Spectrum Sensing for TV Band using NI- USRP and Lab VIEW

S.S.Rokade[1], K.P.fulpagar[2]
[1,2] *Assistant Prof., Dept. of Electronics Dr. D.Y. Patil ACS College Pimpri, Pune, India*

Abstract- **Spectrum sensing is a major part for the implementation of Cognitive Radio (CR) systems in order to enable dynamic access to the radio frequency spectrum. The digital transition of TV transmission will make available some TV frequencies which are to be geographically unused called as TV White Spaces. Our result shows poor spectrum utilization in TV band and good potential for Cognitive radio operation. In our present work, we have correlated Cyclostationary feature detection and Energy detection technique for spectrum sensing with their merits and demerits using NI Lab VIEW. We particularly focus on the detection method based on cyclostationary feature detectors (CFD) estimation. The advantage of CFD is its relative robustness against noise uncertainty compared with energy detection methods. The experimental results present in this paper show that the cyclostationary feature-based detection can be robust compared to energy-based technique in real time.**

Index Terms- **Spectrum sensing; USRP; Energy Detection; Cyclostationary Feature Detection**

1. INTRODUCTION

Cognitive radio (CR) has been launched as a talented technology for spectrum deployment in wireless communication. All the cognitive radio users are divided into the main (licensed) and derived users [3]. In a CR network derived users scan the frequency spectrum (try to identify a spectrum holes in time or frequency domain) and adjust transmission parameters to the existing communication channel.

A key building block in any CR system is the spectrum sensing function, which consists of (a) sensing algorithms to quickly and robustly detect the presence of incumbent signals, and (b) well-designed coordination and communication protocols. Spectrum sensing is the process of periodically and dynamically monitoring a given radio spectrum band (e.g. VHF and UHF TV bands) in order to determine its availability for use on a non-interfering basis. By spectrum sensing, Cognitive Radio has information about its surrounding environment from which it can easily determine presence of primary user and also which part of spectrum is utilized by primary user or left vacant. The three admired methods of spectrum sensing discussed in the above mentioned works are (1) Matched filter reception (2) Cyclostationary analysis and (3) Energy detection.

Energy detector is also identified as radiometry or periodogram [7]. It is the most general way of spectrum sensing because of short computational and functioning complexities. The receivers do not need any information about the principal users. The arriving signal is detected by comparing the output of the energy detector with a threshold.

Matched filtering is painstaking as the suitable method for uncovering of main users if the transmitted signal is known a priori. It is also called as coherent detector. The method requires fine knowledge about main user signal such as modulation type, bandwidth, carrier frequency, etc. The test statistic is compared with the threshold and in distinct form.

Cyclostationary Sensing is also called Feature revealing. Cyclostationary based sensing uses the sole pattern of the signal to identify its existence. Cyclostationary descriptions are grounds by modulated signals or in its figures like mean and Auto-correlation. Chief primary signals are modulated by the sinusoidal carriers or have cyclic prefixes. Periodic correlation utility is used for identify signals in a frequency spectrum.

Cognitive access of TVWSs is the real opportunity for Wireless broadband connectivity to empowering rural India. It can improve rural people lives by affordable access to information and knowledge. Results of the spectrum measurement campaign performed over the TV broadcast spectrum are presented to understand the current utilization of TV band. It was found that utilization of TV band is quite low. The result clearly shows that the spectrum opportunities in India for cognitive radio operation in TV band. To implement a real-time CR system prototype for TV band , single occupied frequency is sensed so as to observe the white spaces present in that particular frequency using two sensing algorithms i.e. energy detection and cyclostationary feature detection, comparative analysis of this two algorithms are observed where, cyclostationary feature detection provide better results compared to energy detection.

2. RELATED WORK: A BRIEF REVIEW

Literature presents the survey for TV band and the need for sensing the TV band. First, Amanpreet S Saini, Zhen Hu, Robert Qiu in [2] has discussed about Spectrum Sensing of Cognitive Radio where it contract with spectrum sensing and spectrum renovation for cognitive radio. Spectrum analyzer is used to imitate cognitive radio to do spectrum sensing. The whole process of spectrum sensing including sensing setup, instrument control, sensing ability, sensing state and sensing outcome is presented in detail. The main advantage of equipment-based spectrum sensing is to perform swift and semi-continuous measurements. The time needed for each measurement is around 80-110ms. 3-D spectrums of CDMA, GSM signal, Wi-Fi signal and DTV signal are shown in this paper. Meanwhile, TV reconstruction method is working here to reconstruct the spectrum and find the margin of the frequency band which is occupied.

