ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2016

Spectrum Analysis in FM Band Using Cognitive Radio Testbench

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ABSTRACT: Frequency spectrum is the scarcest supply for wireless communication. But there are some frequency bands that are not utilized properly. Hence the frequency spectrum is not scarce but it is underutilized. An efficient way to employ the spectrum is cognitive radio. Cognitive radio uses spectrum holes in the band. A spectrum habitation measurement helps to efficiently utilize the spectrum band. It is important to have knowledge about the profession of the frequency bands which can be used by cognitive radio. This includes a detailed examination of the frequency allotment. Here, the measurements are taken in FM band using energy detection and USRP that gives the idea about white spaces present which can further be used by secondary users. Different time intervals of the day are considered for this work.

KEYWORDS: Spectrum Sensing; Cognitive Radio;FM; USRP.

I. Introduction

Cognitive radio is a technology which consists of algorithms and toolboxes for radio environment sensing and verdict making, and a configurable radio platform, which could be a Software Defined Radio (SDR).The theory of Cognitive Radio (CR) was first explained by Mitola and Maguire as “transforming radio nodes from visor architect of predefined protocols to radio-domain-aware intelligent agents that search out ways to convey the services that the user wants even if that user does not know how to obtain them” [2]. CR studies everything about the user requirements, the ability of the radio device, the network requirements and the outside environment (including the radio environment) [3]. It can automatically detect the channels that are not in use and shifts to that unoccupied channels, this optimizes the use of radio frequency spectrum. Therefore CR is a fast growing technology for enabling the reuse of the unused frequency spectrum.The Federal Communications Commission (FCC) in the United States issued a report and order (R&O) which permits cognitive use of the white space spectrum. White space is the idiom used by the FCC for unused spectrum. These new regulatory policy open up an opportunity to grow novel wireless networks to exploit this spectrum.As RF technology improves, wireless equipment has become handy and cheaper. With development in cellular radio and personal communications, subscribers have grown manifold. To contain the growth of subscribers, extra bandwidth is required but the accessibility of Electromagnetic spectrum is restricted and there is severe contest for the available bandwidth. Telecommunication authoritarian bodies assign fixed bandwidths depending on different technical standards, regulatory requirements and applications. The bandwidth allotment is different for different countries and it depends on the geographical conditions of the country [4]. A rigid set of bandwidth is reserved for Military applications which are set distant from commercial use. It is hence not likely for the telecommunication regulatory bodies to constantly change/migrate the allocated bandwidth for count new standards in the existing spectrum. It is observed that even after capable allotment of bandwidth by the telecommunication regulatory body, the spectrum is used inefficiently.

The reasons for the under consumption of the spectrum are: first one is, thetenure of the spectrum is high during the day time and less during the night time (cellular phone spectrum). Second , the existence of guard bands in the spectrum to avoid adjacent channel interference.The current research is not targeted to locating guard bands. High data rate in upcoming wireless channel involvesrequire more sophisticated methods to place inefficiencies in spectrum handling. In parallel more sophisticated radios which can alter modulation techniques, working frequencies and power levels in real time are required.

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There are three key objectives of the work:

1. The precise spectrum sensing of the FM band to achieve a better understanding of the exploitation of spectrum at different time slots.
2. Frequency spectrum is the scarcest supply for wireless communication. The FCC has stated that there are some frequency bands that are underutilized. Hence the frequency spectrum is not scarce but it is underutilized.HenceSubsequent objective is to find white spaces in the FM band.
3. Detailed study of frequency use at different time space slots to get the scheme about overall trafficdistinction.

