WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTEMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Bsc THESIS PROPOSAL

Title: Radio Frequency Spectrum Sensing for Multimple Transmitter Using Cognitive Radio

(This Bsc. Thesis project is submitted to Wolkite University, Electrical and Computer Engineering Department in partial fulfillment of requirement of Bsc. Program in Electrical and Computer Engineering in the focus area of communication stream)

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Declaration

We declar that this thesis project is prepared by student Arega Fiseha, Yonatan Abiye, Rebka Abye and Degefe Shamebo, student at Wolkite University electrical and computer engineering on the focus area of communication stream regular Bsc degree program and as the owners of the paper assured that this thesis project paper and simulation is done by our effort and it is our areal work and it is free from any plagiarism.

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Abstract

The radio frequency spectrum is a scarce natural resource and its efficient use is one of the utmost importance. With the exponential increase in the use of high-powered wireless devices, there is a demand to utilize the spectrum efficiently, intelligently and optimally. Cognitive Radio is an attractive concept and solution, capable of addressing this issue. The spectrum bands are usually licensed to certain services, such as mobile fixed broadcast, and satellite, to avoid harmful interference between different networks. This scarcity of spectrum is the issue that wireless communication technology has to deal with. Primary user is the licensed user of the spectrum. When primary user is idle or not using the spectrum, secondary user can utilize the spectrum. This sharing of spectrum can be enabled by cognitive radio (CR) technology. The heart of enabling this technology is spectrum sensing. Spectrum sensing involves detection of primary signal at very low SNR (in the range of -20 dB), under noise and interference uncertainty. This requirement makes spectrum sensing, a hard nut to crack. Another major issue in detection is hidden node problem wherein the node in vicinity of primary transmitter also indicates absence of the primary signal since it is hidden behind the large object.

CHAPTER ONE

INTRODUCTION

1.1. Overview

For the past few years, radios have been evolving and getting smarter. The electromagnetic radiofrequency spectrum is a highly valuable natural resource, but its use is regulated by governments through licensing agreements. Careful studies on the current usage of the radio spectrum by several agencies reveal that some frequency bands are heavily used; other frequency bands are only partially occupied, while most frequency bands in the spectrum remain largely unoccupied. There are two types of licensed user in spectrum sensing such as Primary User (PU) and Secondary User (SU). Primary User is a user who has higher priority or legacy rights on the usage of a specific part of the spectrum while Secondary User is a user who has a lower priority and therefore exploits the spectrum in such a way that it does not cause interference to primary users. To use the spectrum efficiently the PU could share spectrum with a SU under special negotiable conditions without releasing his own license. This project needs an intelligent radio system to manage the shared spectrum, sense spectrum used by neighboring devices, change frequency, adjust output power, and even alter transmission parameters. Spectrum utilization can be improved significantly by making it possible for a secondary user to access a spectrum hole unoccupied by the primary (licensed) user at the right location and time. The communication systems that are in use today are able to adapt and alter in varying hostile conditions, depending on diverse variables to maintain connectivity. A cognitive radio is one such adaptive device and is vigilant to be very smart with decision making capabilities. It is known to be an artificial brain capable of making decisions to sense, share and mobilize the channels in the spectrum. Spectrum sensing is a key aspect of Cognitive Radio. Our objective is to utilize the empty channels in the spectrum to reduce the traffic in congested areas. Proper sensing forms the backbone of this software defined radio. Spectrum sensing in cognitive radio is applicable to radio frequencies only. Observing the unused spectrum of a licensed user is crucial to a cognitive radio. So, the primary Users is sensed perpetually to allow channel mobility to another part of the spectrum; in case the primary user intimates to transmit. This calls for an efficient hardware with negligible error percent. The threshold for detection forms the crux. This should be in consideration of the interference in the worst - case scenario. In sensing the primary user correctly, future spectrum analysis and decision-making processes are assisted. It can be said as managing the spectrum dynamically.

1.2. Statement of the problem

Due to the increased usage of wireless communications in personal, commercial, and governmental capacities, efficient spectrum utilization has become a prime research topic. Although spectrums are governed and allocated to the licensed client in a specific range, some spectrum ranges are overcrowded while some are under-utilized. The overcrowded spectrum reduces overall quality of service for users in that allotment. A potential solution to this problem is cognitive radios, which performs two major tasks. First, it searches the spectrum and determines which parts are unoccupied, a technique known as spectrum sensing. Second, it determines a method of assigning secondary users to the unoccupied spectrum without interfering with the primary users. Thus, spectrum sensing is the primary task of Cognitive Radios.

1.3. Objective of the project

1.3.1. General objective

To sense and detect RF transmissions for multiple transmitter in order to find spectrum holes for secondary users to avoid interference and overcrowded of the channels which occurs when both primary and secondary users transmit simultaneously.

1.3.2. Specific objective

- To sense vacant radio frequency spectrum
- To avoid overcrowding of transmission channel
- To sense and detect spectrum using cognitive radio for secondary users

1.4. Significance of the project

Cognitive radio (CR) plays a vital role in spectrum sharing and spectrum sensing because it can used to avoid interference with PU and guarantee a good quality of service (QoS) of the PU. This method also performs the task of monitoring and detection of spectrum holes. The spectrum analysis will estimate the characteristic of detected spectrum hole. Our project develops a system that can automatically analyze its radio spectrum environment to identify temporarily vacant spectrum and use it. Moreover, our design is a flexible system because it can change the communications parameters to adapt to channel conditions. Besides, a detection device is useful for signal classifier that improves CR ability. This project was proposed considering the trend towards increasing usage of wireless communications while the allocated spectrum is underutilized. Thus, this project, along with further works, is significant in developing a method for effective utilization of the limited spectrum.

1.4. Thesis Contribution

The spectrum scarcity and spectrum underutilization problem has stimulated a number of exciting activities in the technical, economic and regulatory domains in searching for better spectrum management policies and techniques. The cognition capability of a CR can make opportunistic spectrum access possible which can be implemented by spectrum detection functionality. Therefore, the main contributions of this paper are:

- We perform some detailed theoretical analysis on the performance of Primary user PU) detection.
- We considered noise uncertainty factors for performance evaluation
- We perform the enhancement of cognitive radio

1.5. Scope of the project

While the four main functions that characterize a cognitive radio are spectrum sensing, spectrum management, spectrum mobility and spectrum sharing, this thesis project focuses on only vacant radio frequency spectrum sensing for primary user component for multiple transmitter to use the available vacant radio spectrum efficiently using MATLAB2015b software.

1.6. Limitation of the project

There are many spectrum sensing and detection techniques from these techniques our project concerned only using cognitive radio sensing and detection system, and we can do only the software simulation using MATLAB/R2015b

1.7. Motivation

There many situations which leads to or motivate to do this project from this interference is one of them when we took with our mobile, hearing radio and FM, using internet there is an interference which can caused by when both licensed and unlicensed user of the channel can use simultaneously this situation motivate to do this project.

CHAPTER TWO

LITERIETURE REVIEW

Cognitive Radio System by Md. Jakir Hossain and Md. Shahidullah Kawsar [1]. Based on Software-Defined Radio (SDR) technology, cognitive radios are the product of a multidisciplinary effort involving experts in wireless networks, digital communications, systems engineering, artificial intelligence, and other fields. As a result of these activities, it is hoped that these systems can simultaneously respect the rights of the incumbent license holders while providing greater flexibility and access to spectrum. Given the demand for more bandwidth and the amount of underutilized spectrum, DSA (Dynamic Spectrum Access) networks employing cognitive radios are a solution that can revolutionize the telecommunications industry, significantly changing the way we use spectrum resources, and design wireless systems and services.

Detection of Vacant Frequency Bands in Cognitive Radio by Rehan Ahmed and Yasir Arfat Ghous at Blekinge Institute of Technology May 2010. The Cognitive radio is a radio that adapts to the conditions of the environment by analyzing, observing and learning. The cognitive network makes use of these adaptations for future decisions [2]. Cognitive radio is basically used for maximum utilization of the radio bandwidth. The core of the performance optimization is the cognitive process which is shared by the cognitive radio and the cognitive networks. The main part of this process is to learn from the past decisions and make use of it for future decisions. The radio Knowledge Representation Language (RKRL) is a language which the cognitive radio uses for knowledge. The cognitive radios need variable parameters for the description of the optimization space. These parameters come from the Software Defined Radio (SDR) [2].

Simulation of Cognitive Radio System by using Automatic Insertion of Primary Users BY Priyangu Shaya Sarmah, Digital Electronics and Communication Systems VTU, CPGS, Bengaluru Region. In the static spectrum allocation scheme, every new service is allotted a fixed block of spectrum. So, a time may come when there will be no more spectrum left for assigning. At present different regions or countries have different spectrum environments and different spectrum governing policies which demands extensive synchronization amongst the authorities of these regions/countries to pledge issueless operation which leads to large deployment delays [3].

To tackle the above issues and competently utilize the unused spectrum, a new spectrum access technology called Dynamic Spectrum Access (DSA) is developed [3].

The key concept of DSA is that when a device wants to transmit, then first of all, it senses the environment for the presence of the primary user in the spectrum that it wants to use. Making use of this sensed information, the applicable regulatory policies and its current state information, the device either does not transmit or decides to transmit in a manner limiting the level of interference. A dynamic spectrum access network possesses two classes of users: primary and secondary. The primary users are the licensed users who have license to use a particular spectrum band and always have full access to that band whenever they need it. The secondary users are generally the cognitive radios which can adjust their operating characteristics, such as waveform, power etc, dynamically [2] [3].

Maximizing available spectrum for cognitive radios By Shridhar Mubaraq Mishra. Cognitive radios have been proposed to address the dual problem of spectrum underutilization and the need for vast swathes of new spectrum in the 0-3GHz band for wireless data services. Previous research in the area of cognitive radios has concentrated on signal processing (SP) innovations for improved detection with a limited number of samples (detection sensitivity). However the SP perspective alone is unable to recover much unused spectrum. In this thesis focus on two fronts to maximize the recovery of unused spectrum. First, take a spatial perspective on spectrum usage. Second, it will look at advanced algorithms which use other radios and frequencies to aid the detection process [2] [3]. For opportunistic spectrum reuse to work, a secondary user must be able to reliably identify a spectrum hole. A spectrum hole is defined as a (time, location, frequency band) tuple that a secondary user can use while keeping interference to all primary systems that use the specified frequency band within an acceptable level. To accommodate secondary transmission the primaries need to sacrifice some time and space usage [2].

Spectrum Sensing Methods in Cognitive Radio by Sumit Kumar, in this project, several spectrum sensing technique is introduced but the main work is carried for energy detection methods. Energy detection technique is implemented using VHDL for pseudo random sequence generator. In many areas cognitive radio frameworks coexist with other radio frameworks, utilizing the same spectrum yet without creating undue interference. The electromagnetic spectrum is a characteristic asset. The present spectrum authorizing plan is not able to oblige quickly growing demand in wireless communication due to the static spectrum allocation strategies. This allocation prompts increment in spectrum scarcity issue. Cognitive radio (CR) technology is a propelled remote radio design which aims to expand spectrum utilization by distinguishing unused and under-used spectrum in rapidly evolving environments. Spectrum sensing is one of the key strategy for cognitive radio which detects the presence of primary client in authorized licensed frequency band utilizing dynamic spectrum assignment policies to utilize unused spectrum.