Maziar Nekovee, in [5] discussed about review of Cognitive Radio Access to TV White Spaces where they surveyed the state-of-the-art in cognitive radio admission to TV White Spaces. They showed that a rigid Framework for secondary exploitation of TVWS spectrum is well underway both in the US and UK and central steps in this direction are also being taken within the EU and worldwide. Using result from current derived studies of the TVWS accessibility in the UK and US we illustrated that cognitive access to these bands provides a very significant spectrum chance for a range of indoor and outdoor applications and services. Furthermore, quantitative techno-economical studies of the commercial feasibility and cost versus benefit associated with use cases of cognitive radio crucial in influencing the take-up of the technology by wireless network and service providers but are currently very limited.

Kishor Patill, Knud Erik Skouby, Ramjee Prasad in [10] discussed about Cognitive Access to TVWS in India .The spectrum occupancy evaluation from measurement clearly shows the TV band is underutilized, and digital switchover of TV transmission not only produce digital dividend, but also create opportunity for cognitive operation in TVWS in India. Many scenarios are envisaged for opportunistic access based on cognitive radio in the TV whitespaces. In the context of rural areas wireless broadband access using TVWSs is the most suitable scenario for empowering the rural India. All the gram panchayats of India will get the broadband connectivity under National Optical Fiber Network (NOFN) project. They have proposed cost effective last mile connectivity to the small village population through wireless broadband network using TVWSs.

Saket Srivastava, Mohammad Hashmi and Supratim Das Dibakar Barua in [13] discussed about real time spectrum sensing framework, and a novel machine learning technique to derive a general decision boundary to classify the busy channels from the free channels. In this paper, due to limitations of equipment, the spectrum sensing was restricted to only two bands. Since known transmitters exits in FM bands, supervised machine learning for spectrum classification was reliably performed for these bands. Other spectrum regions such as the GSM and Satellite Imaging bands posed unique problems such as real time frequency hopping (which would lead to a lot of discrepancy while declaring a spectrum as occupied or vacant) and lack of knowledge regarding exact times of transmission. Due to these reasons they could not be included in the dataset which aimed to create a reliable decision boundary for spectrum classification. Nevertheless in future datasets from the above mentioned bands and many other bands will be targeted to gather a larger training set spanning across multiple bands, and apply the same technique to evaluate its effectiveness. A similar approach can also be embraced for co-operative spectrum sensing, where multiple cognitive radios sense the spectrum, and come to unified conclusion regarding the state of spectrum usage in real time.

3. TV BANDS IN INDIA

The terrestrial TV broadcasting in India operates in VHF and UHF bands. The frequency allocation of terrestrial broadcasting is in the line with the other parts of the world. The total spectrum currently available in India present in VHF and UHF TV band is 413MHz. Doordarshan, the public TV broadcaster of India, has assigned only one channel (channel number 4) in the VHF band I for the terrestrial TV broadcast. Doordarshan has assigned all the 8 channels of the VHF III band for analogue TV transmission. There are 14 TV channels available in the UHF band-IV (470-582 MHz) with each having a channel bandwidth of 8 MHz .There are about 330 transmitters operating in this band. Doordarshan's three digital TV transmitters at Kolkata, Chennai, and Mumbai are also operating on an experimental basis in this band.

There are 28 channels available with 8MHz bandwidth present in UHF band-V ranging from (582-806) MHz Doordarshan has not been assigned any channel in this sub band for analogue TV transmission. However, frequency band of (735-755) MHz and (775-795) MHz has been assigned to Doordarshan to operate short distance UHF links. Some of the Government agencies are operating point to point microwave lines ranging from (561-806) MHz .In India, Doordarshan is the only national carrier for TV broadcasting, which covers almost the entire country. Doordarshan runs very few channels such as DD1, DD metro, DD news, and regional channels. In contrast to this, Europe, and US runs many channels and utilize all these available TV channels. Traditionally, broadcast of TV transmission takes place in VHF and UHF band with 6-8 MHz band per channel. But, these band of frequencies which occupy different slots with frequency range (470-698) MHz, remain highly underutilized. Their usage pattern changes with geo-location, and in rural and semi-urban areas, they are mostly unutilized owing to fewer broadcasters.

