

Spectrum monitoring for wireless TV and FM broadcast using software-defined radio

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Abstract In this paper, the deployment of a radio monitoring system using software-defined radio (SDR) technologies is addressed. The main advantage of using software-defined radio is its reconfigurable ability and flexibility to set the communication parameters when monitoring radio signals. We propose a feasible architecture of spectrum monitoring in which a control center is built using GNU Radio platform; some remote monitoring stations are built with SDR devices. At each remote station, an SDR dongle embedded with Realtek RTL2832U chip and a USRP (universal software radio peripheral) device are used to measure radio signals. Through TCP/IP network, measurement results or complex sampled data from the SDR devices can be sent to the monitoring center. Some key measurement tools for radio monitoring such as spectrum analyzer and audio/video player are also implemented in the proposed system. The major benefit of the proposed architecture is the cost-effective and flexible platform as compared with traditional spectrum monitoring systems. Moreover, both the radio signals and demodulated audio/video content can be remotely monitored at the control center.

Keywords Wireless digital TV · FM broadcast · Software-defined radio · Remote control · Spectrum monitoring · GNU radio

1 Introduction

With the rapid growth of demand for wireless multimedia communications, radio spectrum has become one of the most important resources due to its scarcity. Unlike traditional voice service, multimedia communications usually consume much more radio spectrum for high data rate transmissions [20]. In addition, the popular use of wireless multimedia transmissions could result in a serious shortage of spectrum or cause harmful interference. Therefore, a flexible spectrum monitoring system is required to measure the radio signals.

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A nation-wide monitoring system is usually an investment for 10 to 15 years or more. However, the rapid development of communication techniques leads to several formidable challenges in the design, deployment, and functional updating on the monitoring system. For instance, to satisfy the increasing demands of mobile communication services, new wireless communication techniques or services will be continuously introduced to the market after the deployment of monitoring system. The monitoring technique should have the ability to analyze and measure the radio signals radiated from the advanced wireless communication networks.

Software defined radio (SDR) is an innovative reconfigurable and reprogrammable technique [14]. In a traditional communication system, some important components including mixers, filters, and modulators/demodulators are implemented in hardware. With the SDR technique, these components can be done by means of software on a general purpose computer [9]. The reconfigurable ability of SDR can meet the tough requirements of monitoring and analyzing radio signals for an advanced spectrum monitoring system.

The purpose of this paper is to contribute to a better understanding of the challenges of how to build a radio monitoring system with reconfigurable and extensible capability. We attempt to adopt SDR technique to design a prototype of spectrum monitoring system that consists of one control center and some remote monitoring stations. At the control center, an open source software platform called GNU Radio is installed to perform the core missions of radio monitoring, such as signal analysis and demodulation, as well as the display of measurement results. At the remote stations, some advanced and low-cost SDR devices, such as Realtek RTL2832U and the USRP (Universal Software Radio Peripheral) products are deployed as main detecting receivers. The SDR devices is used to detect radio signals and digitalize them by analog to digital convertors (ADCs). The complex sampled data (I and Q) from the SDR devices can be sent to the monitoring center through TCP/IP network or sent to the nearby measurement server via USB (universal serial bus) interface. Some key measurement tools for radio monitoring such as FFT (fast Fourier transform) analyzer and waterfall display are also implemented in our system. With the proposed monitoring system, we perform a few measurement tasks for wireless TV and FM monitoring.

2 Missions and requirements of a spectrum monitoring system

The primary objectives of spectrum management are to maximize spectrum usage efficiency, minimize interference, and clear away unauthorized use of radio spectrum [2]. Spectrum monitoring provides the required way as the eyes and ears of the spectrum management process. This process includes at least measuring the radio waves and identifying their primary parameters such as frequency and bandwidth, through a spectrum monitoring system. Figure 1 shows the relation between the spectrum monitoring and spectrum management [10]. The key measurement data from spectrum monitoring include frequency, bandwidth, occupancy, field strength, and modulation scheme. Through the comparison of the measurement data with spectrum database, spectrum regulators can indicate the infringements, discrepancies, and illegal stations. The enforcement and clearance are mandatory to eliminate unauthorized stations and interference.

One of the most important responsibilities of spectrum regulator is to prevent the spectrum usage of authorized users from possible interferences. The interferences may come from illegal stations or unintended emission of authorized stations. To resolve radio interference, one

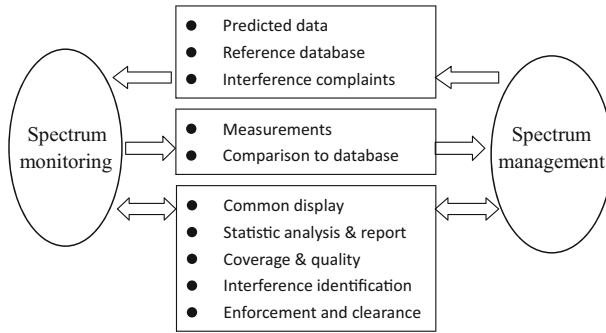


Fig. 1 Relations between spectrum monitoring and spectrum management

should first find out the transmitters that involve in the interference. A spectrum monitoring system can perform a certain measurements to identify and locate the sources of interference. As the sources are detected, monitoring organization would take appropriate enforcement actions to rule out the interference.

A monitoring system is often used to verify whether the license holders radiate their signals in compliance with radio regulations [25]. This verification typically requires a set of detailed measurements of the emitted spectrum of a transmitter, including frequency, radiation level, field strength, bandwidth, modulation scheme, and spectrum occupancy. These measurements can provide information needed in a specific analysis to verify conformance with the characteristics stated in a particular frequency assignment record. License holders often misuse the spectrum by moving transmitter's location, enlarging transmitter's power, or extending the spectrum bandwidth of emission. This kind of spectrum misuses may dramatically increase the interference possibility.