Cognitive Radio Networks, to tackle the static spectrum allocation scheme and competently utilize the unused spectrum, this thesis project develop a new spectrum access technology called Dynamic Spectrum Access (DSA) is developed. The key concept of DSA is that when a device wants to transmit, then first of all, it senses the environment for the presence of the primary user in the spectrum that it wants to use. Making use of this sensed information, the applicable regulatory policies and its current state information, the device either does not transmit or decides to transmit in a manner limiting the level of interference. A dynamic spectrum access network possesses two classes of users: primary and secondary. The primary users are the licensed users who have license to use a particular spectrum band and always have full access to that band whenever they need it. The secondary users are generally the cognitive radios which can adjust their operating characteristics, such as waveform, power etc, dynamically.

Performance Analysis of Cognitive Radio Networks and Radio Resource Allocation, in this thesis, performance analysis of CRNs and radio resource allocation are considered. A continuous time Markov chain (CTMC) based analytical model taking into account all relevant elements as well as addressing the issue of the false alarm rate (FAR) associated with the continuous sensing is developed. In some cases, the PU can be modeled as time-slotted with constant state (transmitting or not) in each slot. In this case, assuming SU can synchronize to the slots, it's intuitive to use beginning of a slot for sensing and rest (possibly) for communication. For this model, M/D/1 priority queueing scheme has been applied in this thesis to find waiting time and queue length for PU and SU. Multiple access among SUs in a time-slotted channel is considered next. A conventional method is e.g. using a channel access probability ψ in each slot similar to the slotted ALOHA. A radically new idea is introduced in this thesis: why not increase the false alarm probability PFA of each SU and use it as a multiple access method?

A game theoretic approach to radio resource allocation for the downlink capacity providing fair resource sharing among mobile nodes located along a multi hop link is presented. Furthermore, the problem of resource allocations in heterogeneous wireless networks is also studied.

Finally, device-to-device (D2D) communication - with localized distribution, where users tend to gather around some areas (clusters/hot-spots) within the cell such as buildings is studied.

Theoretical analysis with two dimensional clustering is presented including cases with correlated clusters.

Spectrum Sensing Techniques for Cognitive Radio Networks by Fatima Salahdine, Wireless networks and information traffic have grown exponentially over the last decade, which has resulted in an excessive demand for the radio spectrum resources [1] [2]. The radio spectrum is a limited resource controlled by regulations and the recognized authorities, such as the federal communications commission (FCC) in the US. The current radio spectrum allocation policy consists of assigning the channels to specific users with licenses for specific wireless technologies and services. Those licensed users have access to that spectrum portions to transmit/receive their data, while others are forbidden even when those spectrum portions is unoccupied [3]. Recent studies reported that the spectrum utilization ranges from 15% to 85% in the US under the fixed spectrum allocation (FSA) policy [4].

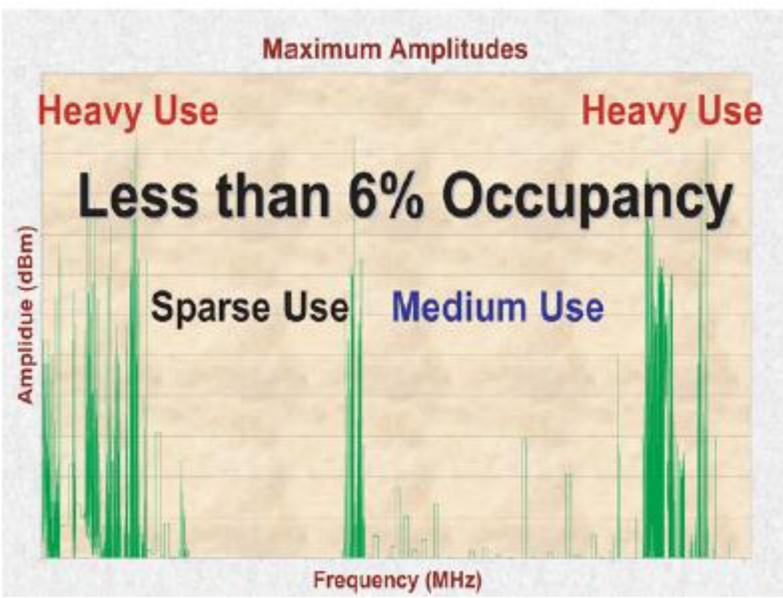


Figure 1 Frequency Occupancy

Allocated spectrum portions are not used all the time by their owners, called primary users (PUs), which creates spectrum holes. A spectrum hole, also called white space, is a frequency band assigned to a PU, but it is not being used at a particular time and at a particular location. Therefore, the radio spectrum is inefficiently exploited [5]. Thus, the scarcity and inefficiency of the spectrum management require an urgent intervention to enhance the radio spectrum access and achieve high network performance. A better way to overcome the spectrum scarcity issue is dynamically managing it by sharing unoccupied channels with unlicensed users, called secondary users (SUs), without interfering with the PUs signals. The opportunistic spectrum access (OSA), also called dynamic spectrum access (DSA), and has been proposed to address the spectrum allocation problems. In contrast to the FSA, DSA allows the spectrum to be shared between licensed and non-licensed users, in which the spectrum is divided into numerous bandwidths assigned to one or more dedicated users [3][1].

In order to advance the use of the OSA, several solutions have been proposed, including cognitive radio. Cognitive radio is an intelligent radio frequency transmitter/receiver designed to detect the available channels and adjust its transmission parameters enabling more communications and improving radio operating behavior. A cognitive radio system can observe and learn from its environment, adapt to the environmental conditions, and make decisions in order to efficiently use the radio spectrum.

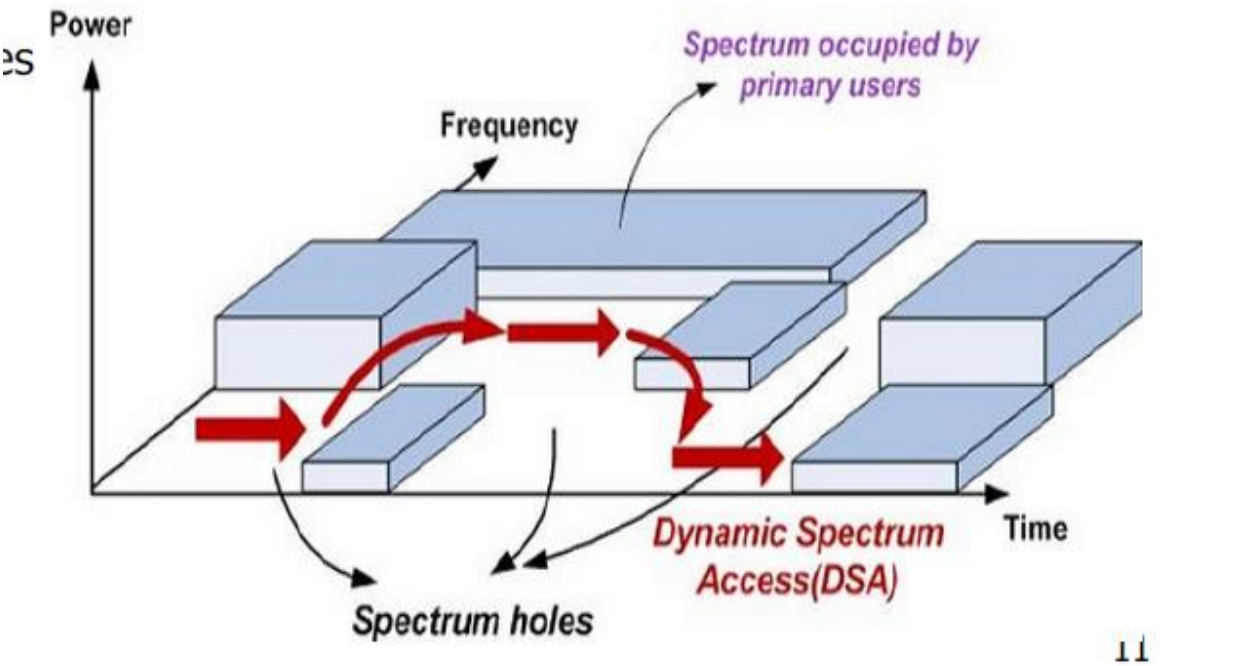


Figure 2 Spectrum Holes

Performance Evaluation on Transmitter Detection Techniques for Cognitive radio by Fikreselam Gared Mengistu at Adiss Abeba University, in this thesis work, various literature reviews on cognitive radio and detection theory by different authors which help to understand necessary theoretical background for thesis work have been made. Performance of energy detector, replica correlation detector and cooperative detector has been evaluated using different performance metrics and the performance of energy detector has been enhanced. To evaluate the performance of the detection techniques MATLAB software has been used for simulation.

The results of performance evaluation for the detectors have shown that the replica correlation detector (delivers Pm of less than 1%) is better than energy detector (delivers Pm of less than 10% but greater than 1%) under both AWGN and Rayleigh fading channel. But due to fading, single node detection is unreliable and results in a high probability of missed detection and lower probability of correct detection. Thus, Rayleigh fading degrades the performance of single node energy and replica correlation detectors. It has been shown that cooperative detection helps to reduce the fading effect of single node detection and it is concluded that cooperative spectrum detection outperforms single user energy detection and replica correlation detector. Thus, the OR fusion rule of cooperative detection delivers better performance. In this paper, noise uncertainty has been shown to introduce considerable amount of degradation in the detection performance of energy and replica correlation detectors. It has been also shown that cooperative detection helps to reduce the effect of noise uncertainty factor in the overall detection performance of cognitive radio. Finally, this work proposes a new enhanced energy detector algorithm method. Its performance has been compared with standard squared law energy detector algorithm. The Simulation results indicate that the new energy detector algorithm method has better performance than square law energy detector. The enhanced energy detector delivers probability of detection 12% better than square law energy detector.

CHAPTER THREE

INTRODUCTION TO COGNITIVE RADIO

3.1. Introduction

The radio frequency spectrum is a limited natural resource to enable wireless communication between transmitters and receivers. Licenses are usually required for operation on certain frequency bands. The use of radio spectrum in each country is nationally governed by the corresponding national regulatory agencies. In Finland, the decision-making body is the Finnish Communications Regulatory Authority (FICORA). In the United States (U.S.), the Federal Communications Commission (FCC) manages the non-federal use of spectrum while the National Telecommunications Information Administration (NTIA) governs the federal use. Traditional communication system design is based on allocating fixed amounts of resources to the user. But the users' increasing demand for new service with good quality is being restricted by the scarcity of spectrum bands because all important spectrum bands for wireless communication are already occupied by the traditional allocation system. This indicates that spectrum is one of the key natural resource. When talking about the frequency spectra, one usually refers to the wide range of signals being licensed and used for different sort of radio communication. The reason for these licenses is that if many people used the same frequencies for different applications these applications would cause heavy interference to each other. The actual spectra of physical radio communication are soon completely bought up.