Few TV channels cannot be used by TV stations in given geographical region after digital switch over since it can cause interference to adjacent or co channel TV stations. These vacant channels can be used by low power unlicensed devices without causing interference to adjacent channel stations. The unused TV frequencies are known as TV white spaces (TVWS). The TV broadcast spectrum is licensed spectrum, which traditionally been used exclusively by licensed television broadcasters. However, regulatory rules don't allow the use of unlicensed devices in the TV bands, with the exception of remote control, medical telemetry devices and wireless microphones. The TVWS can be allowed for cognitive operation without causing harmful interference to the licensed users in TV band including wireless microphones. The introduction of CR in the telecommunication market may require new regulations, or changes to the way a spectrum is licensed, and the conditions under which it can be used. According to one study, the economic potential for the TVWSs was estimated at $100 billion.

4. LAB VIEW AND NI-USRP

Universal Software Radio Peripheral (USRP) is a software-defined radio designed and sold by Ettus Research which is a parent company, National Instruments developed by a team led named Matt Ettus, USRP product family is intended to be a comparatively inexpensive hardware platform for software radio, and is commonly used in research labs, universities, and hobbyists.

For USRP, NI-USRP is the hardware driver where, NI offers development environment that can make driver calls into NI-USRP, but other text based environments can also access the hardware driver.NI-USRP driver currently supports Lab VIEW graphical development environment software for developing rapidly custom applications. NI-USRP connects to a host computer which acts as software defined radio .Incoming signals attached to the standard SMA connector are mixed down using a direct conversion receiver (DCR) to a baseband I/Q components ,which are sampled by a 2- channel, 100 MS/s signal to the specified rate of user. The down converted samples. When represented as 16 bits each for I and Q are passed to the host computer at up to 20 MS/s over a standard Gigabit Ethernet connection.

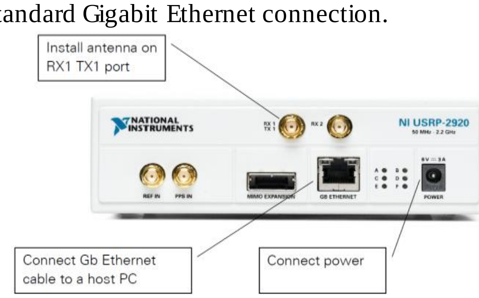

Figure 4.1: NI-USRP 2920 front panel

A Software-Defined Radio is a communication device where components are implemented using hardware that are defined in software and realized using programmable hardware. The implementation can be performed on general purpose computers or dedicated embedded systems. Some of the key characteristics of SDR are multi-band antennas, wide-band RF converters, Digital-to-Analog Converters (DAC), Analog-to-Digital Converters (ADC) and a general purpose processor to manage signal processing. This makes a software defined radio ideal in implementing dynamic spectrum access since it can operate in a wide range of frequencies, realize various modulation and coding schemes. Software defined radios allow us to vary the transmission characteristics on-the-fly based current RF occupancy and the state of the network.

USRP is widely used SDR platforms which possess various abilities of SDR, such as wide range of bandwidth. USRP connects real-time RF system to PCs using Universal Serial Bus (USB) or Ethernet connection. USRP was outlined and designed by Matt Ettus, who has found Ettus Research LLC, a National Instrument's company. Second generation USRPs are able to work with GNU radio, NI-Lab VIEW and Simulink. USRP series under National Instrument's brand are called as NI-USRP and are paired with NI-Lab VIEW tool boxes. NI USRP is SDR prototype platforms capable of numerous applications for education and research.

The combination of NI's hardware and software offers flexibility and functionality for physical layer design, record and playback, signal intelligence, algorithm validation, and more in affordable price. In this project work NI-USRP 2920 is used, it has tunable center frequency ranging from 50 MHz to 2.2 GHz covering FM radio, GPS, GSM, radar, and ISM bands. NI-USRP 2920 is connected to PC using Ethernet connection working in pair with NI-Lab VIEW and both are able to perform multiple input, multiple output (MIMO) functionalities.