Spectrum monitoring data can also be used to identify the causes of poor radio reception. In wireless communications, the radio reception that is closely related to the quality of service usually exhibits a very wide range of values. Spectrum regulators often receive a large number of complaints or queries from the users about their poor radio reception. One of the most frequent complaints may be about the wireless television service. In recent years, the television service has been digitalized to improve the efficiency of spectrum usage and enhance the video quality. Traditional analog TV channel with 6-MHz bandwidth can provide just one video program. Through digitalization, the same bandwidth can accommodate three digital video programs with standard quality or one high definition TV (HDTV) program. Hence, it is a real challenge for broadcasters to satisfy the quality of service or quality of experience [12]. Spectrum monitoring systems provide a useful tool to identify the real causes of low reception.

When planning a spectrum monitoring system, one should be fully aware of the long-term spectrum demands of the communications services, the characteristics of new modulation schemes, as well as the technique of advanced digital signal process. Considering the fast development of wireless communication systems, an effort must be made to avoid the new built system to be out-of-date, even shortly after its launch. Hence, the reconfigurable and extensible abilities for analyzing the radio signals are the primary requirements for the design of a monitoring system.

In practice, a monitoring system is usually operated for more than 20 years. In such a long period, it is inevitable to replace part of the equipment or add a few stations to the existing system. The ability of extension or integration is of great importance for maintaining radio monitoring as well. The SDR technique with its reconfiguration capability supported by the

state-of-the-art software engineering seems to be the most effective solution to the requirements of designing an advanced monitoring system.

3 Software-defined radio technique

SDR technique has evolved from the work of Mitola [13] in 1992. Since the 1990s, considerable efforts have been devoted to the research and development of the SDR products [1, 3, 6, 16, 17, 23]. In recent years, the price of SDR devices has been rapidly declining to a quite low level. A widely used USRP device that can transmit and receive radio frequency up to 6 GHz costs less than US\$1000. If only receiver function is required, the price of SDR devices can be as low as US\$20, i.e., RTL 2832U dongle. In addition to the affordable hardware, well developed software platforms such as GNU radio facilitate the applications of SDR technique.

3.1 SDR concept

SDR is a collection of hardware and software where most of the radio's functions are implemented through programmable software or firmware. The main components of SDR include field programmable gate array (FPGA), digital signal process (DSP), general purpose process (GPP), system-on-chip (ASIC) or other application-specific programmable processors [11]. The use of these techniques makes it possible to add new wireless features to existing radio systems without requiring new hardware.

A schematic of a generalized SDR transceiver architecture is presented in Fig. 2. Like traditional wireless communication systems, a practical SDR consists of analog RF (radio frequency) hardware also called RF front end. This analog module in general includes antenna, low-noise (or power) amplifier, mixer, and filter. For a SDR receiver, one of the most important features of the analog module is to tune the RF signal to a suitable intermediate frequency, where analog-to-digital conversion with reasonable sampling rates can be done. The digital subsystem is responsible for digital processing (i.e., decoding and demodulation) and some higher layer protocols such as multiple-access and decryption. In practice, the possible ways to implement the digital hardware include general purpose processor, FPGA, ASIC, or general purpose computer. The software framework provides fundamental functions and libraries to the development and implementation of a communication service.

3.2 GNU radio

GNU Radio is an open-source software development toolkit that provides the signal processing runtime and processing blocks [7]. It allows designers to easily implement real-world radio systems by using the software defined blocks to control readily-available, low-cost external RF hardware and commodity processors. In GNU Radio, hardware circuits are replaced with signal processing blocks that are implemented by Python objects. A radio system is then expressed as a flow graph in Python. GNU Radio also provides a GUI (graphical user interface) developing environment named GNU Radio Companion (GRC) to help develop the signal processing blocks and create the flow graphs, which comprise radio applications. To increase the speed of runtime, the real operations of the signal processing blocks are implemented in C++ codes. SDR devices are controlled by the GNU Radio module via USB or network interface. The hierarchy of SDR modules used in GNU Radio is presented in Fig. 3 [7].

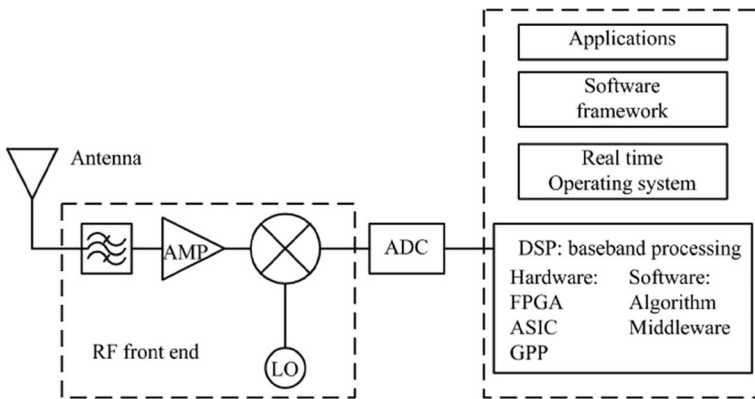


Fig. 2 Architecture of SDR receiver

GRC also provides a few measurement tools to support the signal analysis, such as frequency-domain FFT sink, time-domain oscilloscope sink, waterfall display for spectrum usage, and constellation diagram. Two types of GUI, QT GUI and WX GUI, are adopted in GRC development environment. After receiving waveforms, software defined radios can demodulate the waveforms into bit streams for further treatments, i.e., audio or video play. The reconfigurable and flexible characteristics of GRC allow us to construct the basic architecture of a radio monitoring system.

3.3 SDR devices

In recent years, the cost of SDR devices has declined to an affordable level for many people. There are several vendors who can provide SDR devices with reasonable price and acceptable performance. In this study, we adopt two models, RTL2832U dongle integrated with R820T tuner and USRP B200. Both the two models of SDR devices can be controlled by GNU Radio.