Moreover, the Ethiopian's telecommunication agency frequency allocation chart, Fig.

also indicates that most spectrum bands are allocated for different applications

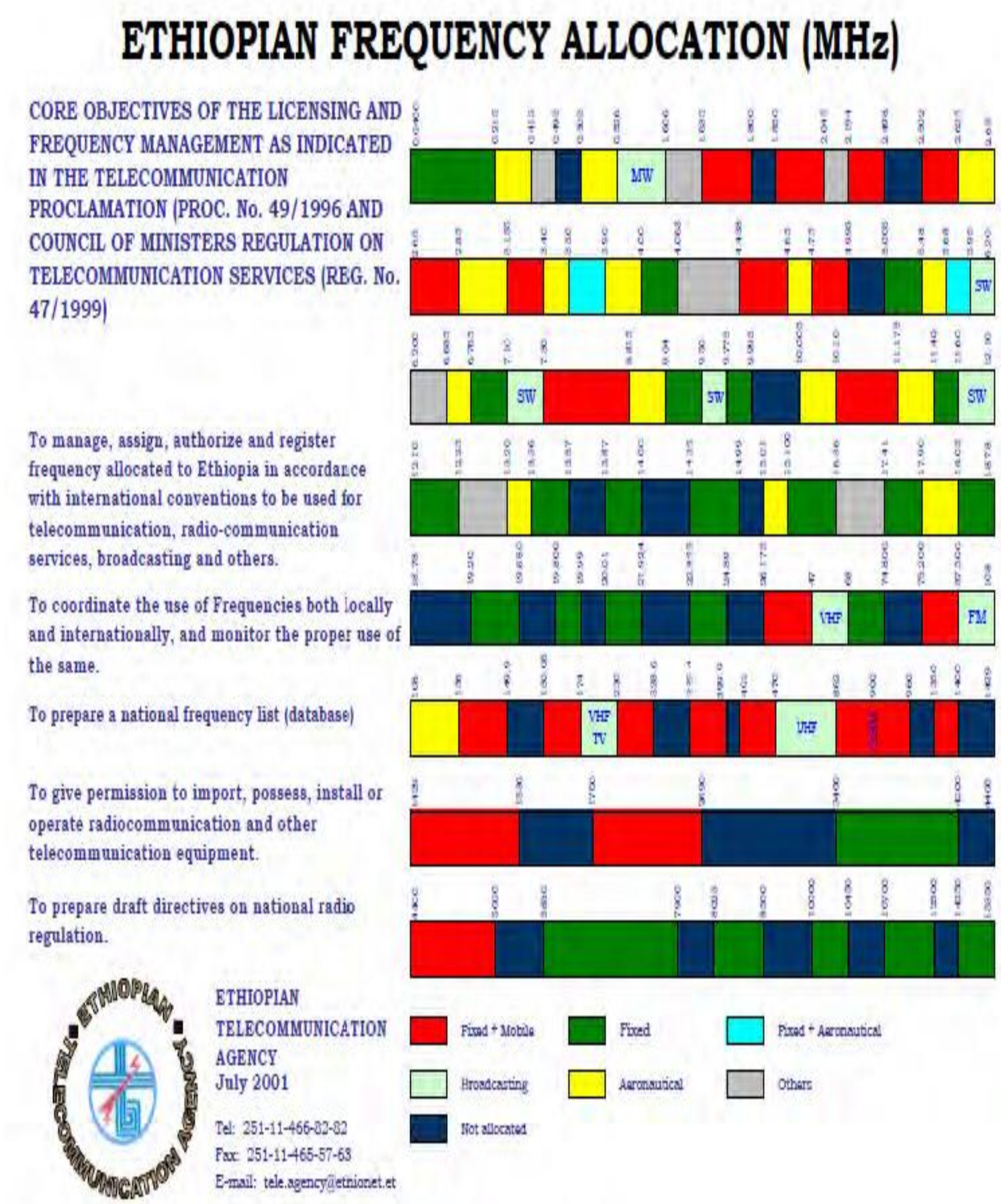


Figure 3 Frequency Allocation

Wireless technologies and wireless devices have proliferated dramatically over the past decade and thus increasing the demand for electromagnetic spectrum. Because of the current approach to spectrum access, spectrum supply has not kept up with spectrum demand leading to the appearance of scarcity in the electromagnetic spectrum. However, research performed by various entities such as the FCC indicates that this assumption is far from reality; there is available spectrum since most of the spectrum allocated sits underutilized.

Practical measurements have shown that although the spectra of available frequencies are more or less bought up, at specific locations, a majority of frequencies are not used at all.

This can easily be seen FIG, which shows measurements made at Berkeley in urban area. From the chart we can see that most of the spectrum ranging from 3GHz to 6GHz is not utilized most of the time.

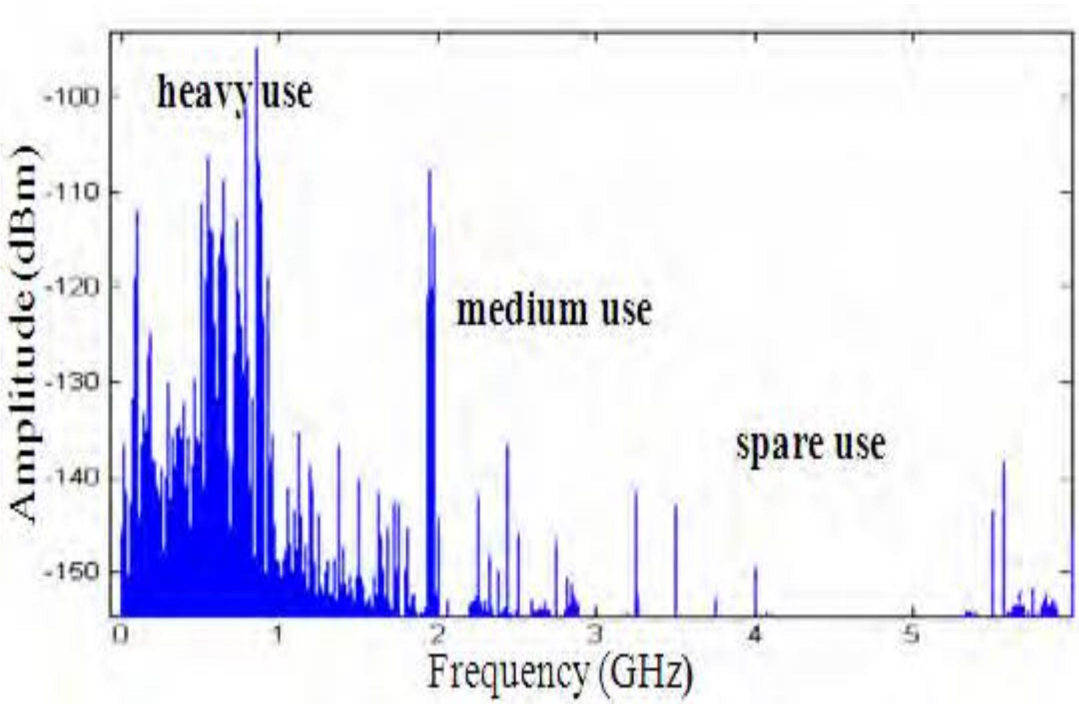


Figure 4 Frequency Usage

If we see the scanned portions of the radio spectrum power spectral density (PSD) measurement of the received 6GHz wideband signal at BWRC shown above, we would find that some frequency bands in the spectrum are largely unoccupied most of the time (spare use), Some other frequency bands are only partially occupied (medium use) and the remaining frequency bands are heavily used (heavy use).

As shown in Fig, actual spectrum measurements taken at Berkeley Wireless Research Center (BWRC) indicate low utilization of the allotted spectrum, especially in the 3-6 GHz Frequency range

3.2. Definition of Cognitive Radio

Cognitive radio is a type of wireless communication where a transceiver can intelligently distinguish the channels for communication which are being used and which are not being used, and move into unused channels while maintaining a strategic distance from occupied ones. This enhances the utilization of available radio-frequency spectra while interference is minimized to other users. This is an ideal model for wireless communication where transmission or reception parameters of system or node are changed for communication dodging interference with licensed or unlicensed clients.

A Cognitive Radio(dynamic spectrum management) is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so more wireless communications may run concurrently in a given spectrum band at a place.

According to Virginia Polytechnic Institute and State University, a cognitive radio is "a software defined radio with a cognitive engine brain."

According to Federal Communications Commission of the United States Government, “A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates.”

The radio frequency spectrum is a limited characteristic asset that is divided into spectrum bands. In the course of the most recent century, spectrum bands have been apportioned to diverse services, for example, mobile, fixed, broadcast, fixed satellite, and mobile satellite services. As all the spectrum bands are as of now dispensed to diverse services, most often requiring licenses for operation, a crucial issue confronting future wireless systems is to discover suitable carrier frequencies and bandwidths to take care of the anticipated demand for future services.

With Cognitive Radio being utilized as a part of various applications, the territory of spectrum sensing has become progressively vital. As Cognitive Radio technology is being utilized to provide a method for utilizing the spectrum all the more productively, spectrum sensing is key to this application.

The ability of Cognitive Radio frameworks to get to spare sections of the radio spectrum, and to continue observing the spectrum to guarantee that the Cognitive Radio framework does not create any undue interference depends totally on the spectrum sensing components of the framework.

‘‘The term cognitive radio identifies the point at which wireless personal digital assistants and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to: detect user communications needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needed.

“An intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming Radio frequency (RF) stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier frequency, and modulation strategy) in real-time, with two primary objectives in mind:

- Highly reliable communications whenever and wherever needed;
- Efficient utilization of the radio spectrum.”

“A cognitive radio goes one step further from software defined radio, and empowers the radio to alter its transmitter parameters based on interaction with the environment in which it operates.” Meanwhile, the other primary spectrum regulatory body in the US, the NTIA [10], adopted the following definition of cognitive radio that focuses on some of the applications of cognitive radio:

“A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, and access secondary markets.” While aiding the FCC in its efforts to define cognitive radio, IEEE USA offered the following definition:

“A radio frequency transmitter/receiver that is designed to intelligently detect whether a particular segment of the radio spectrum is currently in use, and to jump into (and out of, as necessary) the temporarily-unused spectrum very rapidly, without interfering with the transmissions of other authorized users.” The broader IEEE tasked the IEEE 1900.1 group to define cognitive radio which has the following working definition:

“A type of radio that can sense and autonomously reason about its environment and adapt accordingly. This radio could employ knowledge representation, automated reasoning and machine learning mechanisms in establishing, conducting, or terminating communication or networking functions with other radios. Cognitive radios can be trained to dynamically and autonomously adjust its operating parameters.”

The Virginia Tech Cognitive Radio Working Group which has a large involvement in the development of the technology has adopted the following capability- focused definition of cognitive radio.

“An adaptive radio that is capable of the following:

- Awareness of its environment and its own capabilities,
- Goal driven autonomous operation,
- Understanding or learning how its actions impact its goal,
- Recalling and correlating past actions, environments, and performance.”

3.3. Background study of spectrum sensing using cognitive radio

Most of today’s radio systems are not aware of their radio spectrum environment and operate in a specific frequency band using a specific spectrum access system. Investigations of spectrum utilization indicate that not all the spectrum is used in space (geographic location) or time. A radio, therefore, that can sense and understand its local radio spectrum environment, to identify temporarily vacant spectrum and use it, has the potential to provide higher bandwidth services, increase spectrum efficiency and minimize the need for centralized spectrum management. This could be achieved by a radio that can make autonomous (and rapid) decisions about how it accesses spectrum.