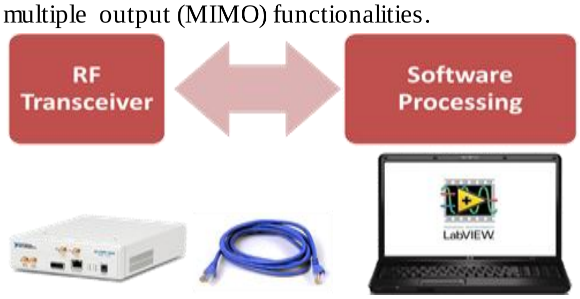

Figure 4.2: Interfacing NI-USRP kit with lab VIEW software for processing

Lab VIEW communication System Design Suite offers a design environment closely integrated with NI software designed radio (SDR) hardware for rapidly prototyping communications systems. The USRP (Universal Software Radio Peripheral) is a flexible and affordable transceiver that turns a standard PC into a powerful wireless prototyping system when paired with Lab VIEW communication System Design Software; USRP transceivers help you to provide a wide range with single-channel and MIMO wireless communication systems. USRP and Lab VIEW communication System Design Suite offer a powerful solution for prototyping RF and communication systems. NI-USRP hardware when paired with Lab VIEW software provides flexibility and functionality, to deliver a platform for rapid prototyping involving physical layer design, wireless signal record & playback, signal intelligence, algorithm validation.

5. SPECTRUM SENSING TECHNIQUES USED FOR SENSING TV BAND IN REAL TIME USING NI LABVIEW

Spectrum sensing is the process of periodically and dynamically monitoring a given radio spectrum band (e.g. VHF and UHF TV bands) in order to determine its availability so as to use, on a non-interfering basis. By spectrum sensing, Cognitive Radio has information about its surrounding environment where, it can easily detect presence of primary user and also, which part of spectrum is utilized by primary user or left vacant .Spectrum sensing is a mandatory functionality in any Cognitive radio based wireless system that shares spectrum bands with primary services, such as the IEEE 802.22 standard, which proposes to reuse vacant spectrum in the TV broadcast bands. We have discussed two methods for sensing TV band in real time using NI Lab VIEW.

5.1 Energy Detection

The received data is obtained by adding the input data with the noise of obtained magnitude. The energy of the received signal is obtained by summing up the squared values of the samples.

A threshold value is required for comparison of the energy found by the detector. Energy greater than the threshold values indicate the presence of the primary user, energy is calculated as:

$$E = \sum_{n=0}^{N} |x(n)|^2 \quad (5.1)$$

The Energy is now compared to a threshold for checking which hypothesis turns out to be true.

$$E > \lambda \Rightarrow H1 \quad (5.2)$$

$$E < \lambda \Rightarrow H0 \quad (5.3)$$

Threshold value of the energy is calculated by using the randomly generated values of Pf using gamma inverse function. If the detected energy value is greater than the threshold value, then it is considered as the correct value i.e primary signal is present.

In below figure 5.1, Energy detection method using NI- USRP method is discussed where in first step we initialize the NI USRP and then in next step we set the parameters of the received signal then later energy is calculated using formula in lab view to plot spectrum of the received signal again threshold is calculated and applied to a comparator where it compares received signal with threshold and if threshold is less than signal the it takes decision of presence of primary user else if value is greater than only noise is present along with signal.

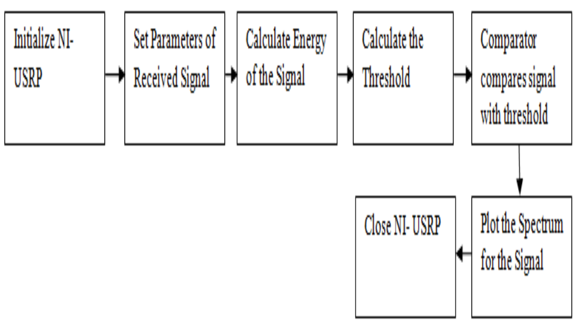

Figure 5.1: Block diagram for Energy Detection using NI-USRP

5.2 Cyclostationary Feature Detection

Energy detection method is used as first stage for spectrum sensing but the required results obtained were not accurate as noise is present in the signal so the decision of threshold is varied, so we have to perform second stage using cyclostationary feature detection method. Cyclostationary detector is one of the feature detectors that utilize the cyclostationary feature of the signals for spectrum sensing. It can be realized by analyzing the cyclic autocorrelation function (CAF) of the received signal. CAF can also be represented by its Fourier series expansion, called cyclic spectrum density (CSD) function.