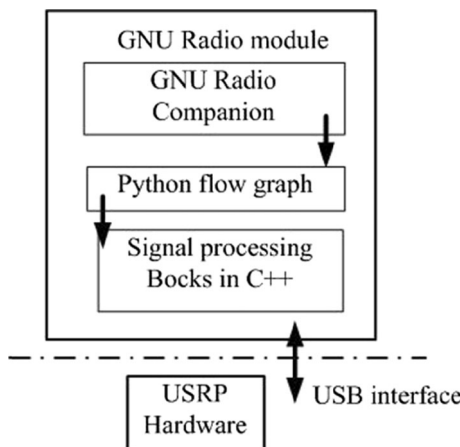


Fig. 3 Hierarchy of GNU Radio module

3.3.1 RTL2832U dongle

The RTL-SDR dongle used in this study consists of RTL2832U chip and R820T tuner, as well as a USB 2.0 interface [15]. The RTL2832U is a high-performance DVB-T (Digital Video Broadcasting-Terrestrial) COFDM (coded orthogonal frequency division multiplexing) demodulator that produced by a Taiwan's company, Realtek [19]. The RTL-SDR dongle can provide an approximate tuning range of 25–1700 MHz that in practice covers the FM and DVB bands. The RTL2832U outputs 8-bit I/Q-samples, and the highest safe sample rate is 2.4 MS/s (mega samples per second) but in some situations up to 3.2 MS/s. Through USB 2.0, the dongle allows transferring the raw I/Q samples to the host, which is generally used for DVB/FM demodulation. The actual output is interleaved; so one byte I, then one byte Q without header or metadata. The samples themselves are unsigned and one can subtract 127 from them to get their actual value (from -127 to +127).

The RTL-SDR dongle has been widely adopted due to its extremely low cost (less than US\$20) and sufficient range of frequency for most wireless communication services. With the use of software platform, the RTL-SDR dongle can be designed as FM/TV tuner, spectrum analyzer, signal analyzer, GPS receiver, and even as the receiver for aircraft or maritime transport communications. The powerful abilities come from the software defined design of the RTL2832U chip.

3.3.2 USRP B200

USRP B200 is a SDR device which is capable of receiving and transmitting radio signals with the frequency range of 70 MHz- 6GHz [5]. This frequency band covers a wide range of applications, including FM and TV broadcast, cellular communications, Wi-Fi, and more. The integrated RF front end on the USRP B200 is a single-chip direct conversion transceiver and digital baseband processor, capable of streaming up to 56 MHz of real-time RF bandwidth. Its maximum sample rate is 61.44 MS/s with 12-bit ADC/DAC converter. USB 3.0 interface is provided for the high speed transmissions of sampling data to the host personal computer. The USRP B200 can be controlled by GNU Radio through USRP Hardware Driver (UHD). The UHD is an open-source, cross-platform driver that can run on Windows, Linux, and Mac operating systems. In practice, USRPs have been commonly used with the GNU Radio software suite to create complex software-defined radio systems. As compared with the RTL dongle, the USRP board has superior specifications particularly in sample rate and hence, is capable of monitoring broadband signals. In addition to monitoring RF signals, the USRP B200 can be operated as a transmitter.

4 Configuration of monitoring system and measurement results

4.1 Two primary monitoring types

The monitoring for FM radio and wireless TV broadcast services is one of the primary tasks for spectrum regulators around the world. A large part of illegal stations transmit FM radio signals. Identifying the parameters of illegal stations is required before enforcement and

clearance. For wireless TV service, the focus of monitoring is on the field strength or quality of experience. The following two subsections give a brief overview of the two services.

4.1.1 FM broadcast

FM broadcast is a traditional analog communication technique. Due to the low cost of equipment and high quality of audio transmission, analog FM broadcast is nowadays widely adopted in the world. Analog FM broadcast uses the frequency range of 88–108 MHz with a channel bandwidth 150 kHz. Figure 4 presents the typical spectrum of stereo FM baseband signal. The audio signal L+R is transmitted in the baseband range of 30 Hz to 15 kHz. The L–R signal is modulated in the range of 23–53 kHz using a 38 kHz DSB-SC (double-sideband suppressed-carrier) signal [8]. A 19 kHz pilot tone is also transmitted for the receiver to regenerate the 38 kHz sub-carrier with the correct phase. These composite signals along with other sub-carriers modulate the FM transmitter.

4.1.2 DVB standard

DVB-T is the European-based consortium standard for the wireless transmission of digital terrestrial television services [4]. The DVB system transmits compressed multimedia data in an MPEG (moving picture experts group) transport stream, using COFDM technique. The DVB-T has been widely adopted by many countries including Taiwan and in general is operated in UHF band. For more detailed specifications of DVB-T, one can refer to the literature [21]. Table 1 lists the main parameters of DVB-T.

4.2 Architecture of SDR monitoring system

The proposed architecture of SDR monitoring system is presented in Fig. 5. It consists of a control center and some remote stations. They are connected via TCP/IP technique as an intranet or VPN (virtual private network), where the security and transmission speed can be easily maintained. The control center is in charge of the control of remote stations. Its main features include:

- spectrum monitoring via remote control operations;
- interference investigation;

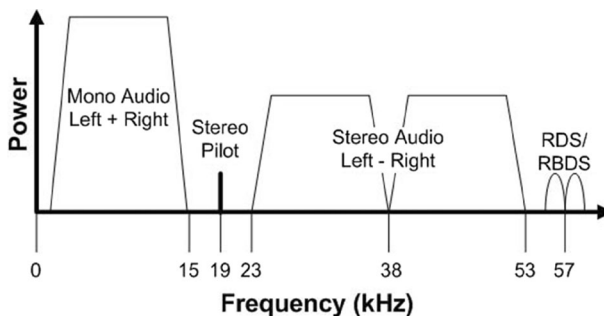


Fig. 4 FM baseband spectrum

Table 1 Primary parameters of DVB-T

Parameter	DVB-T
Channel bandwidth	6 MHz*, 7 MHz, 8 MHz
Number of carriers in signal	2 k, 8 k*
Modulation scheme	QPSK, 16QAM*, 64QAM
Error correction	1/2, 2/3*, 3/4, 5/6, 7/8
Guard interval	1/4*, 1/8, 1/16 1/32

* the parameters adopted in Taiwan

- verification of technical and operation parameters of radio stations;
- identification of unauthorized transmitters.