II. BACKGROUND AND RELATED WORKS

In telecommunications, frequencies which are allocated to a broadcasting service but not used locally are referred as white spaces. National and international authorities assign different frequencies for specific uses, and in most cases license the rights to broadcast over these frequencies [5]. This frequency allocation process makes a frequency band distribution plan, which for technical reasons assigns empty space between used radio bands or channels to avoid interference. In this case, the frequencies which are unused, are specifically assigned for a purpose, such as a guard band. Guard bands are commonly used between two adjacent channels so as to avoid interference .Besides these empty spaces by guard bands there is also radio spectrum which is not at all used or is free because of some technical reasons. Frequency spectrum is the scarcest resource for wireless communication. But there are some frequency bands that are underutilized. Hence frequency spectrum is insufficient for growing demands in wireless communication. An efficient way to utilize the spectrum is CR. CR makes use of spectrum holes in the band. Spectrum occupancy a measurement helps to efficiently utilize the spectrum band, motivation of this work lies in the increasing wireless demand constrained by limited resources. The United States FCC issued a R&O on the unlicensed use of white space spectrum in 2008 [7]. A number of the considerations to be taken while using white spaces that are based on cognitive radio technology including location awareness and spectrum sensing. There are also numbers of other considerations that are intended to provide protection for the licensed services that operate in the FM bands. These requirements impose technical challenges for the design of devices operating in FM white space spectrum.

III. FM BANDS

A spectrum is nothing but a collection of various types of electromagnetic radiations of different wavelength. All communication signals are transferred through spectrum i.e. radio frequency. Radio frequencies are used for different types of services like broadcasting, radio navigation etc.Radio frequency is a natural resource but it has limitations as it gets depleted when used, but sometimes it is not used efficiently and wastage of spectrum is observed. In India, the spectrum assigned to Indian telecom operator is insufficient to provide the service to 640 million mobile subscribers as on date .Ultimately it affects the quality of customer service and resulted in poor quality, call drop and undelivered messages of mobile services in India.

Spectrum allocation is done to ensure interference free operation for each radio service. Unlimited use of electromagnetic spectrum is restricted by all nations since they all share the same electromagnetic spectrum.Spectrum frequencies are allocated for the use of various countries by The International Telecommunication Union (ITU) at the World Radio Communication Conferences. For international roaming facilities, it is necessary to allocate spectrum in the common bands which are used the world over.

IV. WHITE SPACES IN FM BANDS

White spaces are sections of the radio spectrum allocated for a certain use e.g. radio or television that are not being used in a particular area.The most of the frequency spectrum is allocated to different organizations by current spectrum allocation scheme, but the utilization of the licensed spectrum is not efficient neither in time domain nor in spatial domain. CR that adapts environmental changes and according to that alter its coefficients like frequency modulation and other parameters by sensing its environment and location. So as to reuse the available spectrum, can overcome the problem of spectrum scarcity. The fundamental aspect to the success of such technology is the statistical properties of the spectrum occupancy, which forms the basis of the current project.

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V. ENERGY DETECTION SCHEME

Spectrum sensing is nothing but monitoring a given radio spectrum band periodically and dynamically in order to determine its availability for reuse of spectrum. Spectrum sensing is an important stage in cognitive radio to find spectrum holes and opportunistically use the unoccupied channels without causing any interference to the primary user or licensed user.

Energy detector is also known as radiometry or periodogram. It is widely used technique for spectrum sensing because of its low computational and implementation complexities. The receivers do not need any knowledge about the primary users.The signal is detected by comparing the output of the energy detector with a threshold 'λ' which depends on the noise floor.

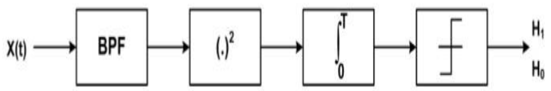

Fig. 1. Energy detection scheme

The decision on the occupancy of a band can be obtained by comparing the decision metric M against a fixed threshold λ. This is equivalent to distinguishing between the two hypotheses H0 and H1, where H0 represents that no signal existsand H1 represents existence of the signal. The decision metric for the energy detector can be written as

$$M = \sum_{n=0}^{N} |y(n)|^2$$

Where, y(n) = Received input signal. M = Decision metric.
Hence the two probabilities will be,

$P_D = Pr(M > \lambda_E|H1)$ & $P_F = Pr(M > \lambda_E|H0)$.

