, after it is fed to the speaker.

The purpose of the paper is to Discuss various architectures of SDR and experimenting audio signal transmission using low-cost VUSDR to Relay unit. A comparison of the architecture of SDR helps for improvements and enables a new design to overcome the limitations of the previous version.

### 3. Related Work

In 1970s US and Europe, both used SDR in the defence sector, especially for military application. Software Defined Radio (SDR) replace a traditional hardware radio by a software one and acts as a bridge between incompatible radios [27]. It uses DSP/FPGA and computer systems with suitable software. It was initiated to use programmable processing, to incorporate new coding, that also acts as nodes in a network in order to provide secure communication with modularity and also provides inter-operability.

Several companies develop SDR with different RF front end and tuning facilities like Flex Radio Systems, SunSDR, BladeRF etc. An open-source hardware USRP develops software radio using Open-source software GNU Radio. Except for Standalone SDR, all Other SDR platforms are Programmable Hardware to meet high-speed wireless [30] communication.

SDR gives the solution through inter-operability[27] by implementing Multi-data and multiple protocols communication through software and generic hardware without any constraint. Overview of the various design approach such as USRP N- series that includes GPPs, GPUs, DSPs, FPGAs are discussed and co-

design approaches mentioned in [28] help to implement different communication standard through programming capability.

The various challenges of the SDR such as

- a) Security Issues like Insertion of malicious software to SDR terminals
- b) alteration or destruction of the configuration data
- c) high speed of ADCs and DACs and their synchronization with DSP,
- d) Increased complexity and development cost
- e) Increased power consumption
- f) Designing of antennas over a wide range of frequencies [29] are also presented by authors.

The current research is towards the design of Software Defined Radio with low cost, compact, and also should consume less power. It should be operable during disaster condition in order to address the challenges encounter in communication. VUSDR which is deployed in this experiment fulfill all the above requirements such as low cost and is operable during emergency.

#### ***Classification of SDR based on its front end :***

- 1) Stand Alone: Front end provided with Knobs and does not require any PC
- 2) Front End requires a PC for operation and control.

TCXO stands for Temperature Controlled Oscillator, controls the Temperature of the device to drift slightly by 0.5 parts per million so that it stay on frequency.

Super Heterodyne Radio architecture include double and triple conversion, mixers, Oscillators and other units like amplifiers, usually followed by DSP chip. Where as the new approach include Direct Digital Sampling(DDS) or Quadrature Sampling Detectors/ Exciters. The initial design of SDR concentrates especially on the audio output. Therefore the first generation SDR is also called Sound card SDR which is economical, thus most of the functions are carried on PC.

In second-generation radio, ADC Chips have been deployed for faster conversion and better performance thus it also allows wider bandwidth than first-generation SDR. Third generation SDR still uses QSD, that include onboard ADC and DSP chips. Several companies develop SDR with different RF front end and tuning facilities like Flex Radio Systems, SunSDR, BladeRF etc.

**Table 1** Comparison of different types of SDR

S.No	Model	Frequency (GHz)	Tuner IC	USB interface	TCXO Clock
1	NooElec NESDR Mini 2 (RX only)	25 Mhz-1750 Mhz	R820T2	RTL2832U	No
2	Noo Elec NESDR SMArtee (RX only)	25 Mhz-1750 Mhz	R820T2	RTL2832U	Yes
3	SDR play RSP1A (RX only)	1KHz-2GHz	R820T2	RTL2832U	Yes
4	VUSDR Half Duplex	1Mhz-40Mhz	Si570	Psoc3	
5	RTL SDR (RX only)	24-1766MHz	R820T	RTL2832U	
6	Hack RF One (TX/RX) Half Duplex	1MHz-6GHz	RFFC5701	LPC4320.	
7	USRP N210 (TX/RX) Full Duplex	Based on Daughter boards UBX, WBX, SBX,CBX	Based on Daughter board	Altera Cyclone EP1C12 FPGA	Yes

## 4. System Model

Several issues such as multipath loss, Fading, Low signal strength etc, and distance are the factors that will degrade the communication system.

The following are the reasons for deploying relay unit in communication system.

i) In order to mitigate the fading, and transmission noise etc, the signal been carried through relay network..

ii) During natural disaster [1] to establish the communication for rescue operation, a relay node is used as temporary station to communicate with nearby station.