The required devices of the control center include a router, an Ethernet, and a few computers. One of the computers must be equipped as a workstation for staff to perform the monitoring measurements. In this study, we adopt a general purpose computer (a notebook computer) as the monitoring workstation in which the Ubuntu Linux OS (operating system) and GNU Radio are installed. Measurement results including signal strength, waterfall, and video content for the monitored signals are shown in the workstation. In fact, the monitoring workstation can be viewed as a measurement client. In practice, the control center requires a spectrum database for the verification of radio stations. For simplification, we do not implement the database in this study.

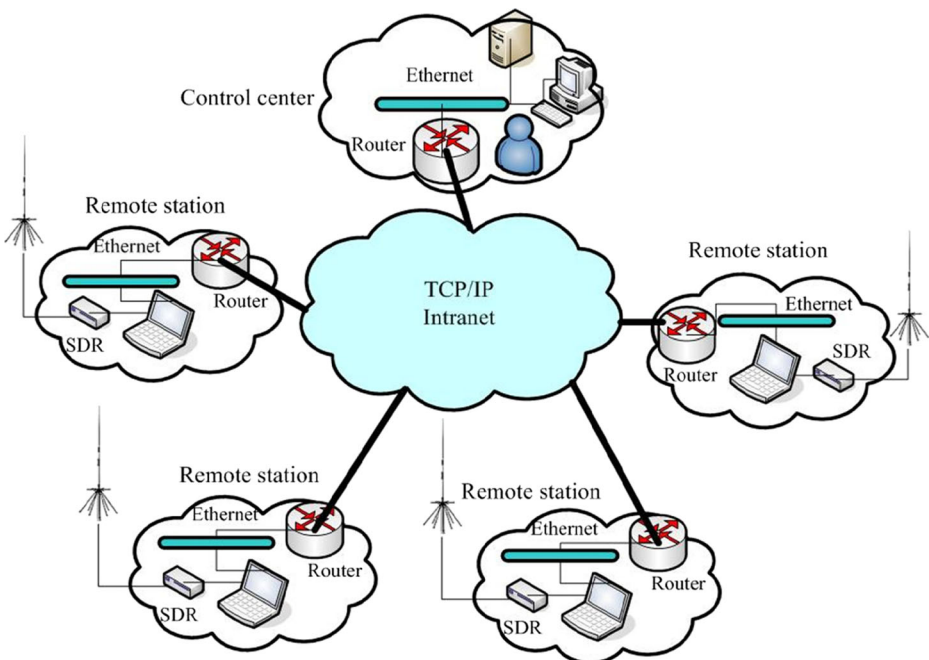


Fig. 5 Architecture of spectrum monitoring

The remote monitoring stations are employed to carry out all measurements under the control of the monitoring center. Their main features include:

- receiving monitoring commands from the control center;
- performing measurement tasks;
- sending I/Q data to the control center;
- decoding video streams and sending the decoded content to the control center.

The required devices of the remote stations include a router, an Ethernet, a computer, a SDR device, and a receiving antenna. In general, the antenna should be omni-directional and suitable for long-term outdoor usage. The SDR device/receiver can detect RF signals coupling from the antenna and change into I/Q sampled data. Most importantly, the measurement tasks of the SDR device should be reconfigurable and be controlled by the monitoring center. The remote station computer is used as a TCP data transmission server, which is in charge of the data communications between the SDR and the workstation at the control center. In this study, we adopt two types of SDR; RTL2832U dongle and USRP B200. In addition to a notebook, we use Raspberry Pi as the data transmission server to simplify the monitoring framework. Raspberry Pi is a credit card-sized, single-board, and Linux-based computer [18].

4.3 FM monitoring configuration and measurement results

Since traditional FM broadcast is a kind of narrowband communications, the transmission speed required for sending I/Q sampled data is limited. Hence, we can adopt a low-cost RTL dongle together with Raspberry Pi as the main modules to construct a remote station. The proposed configuration for FM monitoring is shown in Fig. 6.