Cognitive radios have the potential to do this. Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services.

3.4. When will cognitive radio happen?

Full Cognitive Radios do not exist at the moment and are not likely to emerge until 2030, when fully flexible Software Defined Radio technologies and the intelligence required to exploit them cognitively can be practically implemented. The main obstacle to realizing a full Cognitive Radio is the challenge of making a truly cognitive device, or a machine with the ability to intelligently make decisions based on its own situational awareness. Cognitive science is in its infancy. At this stage it is impossible to tell when machine cognition will be realized, it could be 50 years, 500 years or perhaps not at all. We expect basic intelligent reconfigurable Cognitive Radio prototypes to emerge within the next five years. Some devices available already have some elements of CR. (e.g. WLANs, military follower jammers).

3.5. Why we use cognitive radio

Based on Software-Defined Radio (SDR) technology, cognitive radios are the product of a multidisciplinary effort involving experts in wireless networks, digital communications, systems engineering, artificial intelligence, and other fields. As a result of these activities, it is hoped that these systems can simultaneously respect the rights of the incumbent license holders while providing greater flexibility and access to spectrum. Given the demand for more bandwidth and the amount of underutilized spectrum, DSA (Dynamic Spectrum Access) networks employing cognitive radios are a solution that can revolutionize the telecommunications industry, significantly changing the way we use spectrum resources, and design wireless systems and services.

The main specific benefit of full Cognitive Radio is that it would allow systems to use their spectrum sensing capabilities to optimize their access to and use of the spectrum. From a regulator's perspective, dynamic spectrum access techniques using Cognitive Radio could minimize the burden of spectrum management whilst maximizing spectrum efficiency.

3.6. Function of Cognitive Radio

There are four main use of cognitive radio system this are:

3.6.1. Spectrum Sensing

The principal step of spectrum sensing is that it decides the presence of primary user on a band. The cognitive radio has the capacity to impart the result of its detection with other cognitive radios in the wake of sensing the spectrum. The main objective of spectrum sensing is to discover the spectrum status and activity by periodically sensing the target frequency band.

3.6.2. Spectrum Management

Provides the reasonable spectrum scheduling technique among coexisting users. The available white space or channel is quickly chosen by cognitive radio if once found. This property of cognitive radio is described as spectrum management.

3.6.3. Spectrum Sharing

Cognitive Radio doles out the unused (spectrum hole) to the secondary user (SU) as long as primary user (PU) does not utilize it. This property of cognitive radio is described as spectrum sharing.

3.6.4. Spectrum Mobility

When an authorized (Primary) user is detected, the Cognitive Radio (CR) empties the channel. This property of cognitive radio is depicted as the spectrum mobility, also called handoff.

3.7. Characteristics of Cognitive Radio

There are two main characteristics of the cognitive radio and can be defined as:

- Cognitive ability: Cognitive Capability characterizes the capacity to catch or sense the data from its radio surroundings of the radio technology. Joseph Mitola initially clarified the cognitive capability in term of the cognitive cycle "a cognitive radio constantly observes nature, orients itself, makes plans, decides, and then acts."
- Re configurability: Cognitive capacity offers the spectrum awareness, Re configurability refers to radio capability to change the functions, and empowers the cognitive radio to be programmed dynamically as per radio environment (frequency, transmission power, modulation scheme, and communication protocol).

3.8. Basic Cognitive Cycle of Cognitive Radio

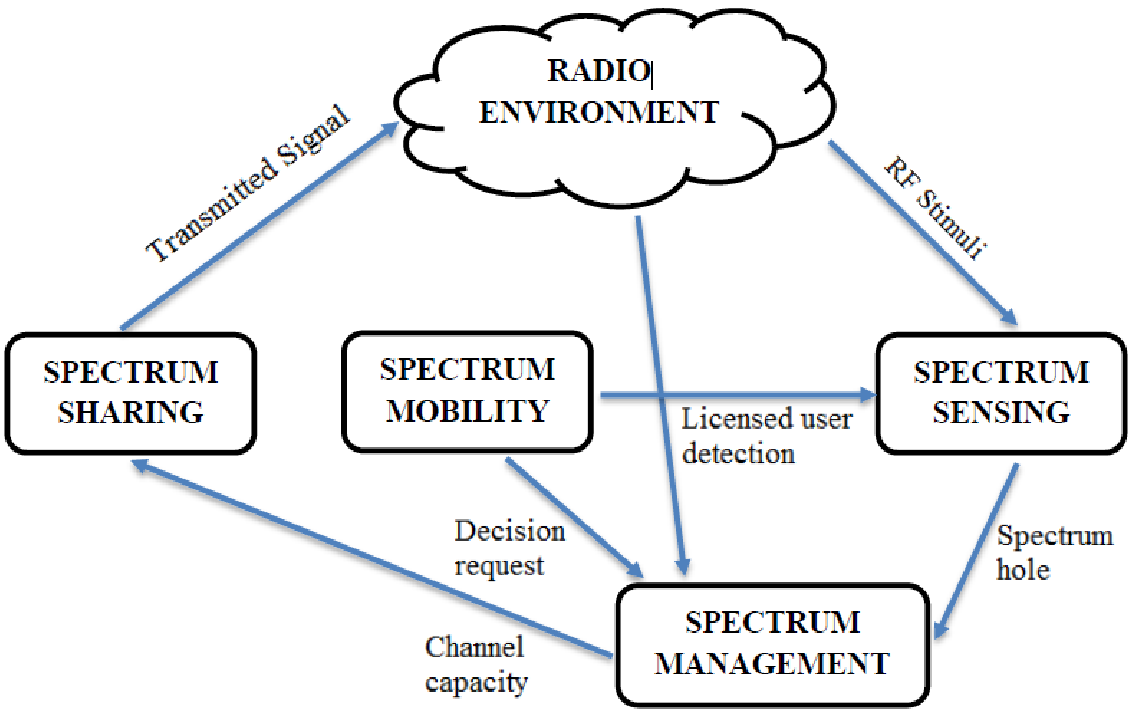


Figure 5 Basic Cognitive Cycle

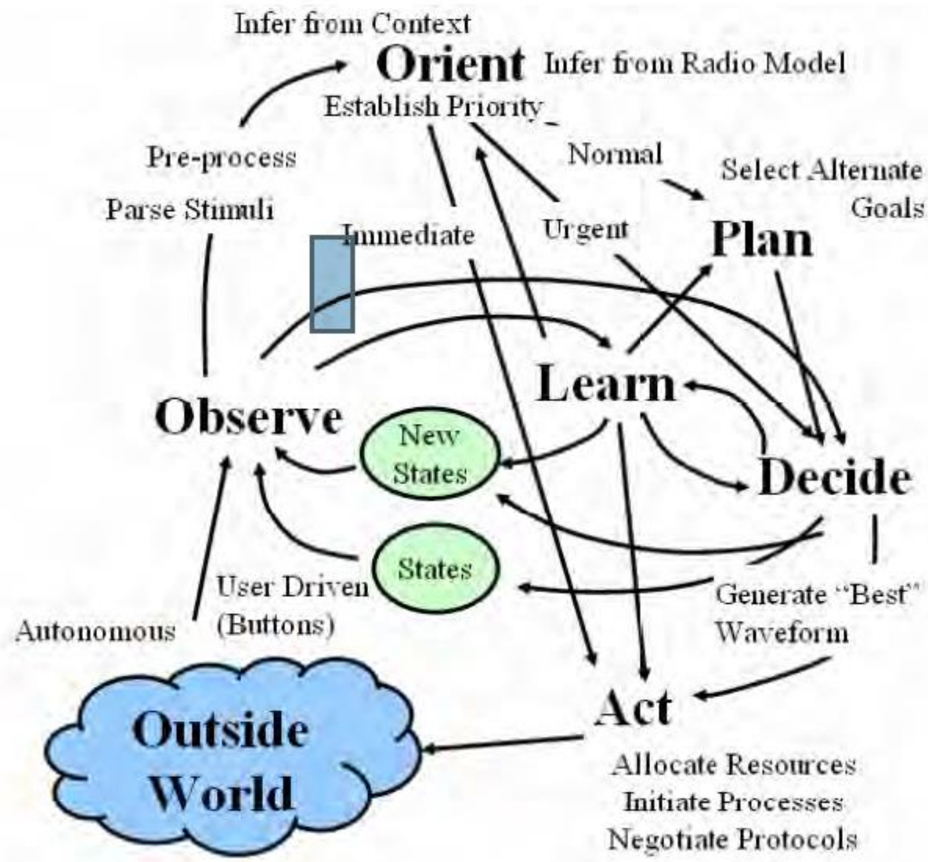


Figure 6 General Cognitive Cycle

3.9. Advantage, Disadvantage and Application of Cognitive Radio

3.9.1. Advantages:

- Mitigate and solving spectrum access issues.
- Spectrum utilization improves.
- Improves wireless networks performance through increased user throughput and system reliability.
- More adaptability and less co-ordination.

3.9.2. Disadvantages:

- Software reliability
- Loss of control
- Regulatory concerns
- Fear of undesirable adaptations.
- Significant research is to be done to commercially use cognitive radio

3.9.3. Application

- Improving reliability in wireless communication system.
- Less expensive radio.
- Advanced network topologies.
- Enhancing SDR techniques.
- Automatic radio resources management.

3.10. Spectrum Detection for Cognitive Radio

Spectrum detection is the art of performing measurements on a part of the spectrum and forming a decision related to spectrum usage based upon the measured data. The recent rapid growth of wireless communications has made the problem of spectrum utilization ever more critical. On one hand, the increasing diversity (voice, short message, Web, and multimedia) and demand of high quality-of-service (QoS) applications have resulted in overcrowding of the allocated spectrum bands, leading to significantly reduced levels of user satisfaction. In recent years, the service providers are faced with a situation where they require a larger amount of spectrum to satisfy the increasing quality of service (QoS) requirements of the users. This has raised the interest in unlicensed spectrum access, and spectrum detection is seen as an important enabler for this. In a scenario in which there exist a licensed user (primary user), any unlicensed (secondary users) needs to ensure that the primary user is protected, i.e., that no secondary user is harmfully interfering any primary user operation. Spectrum detecting can be used to detect the presence or absence of a primary user. The Institution of Electrical and Electronics Engineering (IEEE) has formed a working group (IEEE 802.22) to develop an air interface for opportunistic secondary access to the spectrum via the cognitive radio technology. The guiding philosophy of cognitive radio is to allow universal maximization of the spectrum utilization insofar as the unlicensed users do not cause degradation of service upon the original license holders. In practice, the unlicensed users, also called the cognitive users, need to monitor the spectrum activities continuously to find a suitable spectrum band for possible utilization and to avoid possible interference to the licensed users, also called the primary users. Since the primary users have the priority of service, the above spectrum sensing by cognitive users includes detection of possible collision when a primary user becomes active in the spectrum momentarily occupied by a cognitive user and relocation of the communication channels. Spectrum sensing is based on a well-known technique called signal detection. In a nutshell, signal detection can be described as a method for identifying the presence of a signal in a noisy environment. Analytically, signal detection can be reduced to a simple identification problem, which can be described as shown

3.11. Spectrum Holes and Spectrum Analysis

Cognitive radio is designed to identify and scavenge the spectrum holes in the licensed spectrum bands. A spectrum hole is defined as a licensed spectrum band that can be used by CR users without interfering with the primary or licensed users. A temporal spectrum hole means that there is no primary transmission over the spectrum band of interest during the time of sensing (over a reasonable period); hence, this band can be utilized by CR users in the current time slot. For the temporal spectrum holes, as indicated in Fig, the secondary users are located in the coverage area of the primary transmission. Consequently, it is relatively easy to detect the presence or absence of the primary user activity since CR users only need to have a similar detection sensitivity as regular primary receivers and, more importantly, identifying the presence of a primary signal is much easier than demodulating and decoding it. Therefore, spectrum sensing in this case does not pose an onerous demand on signal processing. A spatial spectrum hole exists when the spectrum band of interest is occupied by the primary transmission only in a restricted area; hence, this band can be utilized by CR users well outside this area. In contrast with the utilization of temporal spectrum holes, secondary users utilizing spatial spectrum holes work outside the coverage of the primary transmission, as indicated in Fig. Since there are no primary receivers outside the coverage area, secondary communication over the licensed band is allowed if only the secondary transmitter does not interfere with the primary transmission and reception within the coverage area. To accomplish this, the secondary transmitter has to successfully detect the presence of the primary signal at any location where the secondary transmission may cause intolerable interference to the possible nearby primary receiver. Since the secondary users fall outside the coverage area of the primary transmission, detection of the primary signal in this case is a challenging task.