To address several issues such as interference, path loss, shadowing etc, relay has been used in several applications such as Multimedia, MIMO, Satellite ground station [2,16,22]

The architecture and design of reconfigurable SDR helps to outperform and realize any type of communication system in short time [4]. Due to this reason SDR can be deployed as Relay unit so that it acts as temporary station to communicate with nearby stations.

Three units are considered namely remote, relay and Receiver/central unit. Here three different types of SDR been used in order to verify the inter-operability in real time environment. Objective of the experiment is, to provide facility to the farmers/workers during typical situations. An Audio signal/information from remote location such as field or agriculture is send through VUSDR in a HF band to the relay unit. The signal is then sent from the remote location to the central unit via relay unit.

### **VUSDR and Architecture:**

HSDR is written by Alberto diBene , and it is an improvement on Winrad,. It provides Waterfall spectrum displays the RF and AF that fit the window . The software provides various modulation techniques like AM, ECSS, FM, SSB and CW demodulation and also provides record and playback options.

The flexibility offered by Software Defined radio allows the user to reconfigure any type of communication system using PC and Frontend Hardware. The Frontend can be DSP or FPGA based platform. Usually, in any transceiver kit, the Knobs are provided at the front panel for tuning purpose. In VUSDR the HSDR Software is deployed to adjust the parameters such as Sound card setting, volume setting, bandwidth setting, filter adjustments, Center frequency selection, Adding frequency, Tuning fine/coarser, AGC, etc. It requires EXT/IO Library to support the Win rad EXTIO to allow the software to work with hardware systems.

### ***VUSDR Architecture includes IC and Circuitry :***

PSoc3 CY8C3246PVI-147 -Control and Interface with PC

PCM3060-CODEC chip ,Si570 - Local oscillator

74AC74 -Shifting the phase to 90

FST3253 - Mixer/detector

2N7002-Gate/Switch

TLV2464CD-Amplifier

PZT2222A-Switching Transistor.

All the SDRs require dual sound cards or an expensive Sound card with twin input - outputs(like M-Audio).The Peaberry open source firmware got a sound card functions built-in. All the control functions and audio functions are handled by PSoc3 - a system on chip and a CODEC.

VUSDR is a QSD based SDR i.e. operates on the principle given by Tayloe and thus it is called as Tayloe detector. It consist of switch rotates at the carrier frequency so that each capacitor samples the signal once each revolution. The 0o and 180° capacitors differentially sum to provide the in-phase (I) signal and the 90o and 270o capacitors sum to provide the quadrature (Q) signal.

The set up includes three different types of SDR in order to verify the interoperability in a real-time environment. The signal been transmitted from Remote location using an Inverted V Antenna in HF band i.e. 1-40MHz). Hack RF One is the SDR developed by Michael Ossmann is used as the relay node in the experiment. It offers flexibility with frequency range from1Mhz to 6Ghz. The Open source software GNU Radio used for implementing USRP and Hack RF One, provides Digital processing Blocks that allows it to reconfigure through the same generic hardware. Once the relay SDR Hack RF receives the signal it records and can retransmit the signal to USRP.

*Relay Unit Hack RF One:* Hack RF is a Wideband Half duplex transceiver[9], operates from 1MHz to 6 GHz. It consists of Micro USB Cable, ANT500 Antenna. The program is set in GNU Radio and also compatible with the software's like HSDR, SDR Console and GQRX.

Universal Software Radio Peripheral USRP N210 developed by Ettus Research consists of generic hardware called motherboard and daughter boards. SBX, UBX, WBX, and CBX are the daughter boards used based on the frequency requirement. The Motherboard [9]includes four ADC/DAC IC , Programmable Gain Amplifier (PGA) and FPGA.USRP NXX is the Network series board, that offers High Bandwidth, High Dynamic range processing capability and Large FPGA .Spectrum sensing using Energy Detection technique is also performed using GNU Radio.

VUSDR is used to send a signal from a remote location to HACKRF (Relay Unit). In hazardous situation ham radio has already proved itself as a bridge in establishing communication. VUSDR or Micro Ubitx (Low-cost Transceiver) transmit the signal, that signal can be collected by the relay node by Hack RF and re-transmitted from Hack RF to central unit USRP.

GNU Radio being an effective software tool, is compatible with RF Frontend for implementing SDR in real time environment. If any VUSDR or Micro Ubitx (Low-cost Transceiver) transmit the signal, that signal can be collected by the relay node by Hack RF and re-transmitted from Hack RF to central unit USRP.