In this configuration, the RTL dongle detects RF signal and converts into I/Q sampled data stream. The I/Q data should be sent to the control center by the Raspberry Pi via TCP/IP network. In fact, the Raspberry Pi only plays as a data transmission server. A driver for the RTL dongle and a TCP/IP communication code (rtl-tcp) must be installed and run in the Raspberry Pi as follows:

```
rtl_tcp -a 140.116.54.153,
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where the last string is the IP address of the Raspberry Pi. Figure 7 presents the real connection between Raspberry Pi and RTL dongle at the remote site.

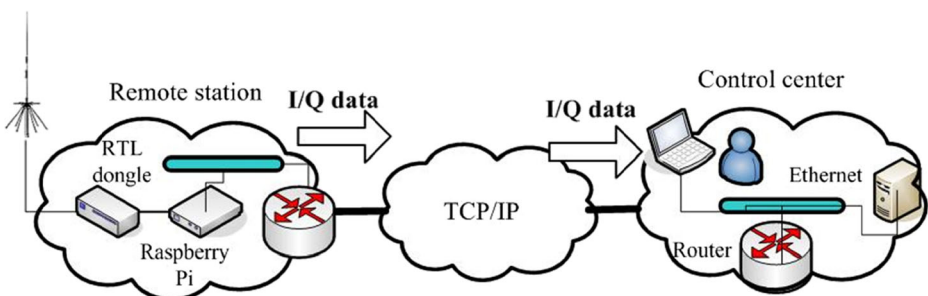


Fig. 6 FM monitoring configuration

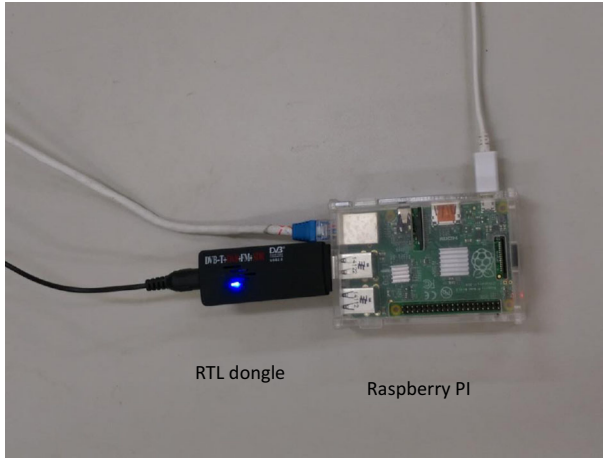


Fig. 7 Connection between Raspberry Pi and RTL dongle for FM monitoring

At the control center, we adopt a notebook PC with Ubuntu 12.04 Linux OS as the measurement workstation where GNU Radio 3.7.3 is installed. We have developed a Python code for the FM monitoring by using the development tool, GNU Radio Companion (GRC). With the Python code, we can remotely control the SDR dongle, get the I/Q sampled data, perform signal analysis, display the measurement results, and listen to the audio signal. Figure 8 presents the GRC flow graph for the FM monitoring task. In this graph, the block, “osmocom” represents the remote SDR device located at the IP address 140.116.54.153. The monitoring frequency can be adjusted through setting the parameter “freq” in the WX-GUI-Slider block.

At the control center, we can obtain the measurement results. The RF signal power distribution versus frequency is shown in Fig. 9. From this figure, we can observe three

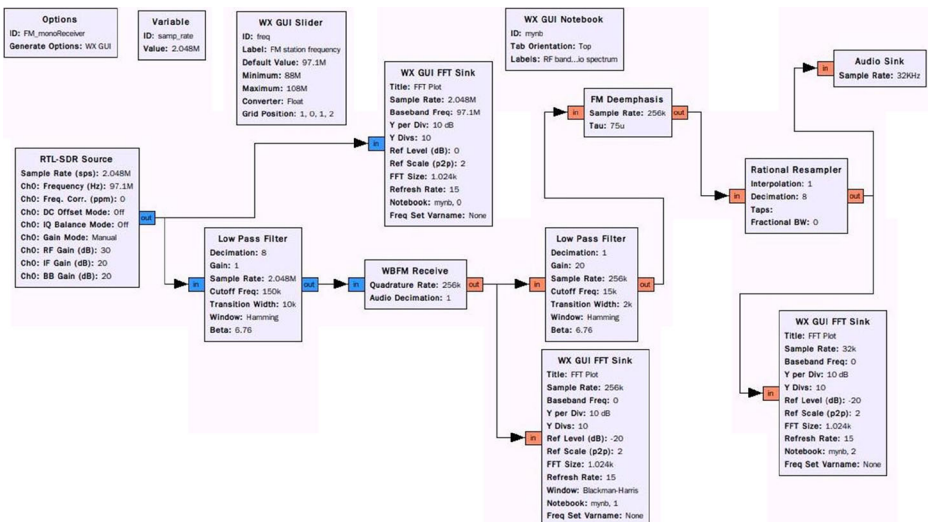


Fig. 8 Flow graph for FM monitoring

FM stations in the 2-MHz span. The carrier frequencies for the three stations are 96.3, 97.1, and 97.9 MHz, respectively. Figure 10 presents the baseband signal after demodulation for the FM 97.1 MHz station. We can easily observe that there are 30Hz-15kHz mono audio signal, 19 kHz pilot signal, and DSB-SC audio signal in the range of 23–53 kHz. We can also listen to the audio signal from the speaker of the notebook PC at the control center.

In the FM monitoring configuration, the sample rate is set to about 2 MS/s. Since each sample is encoded as an 8-bit number, sending the I/Q data stream requires a transmission speed of 16 Mbps. It is feasible to deliver this kind of I/Q data stream through a general TCP/IP network.

4.4 Wireless TV monitoring configuration and measurement results

