Software Defined Community Radio Using Low Cost Hardware and Free Software

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ABSTRACT

Community radio is the third model of radio broadcasting besides the commercial and public systems. It aims to provide individuals with local news and information that are important to a small community. This paper presents a new software defined radio approach to implementing community radio using Raspberry Pi, GNURadio, USB RTL – SDR sticks, and Universal Software Radio Peripheral (USRP). The main goal is to define and demonstrate a low cost, flexible transmitter and receiver using cost effective devices such as Raspberry PI computer, RTL-SDR dongle and USRP.

KEYWORDS

Community radio; Raspberry Pi; USRP; GNURadio, RTL-SDR, SDR.

1 INTRODUCTION

A community radio (CR) station is one that functions in a geographical community, for the community, by the community and about the community. They are nonprofit radio stations which are commonly used to disseminate local news, entertainment, and information such as agriculture, health, environment, gender equality to the individuals within the community they serve. Being a subset of radio broadcasting, community radio shares its space along the traditional commercial and public radio stations [1]. What distinguishes this type of radio communication system from other media is that it is owned, operated, and influenced by the people living within the community. The operators and participants of community radio are most often volunteers who are motivated by the community well-being and not commercial considerations [2].

In many countries around the globe, community radios act as a vehicle for local community groups, agencies, voluntary services, and residents to work together to further societal development. There is no universal definition of community radio – laws and legal framework vary across countries. Numerous internationally recognized principles promote community radio broadcasting [3]. In spite of these advances, there are still challenges with regards to regulation, competition with commercial entities for spectrum usage rights, human resource development and sustainability. Of the mass communication media, community radio is one that is the most cost-effective, universal as well as the most flexible and immediate. Therefore from a technical point-of-view, it is essential for organizers to ensure a simple, low-cost and viable community radio infrastructure. Traditional CR implementation ranges from ones that utilize high end commercial equipment costing US$ 23,900 – 140,700 to mobile "suitcase radio" type devices costing US$ 3,000 – 5,000 [4]. These hardware based implementations offer very little in terms of spectrum flexibility, support for new standards and protocols, enhanced services and simplified operation and maintenance. Software defined radios (SDR) also called software radio, have many of the features desired above and can be viewed as the most appropriate solution for future community radio platforms. The term "Software Radio" was coined in the early nineties by Joseph Mitola [5] and can be defined as one in which all or part of the physical layer radio architecture is implemented on a programmable or reconfigurable platform. The advantage of such a system is that the software can be easily reconfigured and so the same hardware can be used for a variety of protocols, standards and applications. There are several projects recently focusing on reducing the cost of the implementing community radio and few on utilizing SDR for community radio. A good example to mention on this direction is the paper presented by Gandhiraj and Soman [6]. This paper will investigate the implementation of community rdio using low cost devices such Raspberry PI, USRP, and RTL-SDR dongle. Doing so will reduce not only the total cost but also the power consumed by the system. The power consumed by Raspberry Pi is considerably less than that consumed by the traditional computer. The size of the whole system will be very small as compared with other models.

The rest of the paper is organized as follow; section II is going to explain the technical concept of community radio. Section III will present the implementation methods of community radio transmitter and receiver using USRP B100, Raspberry Pi, and RTL-SDR. Results of system validation using FM transmission/reception on GNURadio will be presented. And finally section IV provides conclusions and future work.

2 COMMUNITY RADIO TECHNICAL CONCEPT

In comparison with commercial broadcasting, a community radio often uses the basic production and transmission equipment appropriate for the size, needs and capability of the community. One can find a diverse range of technologies applied to CR broadcasting, ranging from simple and low-cost to complex and expensive. Major issues that dominate the role of technologies applicable to community radio are:

2.1 Type of Modulation

The common modulation scheme in community radio is angle modulation. It is very will-known that there are two kinds of angle modulation which are the frequency modulation (FM) and phase modulation (PM). Both are considered as a nonlinear modulation [7]. Angle modulation is widely used in commercial FM radio broadcasting, NTSC TV audio broadcasting, and other point to point communication systems. For a message signal m(t), the frequency modulated signal u (t) will be [7]:

$$u(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(t)\,dt) \qquad (1)$$

Where A_c and f_c are the amplitude and frequency of the carrier signal and k_f is the frequency deviation. The phase modulated signal is similar to the frequency modulated signal but without integration. Assuming the same message signal m(t), then the phase modulated signal will be [7]:

$$u(t) = A_c \cos(2\pi f_c t + 2\pi k_p m(t)) \qquad (2)$$

Where k_p is the phase deviation. FM is more common than PM even if they look almost the same. Figure1 shows an AM, FM and PM modulated signal. If the message signal is a sinusoidal signal ($m(t) = a\cos(2\pi f_m t)$) then the frequency modulated signal will be:

$$u(t) = A_c \cos(2\pi f_c t + \beta_f \cos(2\pi f_m t)) \qquad (3)$$

Where $\beta_f = {k_f a}/{f_m}$ is the modulation index. Equation (3) can be represented by:

$$u(t) = \sum_{-\infty}^{\infty} A_c J_n(\beta) \cos((2\pi f_c + n f_m) t) \qquad (4)$$

Where J_n is the Bessel function of the first kind of order n.

The bandwidth of the modulated signal based on equation (4) is unlimited but the effective bandwidth which contains the significant power of the modulated signal can be estimated using Carson's rule [7]:

$$B_T = 2(\beta_f + 1)W \qquad (5)$$

Where B_T is the bandwidth of the modulated signal while W is the bandwidth of the message signal. Based on the bandwidth used to transmit the signal, there are two kinds of FM modulation, narrow band and wide band FM (NBFM and WBFM).

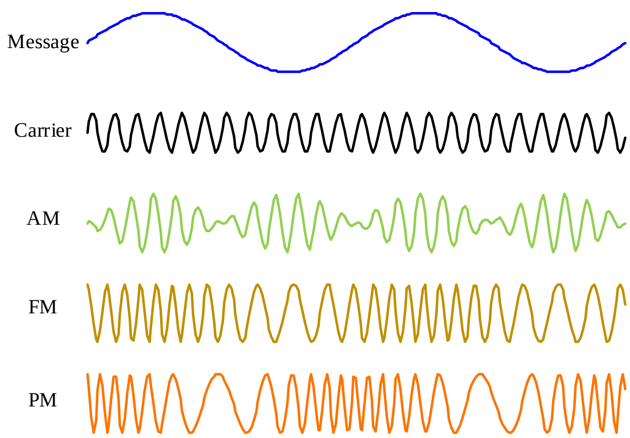

Figure1: FM and PM modulated signal.

2.2 Transmitter

The transmitter is the core piece of equipment in a CR setup. CR stations typically use low power FM transmitters with geographical coverage from 0 – 35 km. it should be mentioned here that the power of the transmitter is not solely responsible for range, other factors like efficiency, antenna terrain and atmospheric conditions also play a crucial role. However, a rough estimate of the coverage achieved with different power levels is provided by United Nations Educational, Scientific and Cultural Organization (UNESCO) [2] and is reproduced in Table 1. For a town level community, the recommended power level is 20-watt. Additional technologies like linear or a power amplifier may be employed to boost the power level of the transmitter.

Table 1: Estimated reach of different transmitter power.

Power	Class A	Class B	Class C
10 Watts	0 – 4 km	4 – 6 km	7 – 15 km
20 Watts	0 – 6 km	6 – 8 km	8 – 15 km
50 Watts	0 – 8 km	8 – 14 km	14 – 25 km
100 Watts	0 – 10 km	10 – 20 km	20 – 35 km

2.3 Receivers

An aspect of community radio that is often overlooked are receivers. This is due to the fact that traditional CR implementations have fixed signaling format (FM) combined with the ubiquity of low-cost FM receivers. If fully reconfigurable SDR transmitters and receivers are investigated, then low-cost, low power computing platforms like Raspberry Pi and USB based SDR modules may be required.

2.4 Antenna

Antenna design plays another crucial role in the coverage and quality of the community radio implementation. Various antenna makes and designs could be fabricated, the most common of which is the folded dipole. Since FM is the most preferred method of modulation, the height of the antenna is an important factor that determines signal reach. A transmitting antenna of approximately 20 to 30 meters in height fabricated from galvanized iron water pipes will be adequate for wide range of scenarios. On the receiver side, a quarter wavelength whip antenna is the most suitable for FM.