## 5. Conclusion

SDR as Relay Node in the wireless communication can supports greater flexibility and helpful during emergency situation for Multiband Operation rather than conventional radio. Conventional relay has limitations, which may not be suitable for wide tuning applications. Therefore for best performance and Reconfigurability ,the real-time implementation of SDR as Relay Node has proved that, it is operable even they differ both in architecture and software platform.

## 6. Declarations

**Author Contributions:**Madhuri Gummineni performed the experiment and wrote the paper, and Trinatha Rao Polipall helped to revise and improve the whole paper. All authors read and approved the final manuscript.

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**Conflicts of Interest :**The authors declare no conflict of interest..

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## Figures

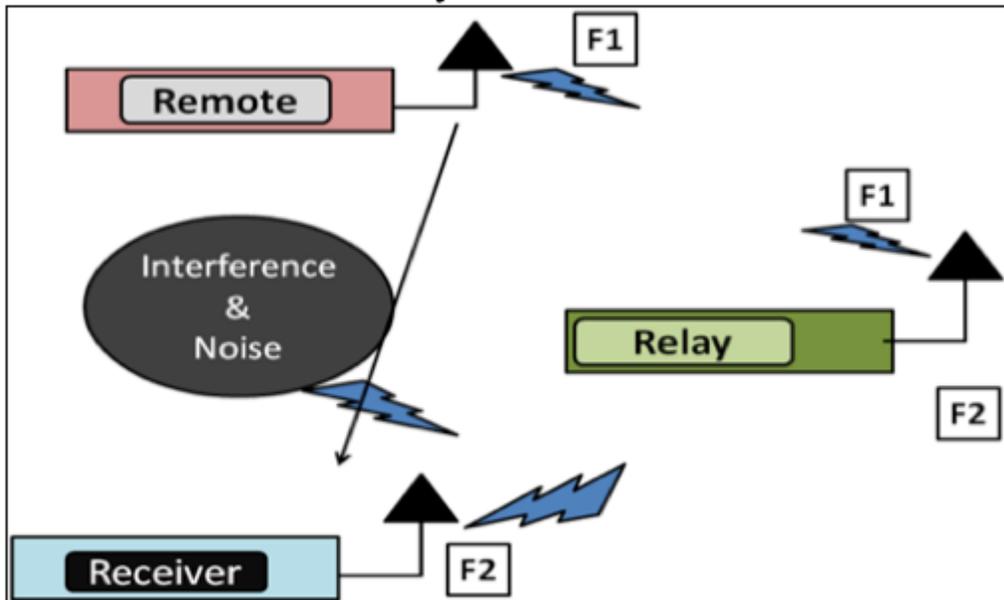


Figure 1

Block diagram of System Model

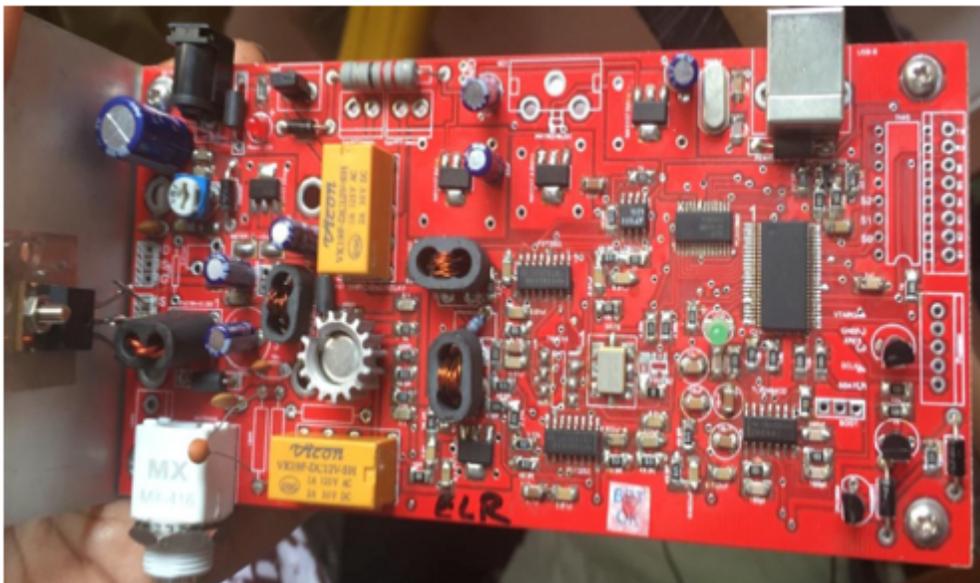


Figure 2

VUSDR A Low Cost SDR designed by HAMS

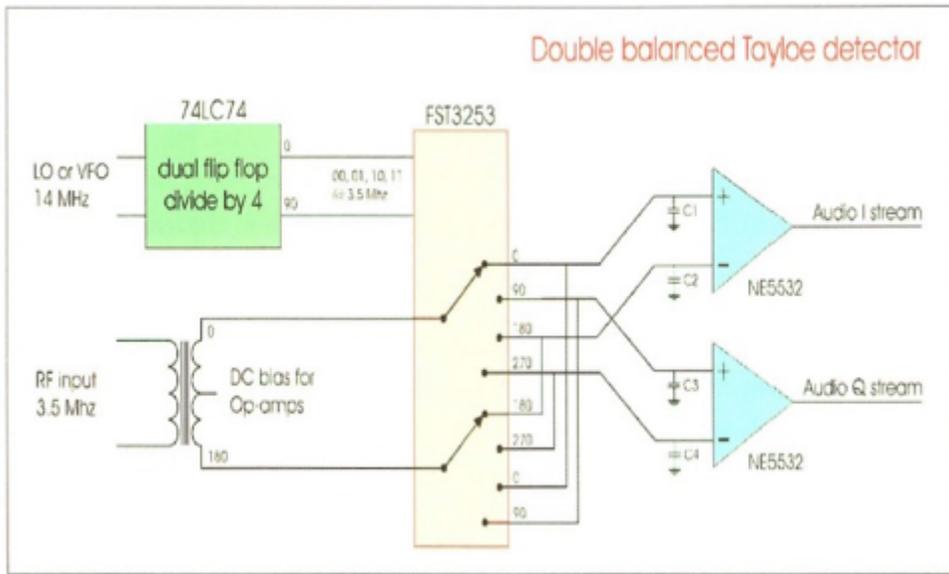


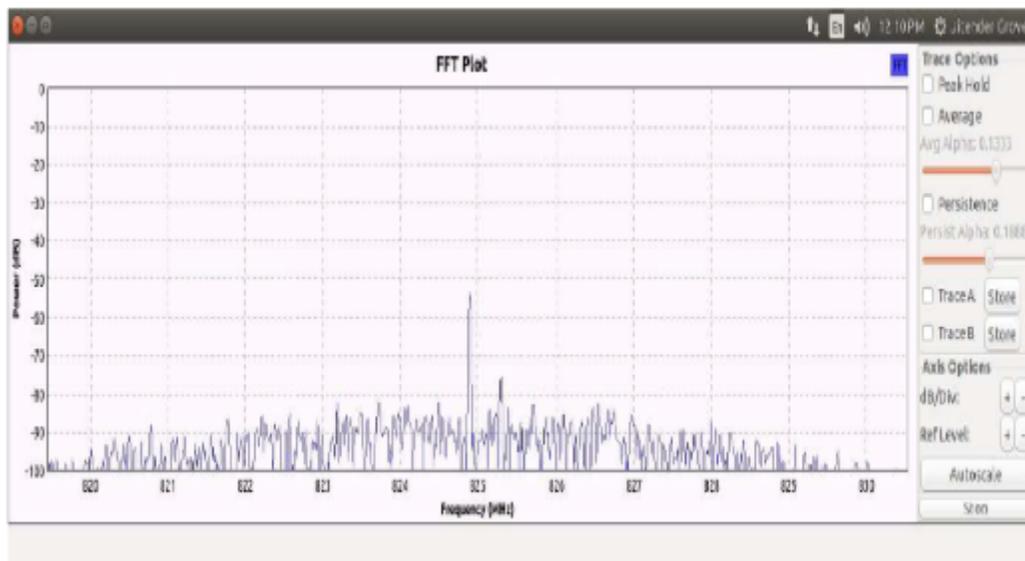
Figure 3

Tayloe detector



Figure 4

Experiment set up photograph of signal transmission from VUSDR to HackRF One



## Figure 5

Spectrum sensing