Since digital TV broadcast is a kind of broadband communications, it requires considerable sample rate. Hence, we adopt USRP B200 that has sample rate up to 61 MS/s, as the measuring receiver. Each I/Q sample is encoded as a 12-bit number for USRP B200. Sending this kind of data stream will consume extremely high transmission bandwidth. Hence, the receiving signal will be first analyzed, demodulated, and decoded at the remote station. Then, the measurement results with smaller amount of data are sent to the control center. The proposed configuration for wireless TV monitoring is shown in Fig. 11.

In this configuration, the USRP B200 detects RF signal and converts into I/Q sampled data stream. Through USB interface, this data stream is sent to and analyzed by GNU Radio which is installed in a notebook PC at the remote station. The main modules for TV monitoring are shown in Fig. 12. Measurement results including RF spectrum and waterfall of spectrum usage can be obtained at the remote station. We have developed a Python code to measure the RF spectrum and the waterfall of frequency occupancy for

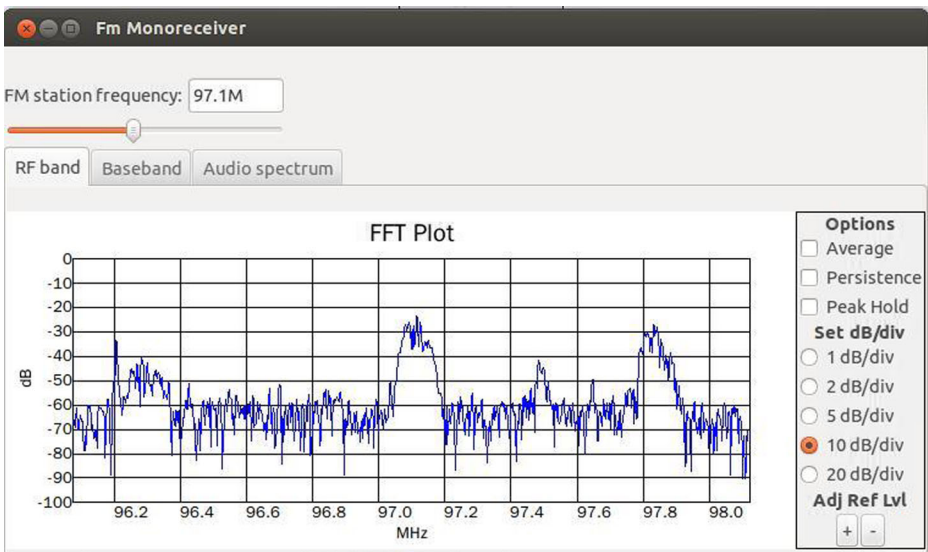


Fig. 9 RF spectrum for FM stations

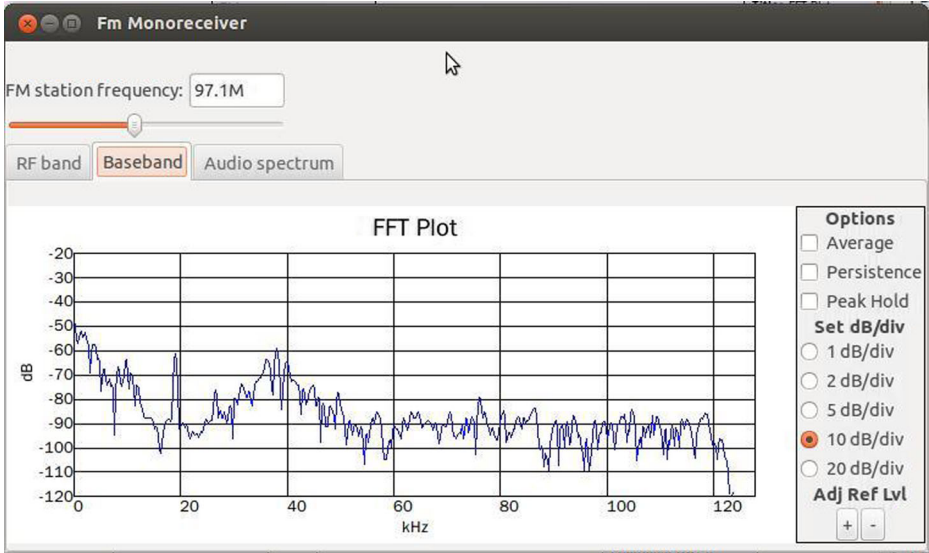


Fig. 10 Baseband spectrum for 97.1-MHz FM station

TV monitoring. The tuning frequency and sample rate can be easily adjusted through WX-GUI blocks. To control the remote station, we adopt a well-known free software package, TeamViewer [22]. Through its ability of desktop sharing, we can remotely control the measurement tasks at the control center.

To reduce the computation load of GNU Radio, we also adopt an open-source media player, VLC [24] to decode and play the DVB-T video. At the remote station, the VLC receives the I/Q sampled data provided by RTL dongle and converts into video stream. We set the remote station and the control center as streaming media server and client, respectively. With this configuration, we can watch TV program at the control center, while this TV radio is demodulated and decoded at the remote station.

Figure 13 presents the signal strength and video content at the control center. The sample rate of USRP B200 is set to 30 MS/s. From this figure, we can easily observe two TV channels, 542–548 and 554–560 MHz. These two stations are PTS (public

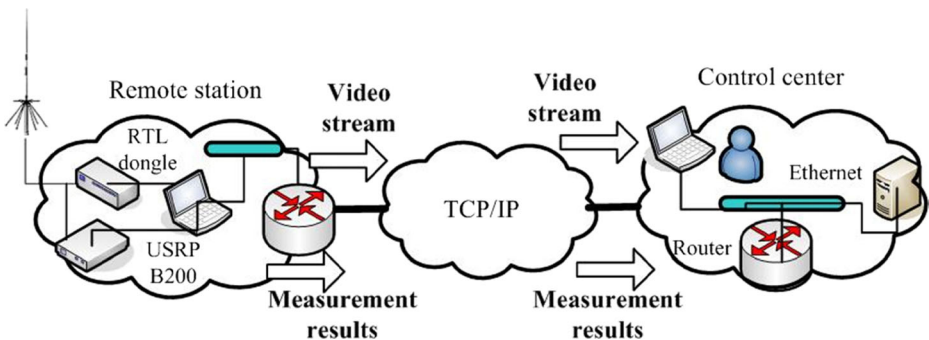


Fig. 11 TV monitoring configuration

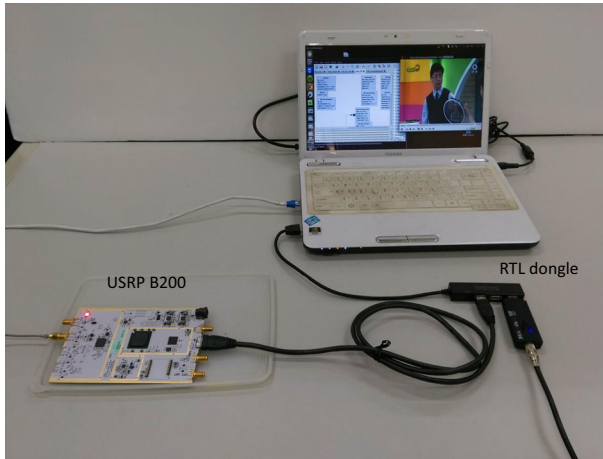


Fig. 12 SDR devices for TV monitoring