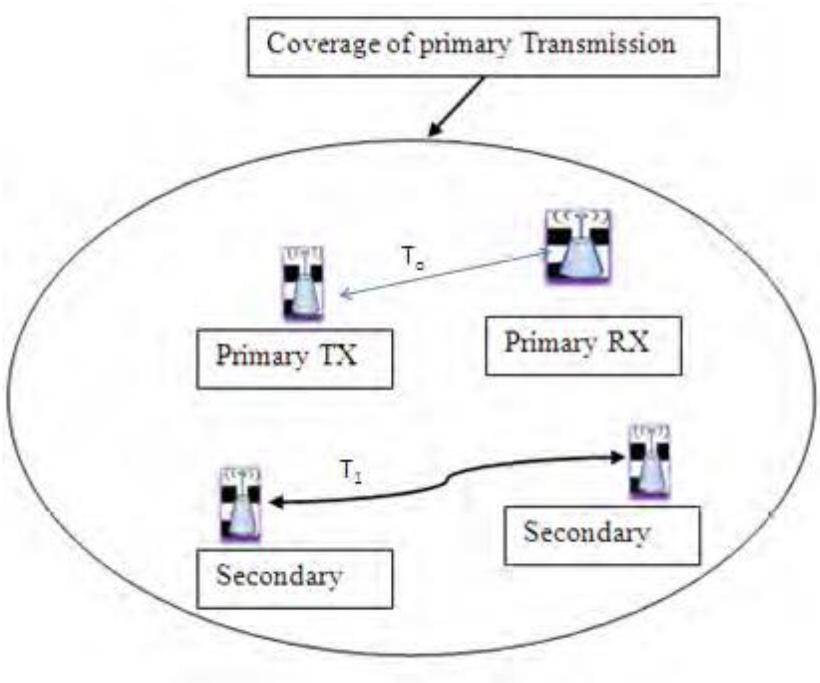


Figure 7 Coverage of Primary Transmission

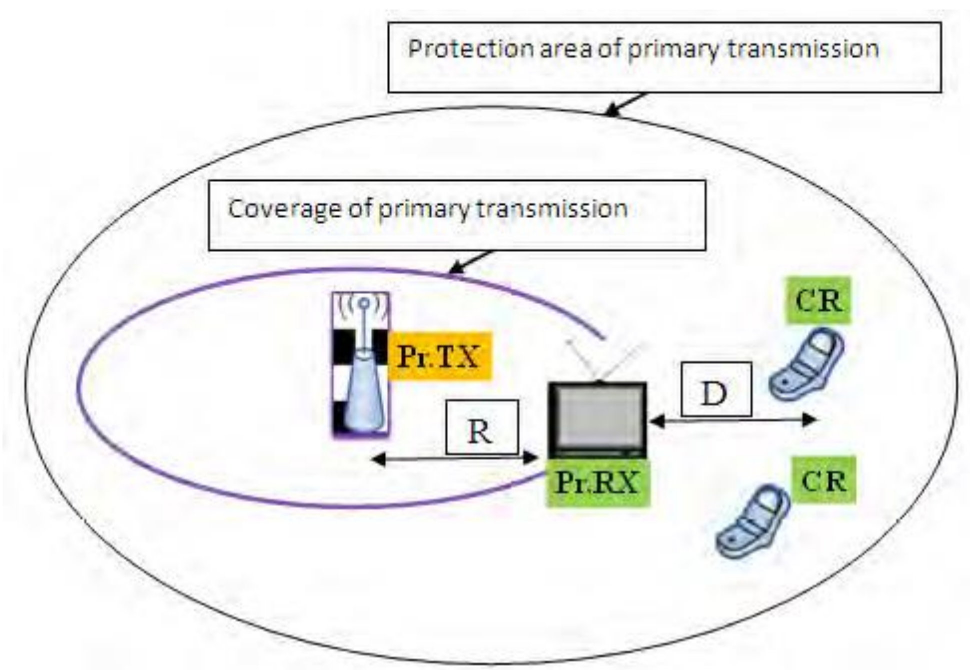


Figure 8 Protection Area of Primary Transmission

3.12. Limitation of Cognitive Radio

As there are significant advantages of CR, there are a number of key challenges. Ideally a CR should have no impact on other radio users, but in reality, some impact is expected particularly on non-cognitive primary radio users. The autonomous adaptive nature of CR means that it could be difficult to predict and control the spectrum behaviors of individual radios: a concern for anyone who might suffer from CR interference. A method may be required to audit and trace CR spectrum usage in legacy bands. The communications industry's greatest concern with CR is the hidden node problem. This situation arises when a CR is unable to detect all of the radios with which it might interfere, not because its own spectrum sensing is ineffective, but because some radios are hidden from it. The hidden node problem is a big challenge facing the widespread market deployment of spectrally aware CR. Figure shows an example which demonstrates the hidden node problem: a CR is located far away from a transmitting contemporary user, but is very close to a receiving contemporary user. The receiving contemporary user is at the edge of its cell. Therefore, as the figure shows there is a section where the carrier-to-interference ratio falls below the minimum required for reliable communications. CR will suffer from the same security issues as SDR such as malicious use, leading to unexpected or problematic behavior of individual CRs or potentially entire networks.

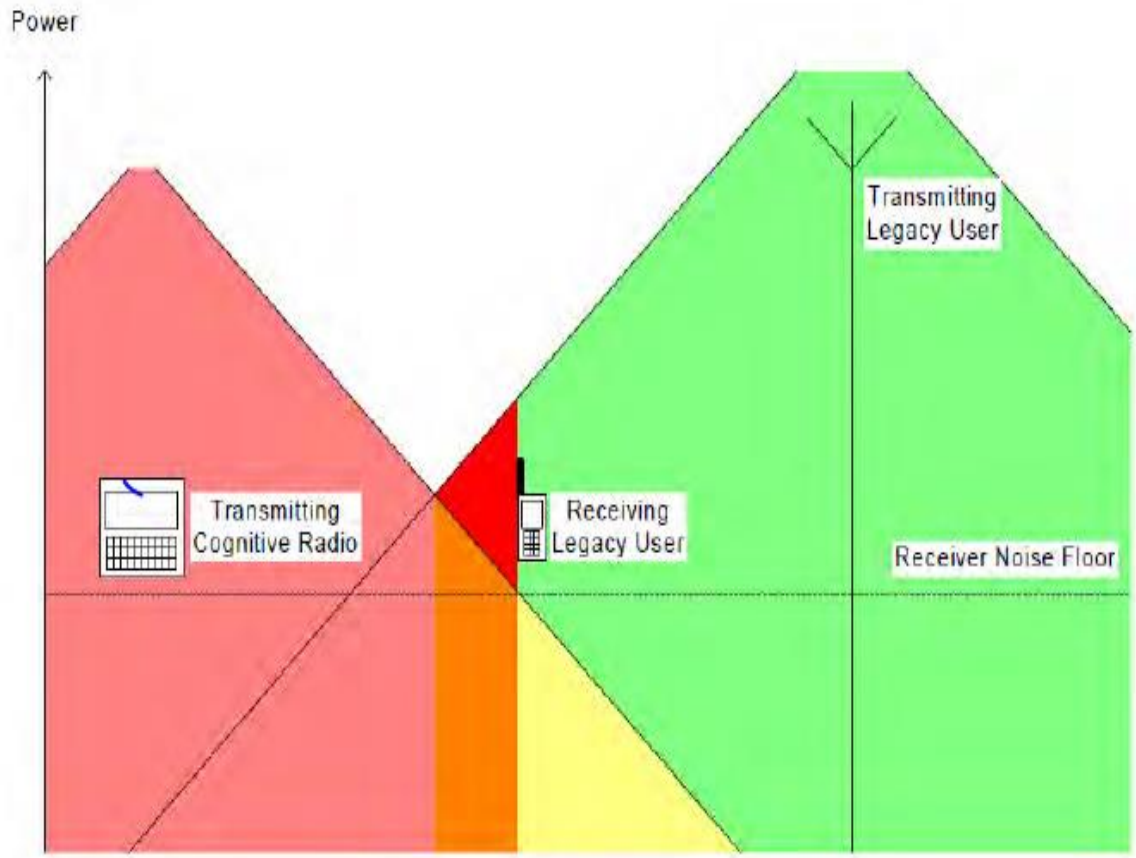


Figure 9 Limitation of Cognitive Radio System

CHAPTER FOUR

METHDOLOGY

5.1. Process to Perform the Project

This section covers the details explanation of methodology that is being used to make this thesis project well. Many methodologies or finding from this field mainly generated into journal for others to take advantages and improve as upcoming studies. The method is used to achieve the objective of the project that will accomplish a perfect result.