The threshold used in energy detector based sensing algorithms depends on the noise variance. Significant performance loss causes due to a small noise power estimation error. The another reason for selection a energy detection method can be shown from the below comparisons that energy detection have least complexity.

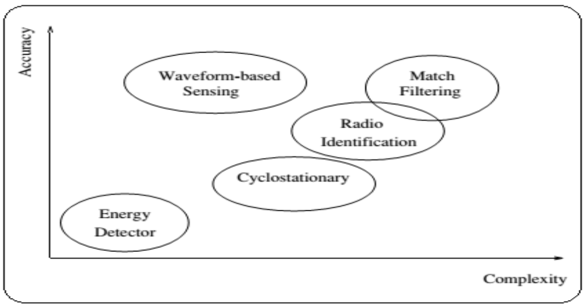

Fig. 2. Different types sensing detection scheme

VI. COGNITIVE RADIO TESTBENCH

The USRP software-defined radio is used for wireless communication research; it acts as an antenna and receives RF signals across a real time bandwidth up to 40MHz. USRP connects real time radio frequency systems to PCs using an Ethernet cable. The NI USRP-2920 includes an integrated GPS-disciplined reference clock. The reference clock provides improved frequency accuracy, synchronization capabilities, and GPS position information. Figure 3 shows the USRP system block diagram.

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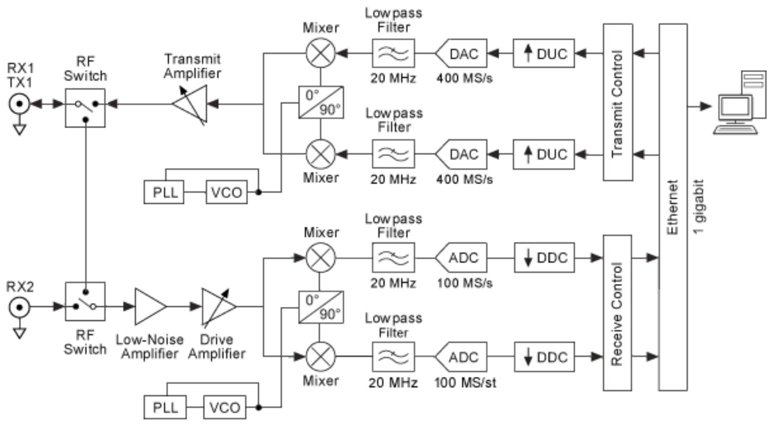

Fig 3. NI USRP-2920 System Block Diagram

VII. LAB-VIEW IMPLEMENTATION

Real time measurement and analysis of the signal received from the NI-USRP hardware is accomplished by Lab-VIEW software.

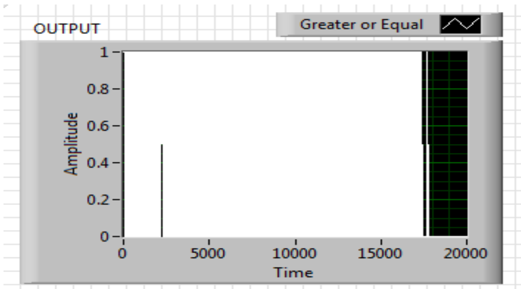

Fig.4 shows a snapshot of the output for NI USRP 2920 radio transceiver considering frequency 98.3MHz showing the comparator output , where '1' represents that primary user is present and '0' shows that primary user is absent at that particular moment.

VIII.CONCLUSION

Spectrum monitoring analysis for FM band is done using NI-USRP and Lab-VIEW. Also, measurements are taken at different timeslots of the day to understand how the spectrum can be best exploited. Thesereal-time measurements enable the radio to predict occupancy more correctly. By observing frequency spectrum at different time intervals, it can be observed that the strength of the FM signal varies and it is maximum in the morning whereas minimum in the afternoon.

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