television service) and Formosa TV in Taiwan. The video content shown in Fig. 13 is transmitted by Formosa TV. The waterfall of frequency occupancy can be found in Fig. 14. After the process of digital signal analysis, we can measure the constellation of the TV channel, as shown in Fig. 15. It can be easily observed that there are 64 constellation points in the digital modulation scheme. The real environment of the control center is shown in Fig. 16.

In the wireless TV monitoring configuration, the sample rate is set to 30 MS/s. Since each sample is encoded as a 12-bit number by USRP B200, sending the I/Q data stream requires a transmission speed of up to 360 Mbps. It is hard to deliver such a large amount of data to the control center through a general TCP/IP network. Therefore, the signal analysis including demodulation and decoding should be performed at the remote station. Instead of sending I/Q

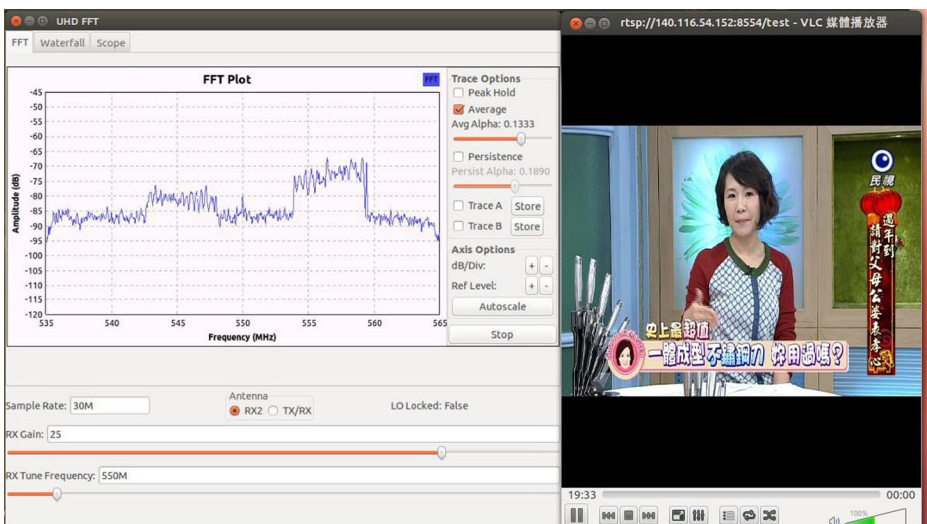


Fig. 13 RF spectrum and video content for TV monitoring

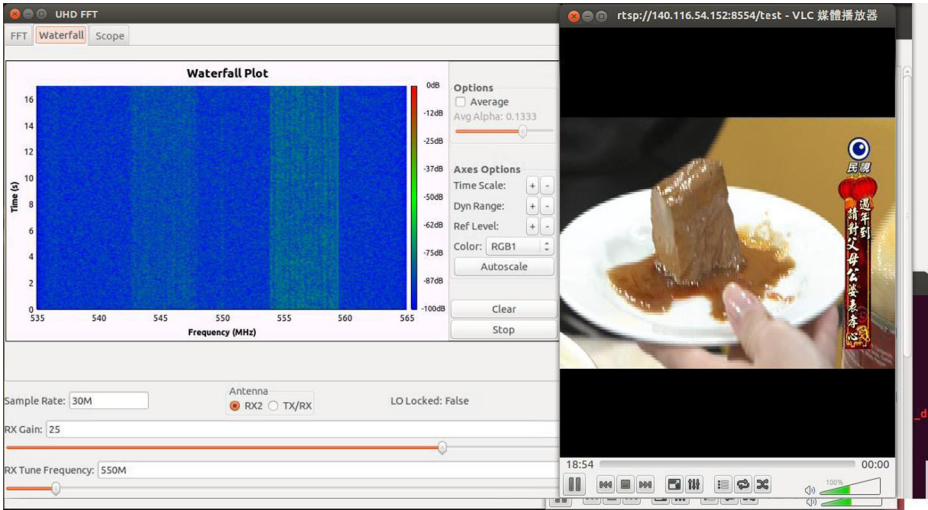


Fig. 14 Waterfall display for TV monitoring

sampled data, the transmissions between remote station and control center are the measurement results that have been processed.

4.5 Summary

From the real measurements using the proposed monitoring system, we make sure that the reconfigurable ability of SDR indeed allows us to adjust the main parameters of monitored

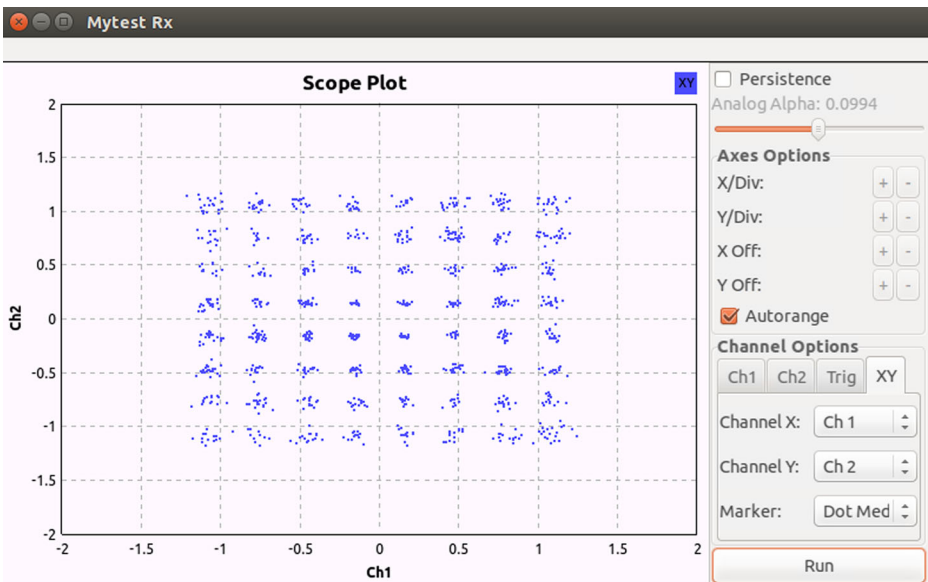


Fig. 15 Constellation of the measured TV channel

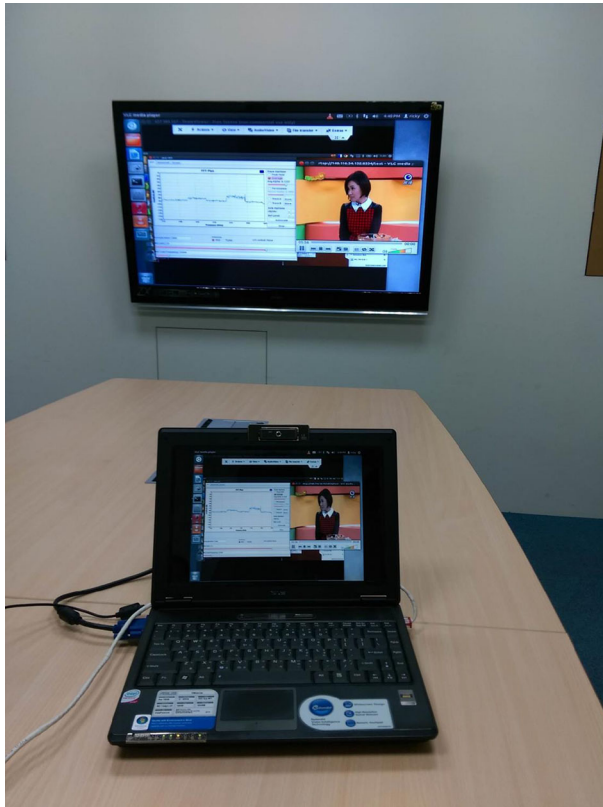


Fig. 16 Control center environment

signals easily and flexibly. For instance, we can adjust channel frequency and bandwidth for the FM monitoring by software control at the control center. We can also dynamically select the display of measurement results, i.e., RF spectrum or baseband spectrum.

From the implementation point of view, the RTL-dongle-based monitoring configuration is suitable for monitoring narrow bandwidth signals such as FM broadcast. The main devices for such a remote station include an antenna, an SDR dongle, an Raspberry Pi, as well as a TCP/IP network. The costs of these devices are quite low. In the real world, illegal FM stations frequently exist and often cause harmful interference. Monitoring and dealing with the illegal FM stations have become one of the most important tasks for the spectrum regulators around

Table 2 Comparison between SDR-based monitoring and hardware-based monitoring

	SDR-based monitoring	Hardware-based monitoring
cost	low	high
flexibility	high	low
extensibility	high	low
Measurement accuracy	low but can be improved by calibration	high
Measurement speed	low	high

the world. The low-cost advantage makes it feasible to build a dedicated subsystem consisting of a large amount of dongle-based monitoring stations.