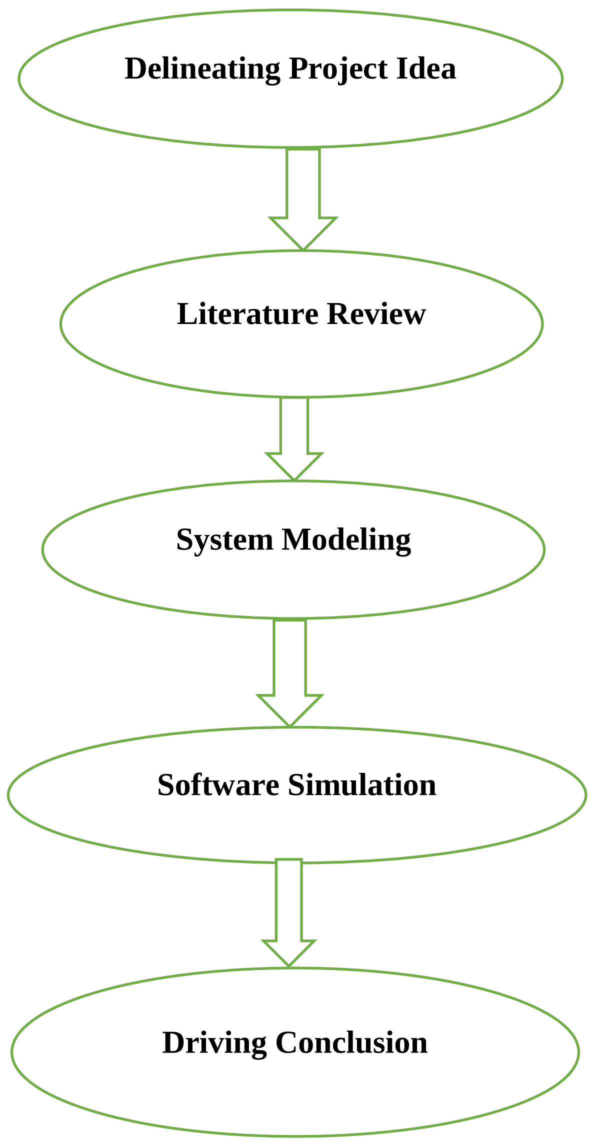


Figure 10 Process of the Project

5.2. Flow Chart of the Project

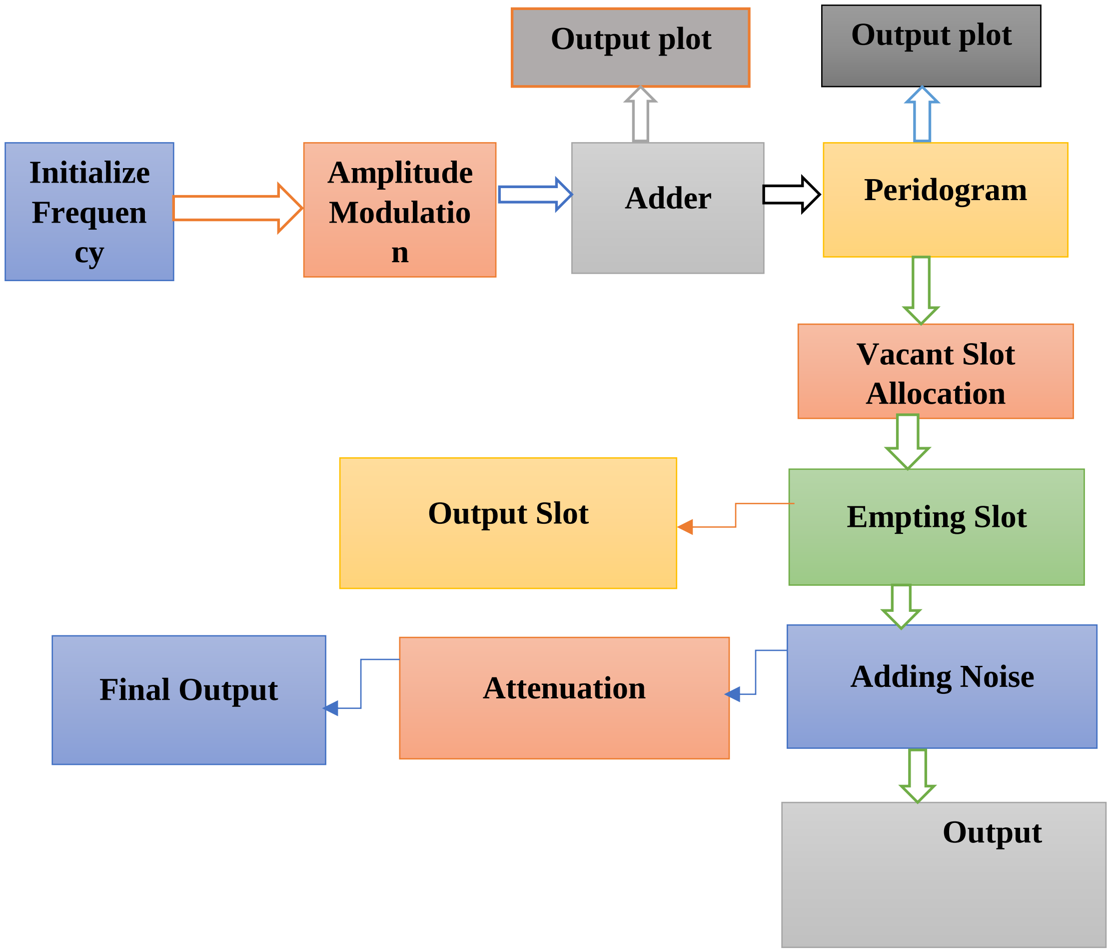


Figure 11 Flow Chart of the Project

- **Initialization-** 5 Carrier Frequency Bands for Users, Message Frequency and the Sampling Frequency are initialized.
- **Modulation-** Modulates user data over the respective frequency band by amplitude modulation.
- **Adder-** Addition of all the modulated signals to produce a transmitting signal.
- **Periodogram-** To estimate the power spectral density of received signal.

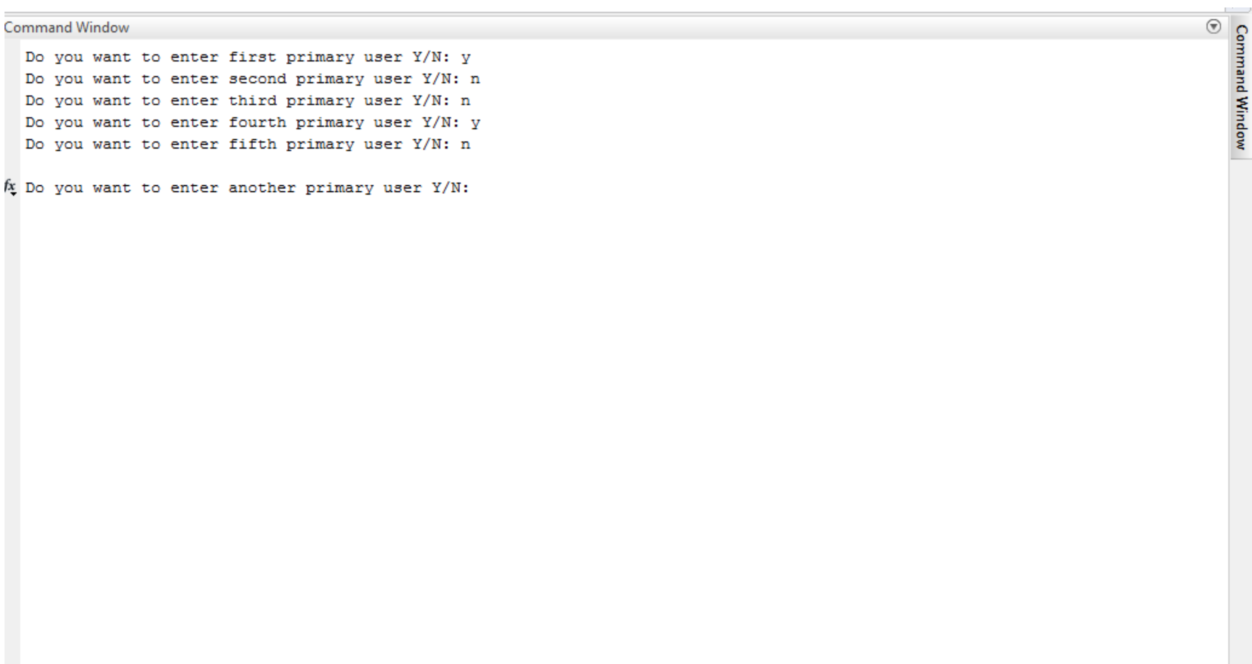
- **Vacant Slot Allocation-** New User is allocated0 to the first spectral hole when he arrives.
- **Emptying a slot-** Asked user to empty a specific slot if all the slots are engaged.
- **Addition of noise-** Amount of Noise to be added.

CHAPTER FIVE

SIMULATION AND RESULT

5.1. Assigning Primary User to the Frequency Spectrum

We've designed our system to have 5 different frequency channels and each User is assigned a particular frequency band. Once we run our program it'll ask to add a User and assign it a particular band in ascending order. In our simulation result bellow here we haven't entered user 2, 3 and 5 in the spectrum, thus their respective bands are still un-allocated. We can see them below in the power spectral density graph of our carrier signal.



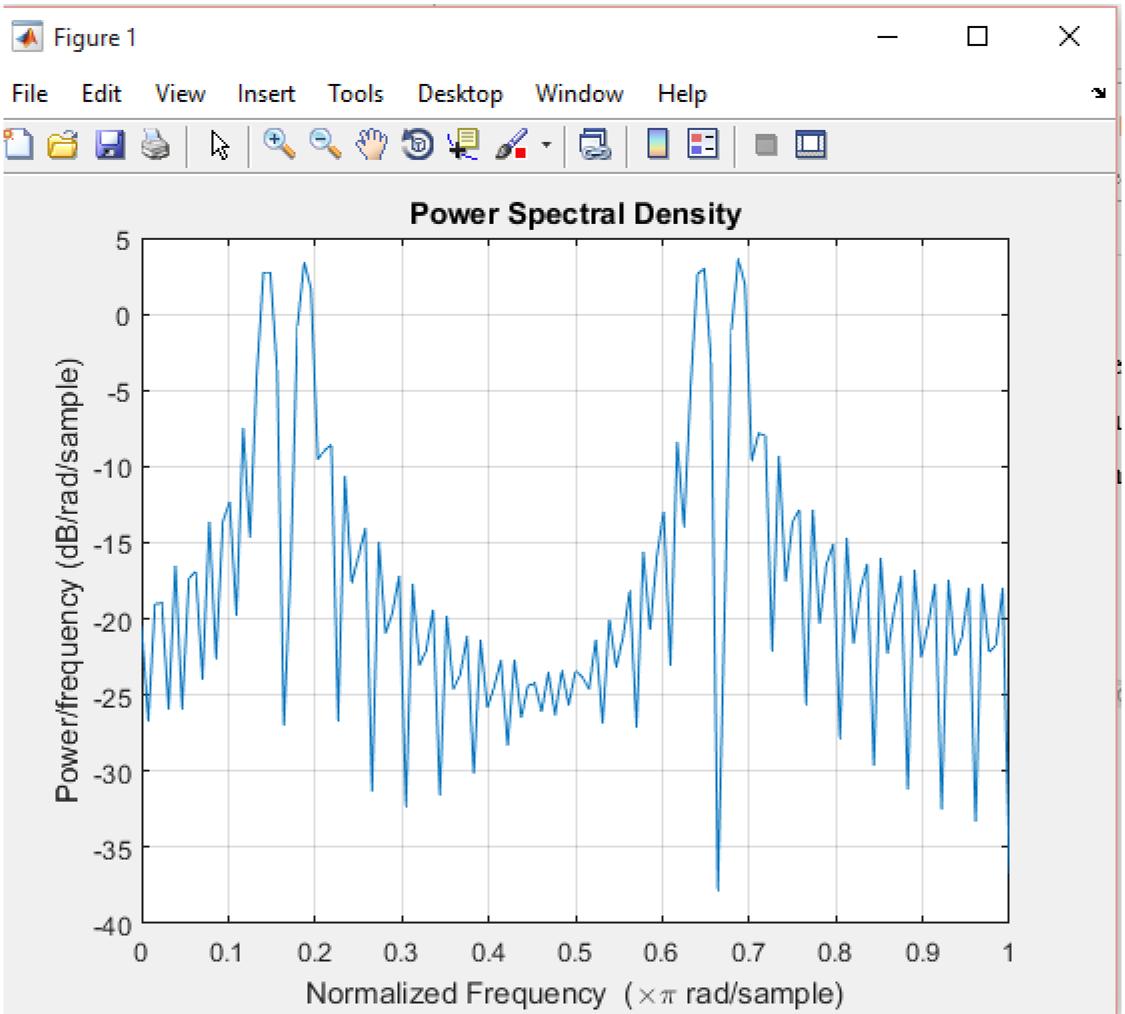


Figure 12 Assigning Primary User

5.2. Assigning New User in the Spectrum Hole

Now we're adding another User, the system will search the first available gap in the spectrum and automatically assign it to the new user. As the first available gap was after User-1 as User-2 was not sending any data so the band reserved for User-2 at start is now assigned to this new User. Here we can see that the first spectral gap has been filled by assigning the new incoming User's data. The first spectral gap belonged was that of User-2.