3 IMPLEMENTATION METHODS

The implementation methods included two experiments. The first one was the implementation of community radio transmitter using PC and USRP N210. The experimental set up of this experiment is shown in Figure 2. To validate the functionality of the implemented transmitter, an SDR based receiver was built using RTL-SDR dongle and Raspberry PI as shown in Figure 3.
The second experiment was the implementation of community radio transmitter using Raspberry PI and USRP B100. The experimental set up was similar to Figure 2 but a USRP B100 was used instead of the RTL-SDR dongle. The output signal from the Raspberry PI based transmitter was received by RSA 3303A real time spectrum analyzer to test the performance of the implemented system.

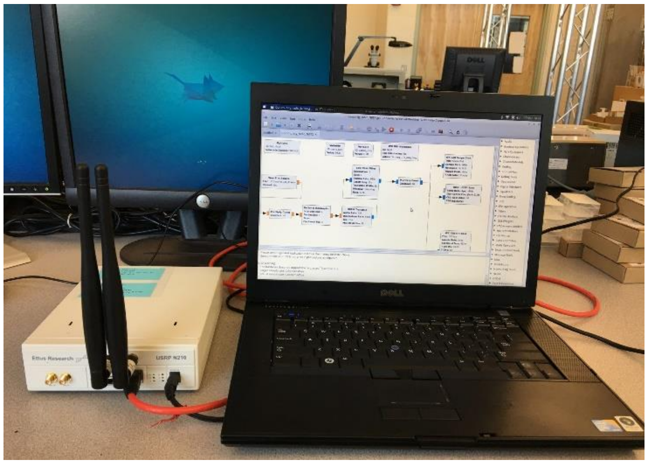

Figure 2: Community radio transmitter using PC, and USRP N210.

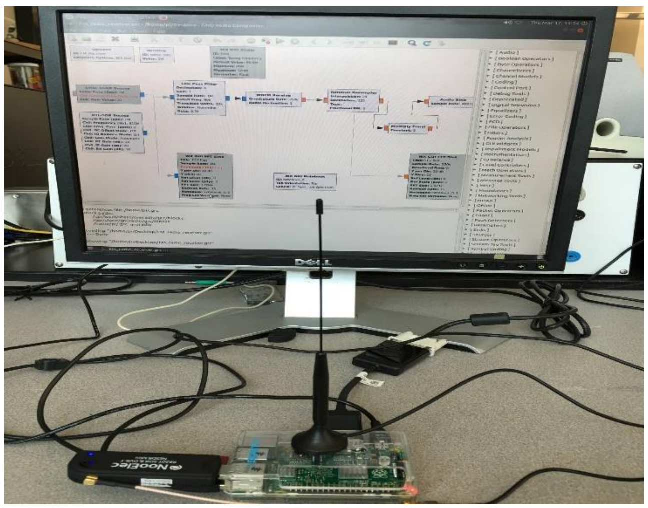

Figure 3: Community radio receiver using Raspberry PI, and RTL-SDR dongle.

4 IMPLEMENTATION RESUTS

For the first experiment, 915 MHz frequency was selected as the frequency of operation since it is in the ISM (industrial, scientific, and medical radio band) and it meets the specification of the USRP N210. The CR transmitter and receiver flow graphs are shown in Figures 4-5 respectively. The transmitted signal in time and frequency domain are shown in Figures 6-7 respectively. The transmitted signal was originally an audio signal which was received without errors. For the second experiment 40.68 MHz frequency was used as the frequency of operation since it is in the ISM band and it also meets the USRP B100 specifications. The GNURadio transmitter and receiver was similar to those in the first experiment but with different frequency of operation. A snapshot of the received signal on the RSA 3303A real time spectrum analyzer is shown in Figure 8.

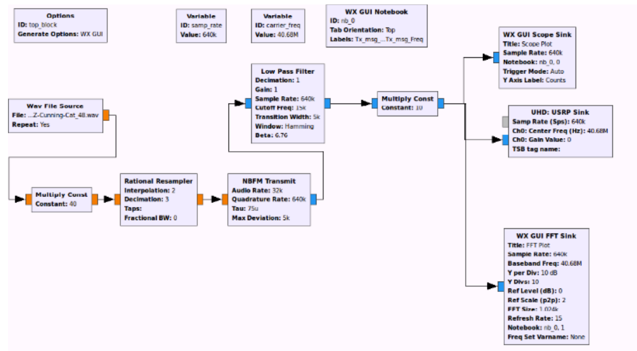

Figure 4: CR transmitter flow graph.