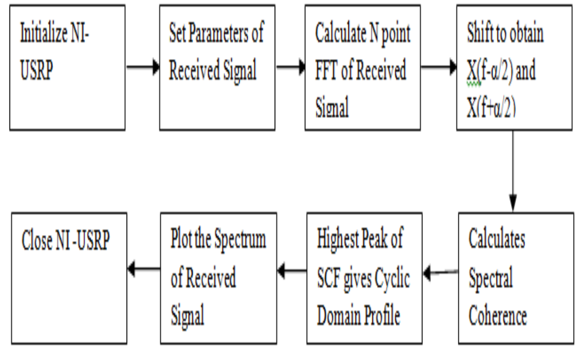

Figure 5.2: Block diagram for Cyclostationary Feature Detection using NI-USRP

Cyclostationary feature detection using NI-USRP is discussed in above figure 5.2 ,where it initialize and set the parameters and later calculate FFT of received signal and shift to obtain Cyclic Autocorrelation function and then calculates Spectral Coherence Function .The highest peak observed in Spectral Coherence Function plots the Cyclic Domain Profile. In this method, we can easily distinguish noise as there is no correlation amongst itself i.e it is random in nature. Presence or absence of primary user can be easily found using cyclostationary feature detection method.

6. SIMULATION

A software defined radio was developed using USRP and Lab VIEW for conducting real time spectrum in UHF TV band. The experiment was conducted in an indoor environment. The experimental setup of NI USRP 2920 and PC . The software platform used was NI Lab VIEW. In this section we have discussed, the performance of the two algorithms evaluated through simulations. All the experiments are conducted using Lab View software. The performance parameters are also evaluated to check the feasibility of two different types of algorithms for TV band. Spectrum sensing was carried out in an indoor setup consisting of the USRP and a PC.

Comparative analysis of energy detection and cyclostationary feature detection sensing algorithms is done for TV band where we considered the terrestrial part i.e. Digital Video Broadcasting - Terrestrial (DVB-T) for two frequencies at175.25MHz and 535.25 MHz which are occupied and allotted for Doordarshan channel i.e DD National and DD News at channel 5 and channel 29 respectively.

7. CONCLUSION

The spectrum occupancy evaluation from measurement clearly shows the TV band is underutilized, and digital switchover of TV transmission not only produce digital dividend, but also create opportunity for cognitive operation in TVWS in India. The goal of this study was to test real time TV band channels. The testing was done using NI USRP hardware devices and NI-Lab VIEW platform. We presented the measurement and the methodology to estimate the spectrum occupancy of TV band. We used two spectrum sensing algorithms and they are analyzed in terms of its detection performance. We considered DVB-T signal for our analysis and compared our two sensing algorithms and observed the results using NI Lab-VIEW, where the energy detector shows the degraded results due to large presence of noise which is overcome by the cyclostationary feature detection method.

REFERENCES

[1] Simon Haykin, “Cognitive Radio: Brain-Empowered Wireless Communications” IEEE journal on selected areas in communications, vol. 23, no. 2, February 2005.

[2] Kishor Patill, Knud Erik Skouby, Ramjee Prasad, “Spectrum Measurement and Analysis of TV Band in Support of Cognitive Radio Operation in India”2013.

[3] Siddhatth Shetty , Akshay Mishra and Abhay Karandikat, "Proposal for TV White Space towards National Frequency Allocation Plan (N FAP) 2010”.

[4] Amanpreet S Saini, Zhen Hu, Robert Qiu,” Spectrum Sensing and Reconstruction for Cognitive Radio” April 2009.

[5] Maziar Nekovee ,” A survey of cognitive radio access to TV White Spaces Published “,in 2009 International Conference on Ultra Modern Telecommunications & Workshops BT Innovate and Design, Polaris 134, Adastral Park, Martlesham, Suffolk, IP5 3RE, UK.

[6] Simon Haykin, David J. Thomson, Jerry H. Reed, “Spectrum Sensing for Cognitive Radio”, Proceedings of the IEEE (Invited paper), Vol. 97, No. 5, May 2009.

[7] Md.Shamim Hossain, Md.Ibrahim Abdullah, Mohammad Alamgir Hossain, “Energy Detection Performance of Spectrum Sensing in Cognitive Radio”, I.J. Information Technology and Computer Science (vol.4, no.11), 2012, pp. 11-17.

[8] Shahzad A. “Comparative Analysis of Primary Transmitter Detection Based Spectrum Sensing Techniques in Cognitive Radio Systems,’’ Australian Journal of Basic and Applied Sciences, 4(9), pp: 4522-4531, INSInet Publication, 2010.

[9] A. Tkachenko, D. Cabric, and R. W. Brodersen, “Cyclostationary feature detector experiments using reconfigurable BEE2,” Proc. IEEE Int. Symposium on New Frontiers in Dynamic Spectrum Access Networks, Dublin, Ireland, Apr, 2007, pp 16- 219.