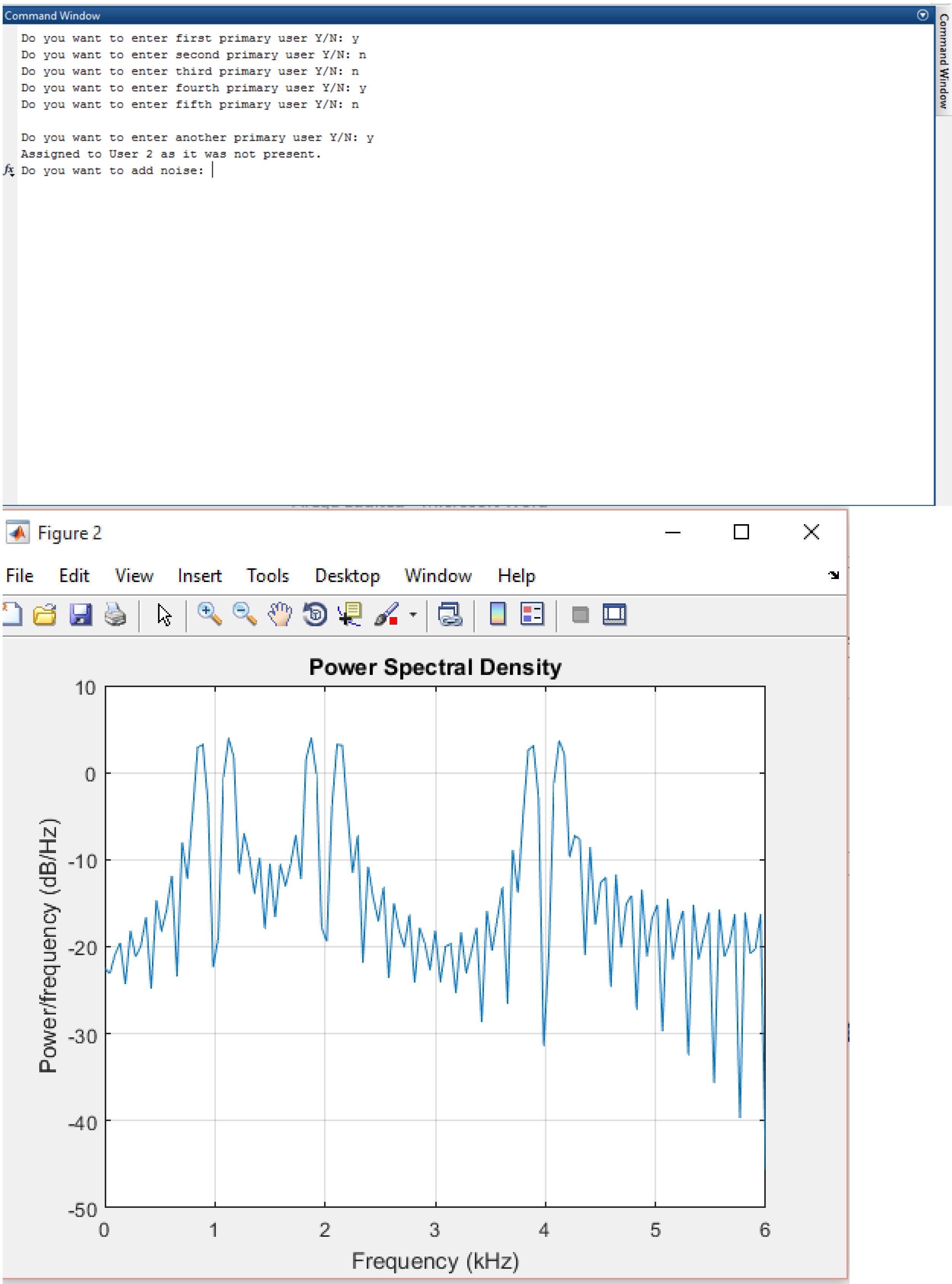
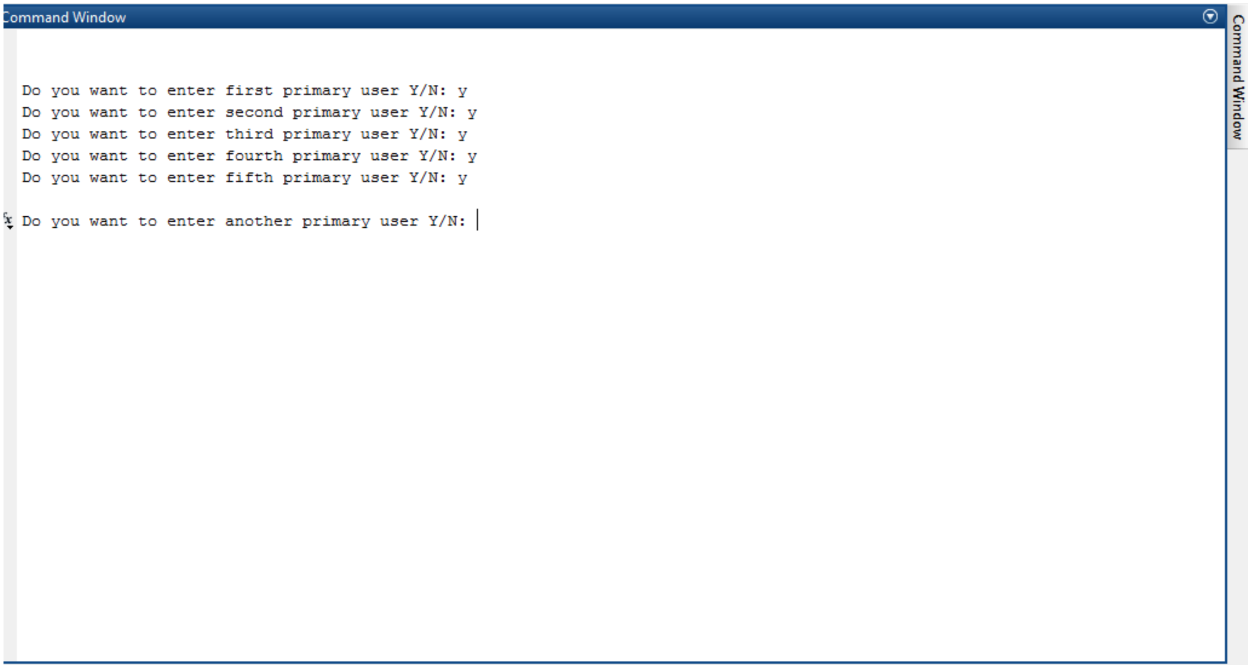


Figure 13 Assigning New User for Spectrum Hole

5.3. Efficient Frequency Bandwidth

Now we've just one empty slot left which will get filled by addition of another Primary User.

The power spectral density curve of the signal shows us that all of the frequency bands are efficiently in use after the addition of the last incoming user.



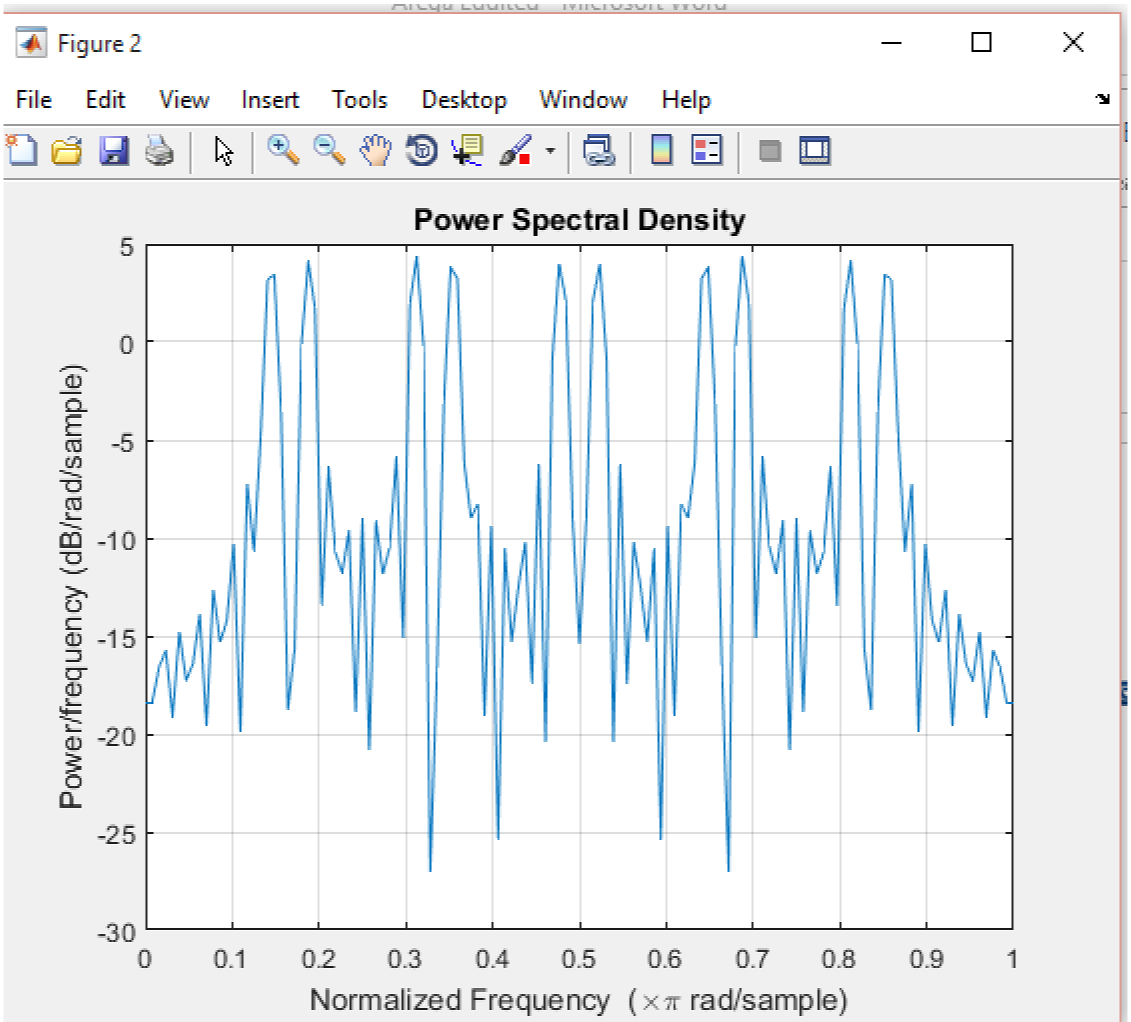


Figure 14 Efficient Frequency Bandwidth

5.4. Elimination of Slot

Once all the slots are being assigned, our system will entertain no other User and will be able to free up the slots one by one as shown below.