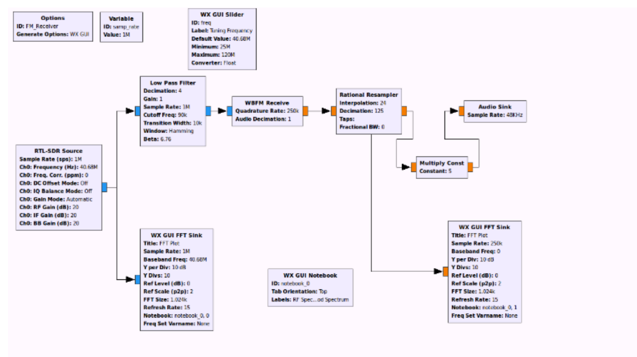

Figure 5: CR receiver flow graph.

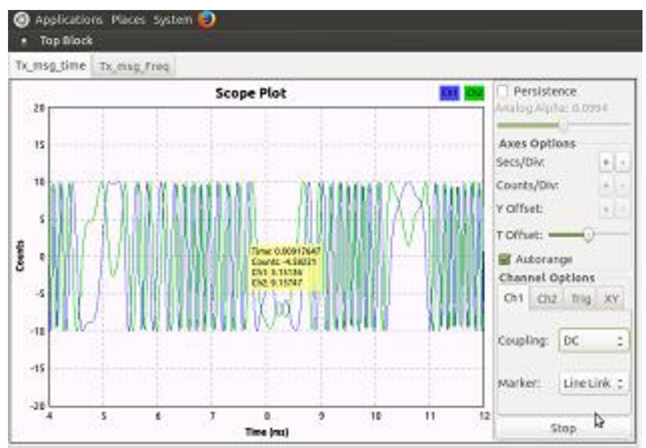

Figure 6: Transmitted signal in time domain.

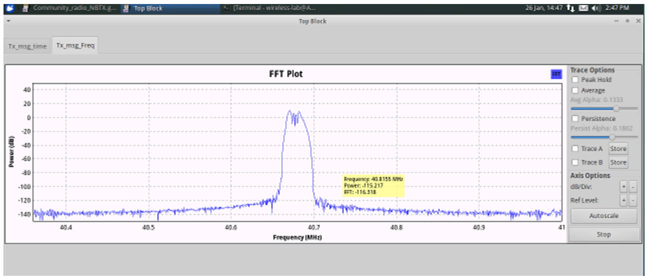

Figure 7: Transmitted signal in frequency domain.

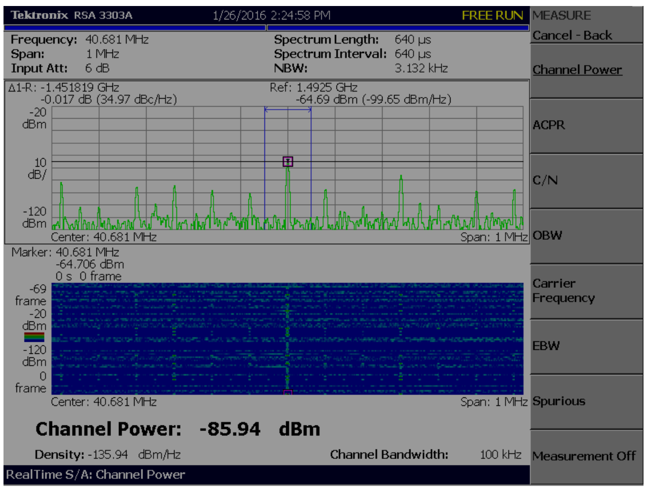

Figure 8: RSA 3303A real time spectrum analyzer snapshot.

5 CONCLUSION AND FUTURE WORK

This paper presented two efficient ways of implementing community radio. The first one included PC, and USRP N210 while the second one included Raspberry PI and USRP B100. The performance of the built systems was verified by SDR based receiver and RSA 33303A real time spectrum analyzer. Successful reception of FM signal was achieved. Future research will involve utilizing this community radio architecture to implement other kinds of communication protocols and services. There are also plans to accommodate open source radio automation platform like Rivendell and demonstrate a complete community radio platform that can be an effective substitute for commercial systems.

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