To monitor wide bandwidth signals, USRP B200 is more appropriate than RTL dongle due to its high sample rate (up to 61 MS/s). The USRP B200 is capable of monitoring up to 56 MHz of RF bandwidth. However, the high sample rate would generate an extremely large amount of I/Q data. To avoid sending this kind of data over the monitoring network, the I/Q data should be processed at the remote station and then, only the processed results are delivered to the control center. It is worth noting that USRP B200 can be operated as a transmitter. In fact, the transmitting function is not required for spectrum monitoring. If we can adopt USRP devices that have receiving function with enough sampling rate but not include transmitting, the cost of TV monitoring can be further reduced. Finally, the proposed SDR monitoring system can be used to monitor any wireless communication services within the frequency range of up to 6 GHz, if some software modules are added to the GNR Radio platform. For instance, the proposed monitoring system can measure the signals radiated from 4G telecommunication networks if the LTE (long term evolution) GNU Radio module is installed.

A comparison between the SDR-based monitoring and traditional hardware-based monitoring is listed in Table 2. The primary benefits of SDR monitoring systems include low cost, high flexibility, and high extensibility. However, traditional monitoring systems have high accuracy and fast speed for radio signal measurements, i.e., less than 1° for the accuracy of direction finding.

5 Conclusions

In this paper, we have implemented a prototype of spectrum monitoring system to measure the radio signals of TV and FM broadcast. Two types of well-developed SDR devices, RTL2832U dongle and USRP B200 are deployed as detecting receivers at remote stations. The GNU Radio is installed as a communication platform between SDR devices and measurement servers. With the proposed monitoring system, we can flexibly select the channel frequency and bandwidth for monitoring TV/FM signals by software control at the control center. We can also dynamically select the display of measurement results. The major benefit of the proposed architecture is the cost-effective platform as compared with traditional spectrum monitoring systems. Also, the reconfigurable ability of SDR makes it feasible to build an extensible spectrum monitoring system that must be operated at least 20 years. In addition to monitoring TV and FM broadcast, the proposed SDR monitoring system can be used to monitor any other wireless communication services within the frequency range of up to 6 GHz.

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