If we ask it to empty a slot, it will remove the data of that slot and make it ready for the next assignment.

Command Window

```
Do you want to enter first primary user Y/N: y
Do you want to enter second primary user Y/N: y
Do you want to enter third primary user Y/N: y
Do you want to enter fourth primary user Y/N: y
Do you want to enter fifth primary user Y/N: y

Do you want to enter another primary user Y/N: y
all user slots in use. try again later,
Do you want to empty a slot: y
Which slot do you want to empty for your entry: 2
slot2 is fired
fx Do you want to add noise:
```

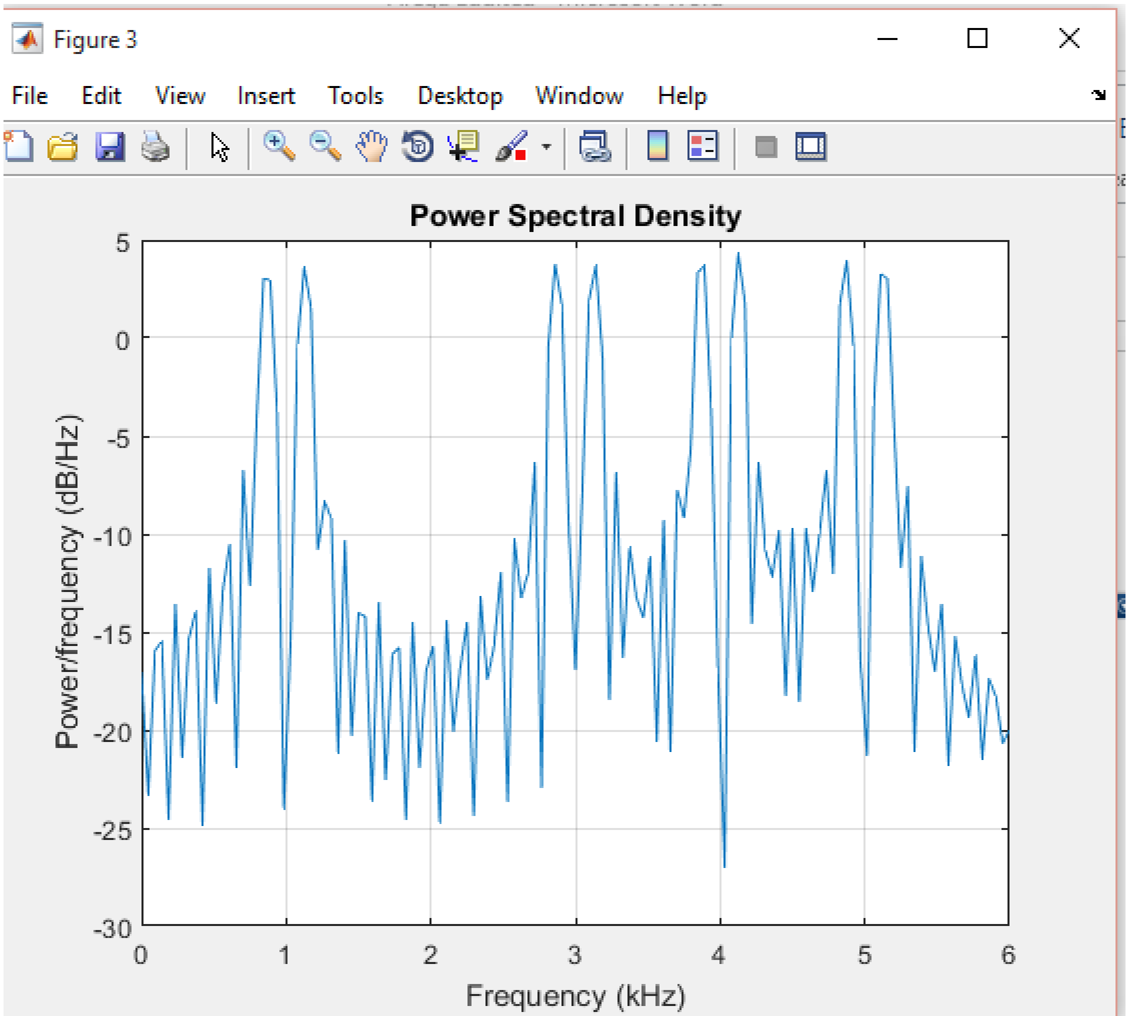


Figure 15 Elimination of Empty Slot

5.5. Addition of Noise Parameter to Analyze Channel Characteristic’s

Now we can add noise in our carrier and the system will ask for the SNR (Signal to Noise Ratio) required in dB. Here we’ve added noise to our signal. The resulting noisy carrier’s power spectral graph is given below.

Command Window

```
Do you want to enter first primary user Y/N: y
Do you want to enter second primary user Y/N: y
Do you want to enter third primary user Y/N: y
Do you want to enter fourth primary user Y/N: y
Do you want to enter fifth primary user Y/N: y

Do you want to enter another primary user Y/N: y
all user slots in use. try again later,
Do you want to empty a slot: n
Do you want to add noise: y
Enter the SNR in dB: 5
fx Do you want to attenuate the signals? [Y/N]:
```

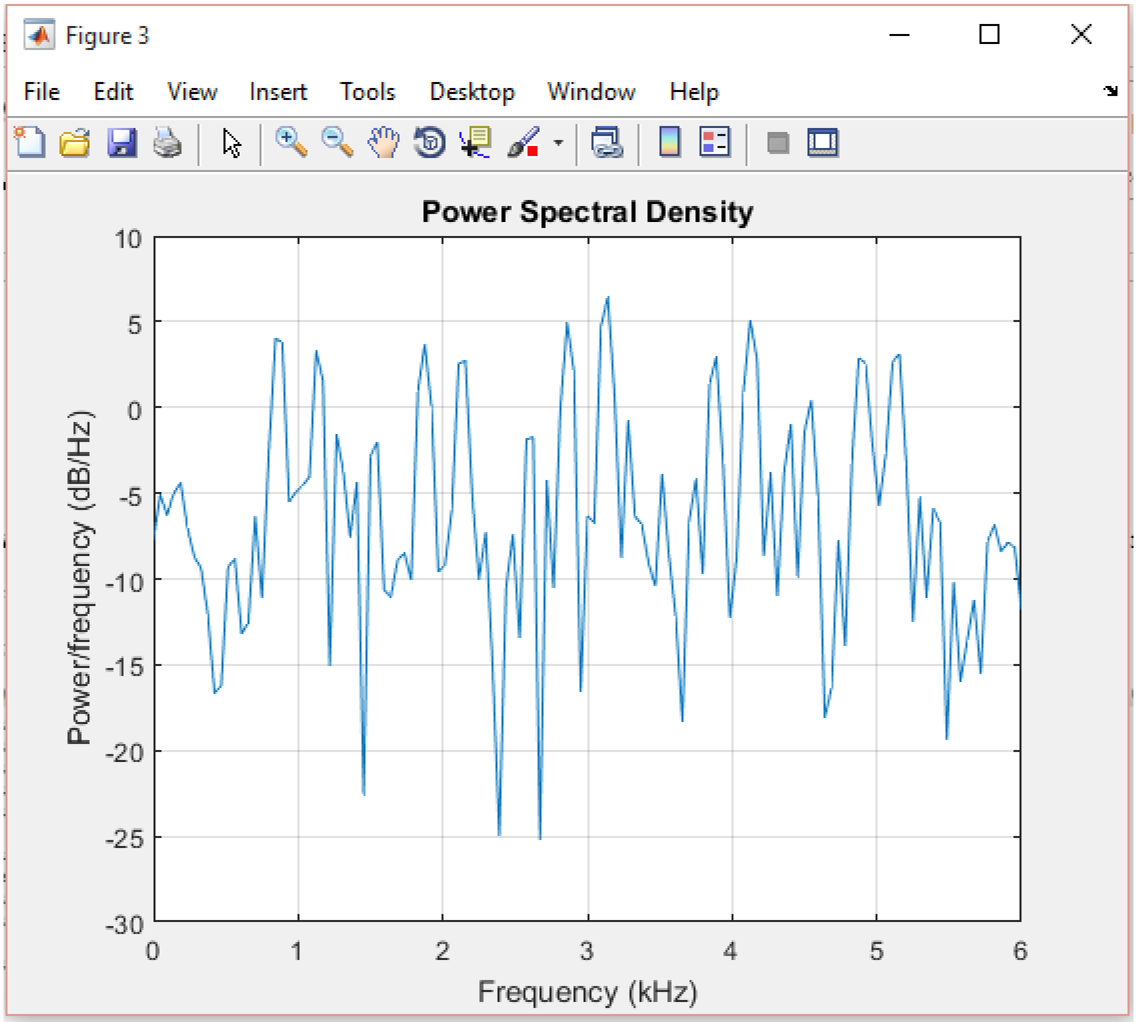
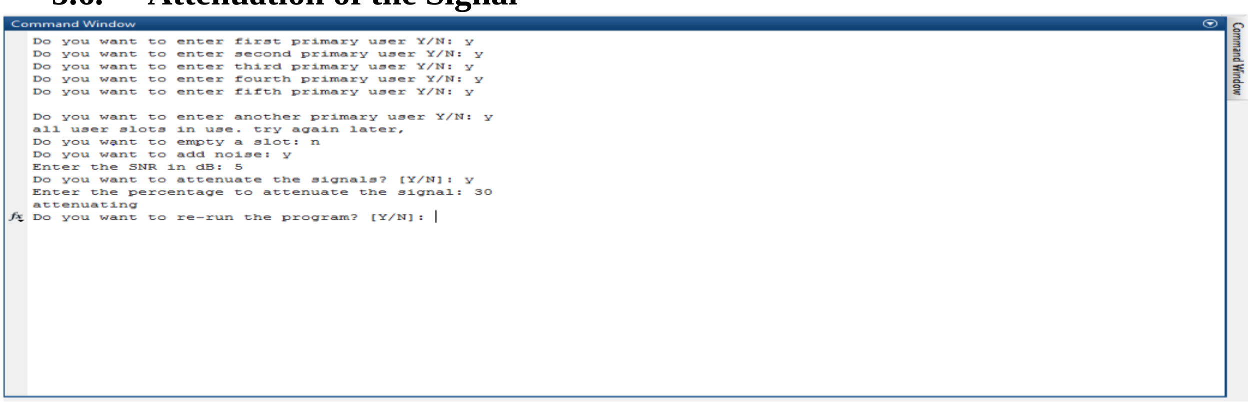


Figure 16 Addition Noise

5.6. Attenuation of the Signal



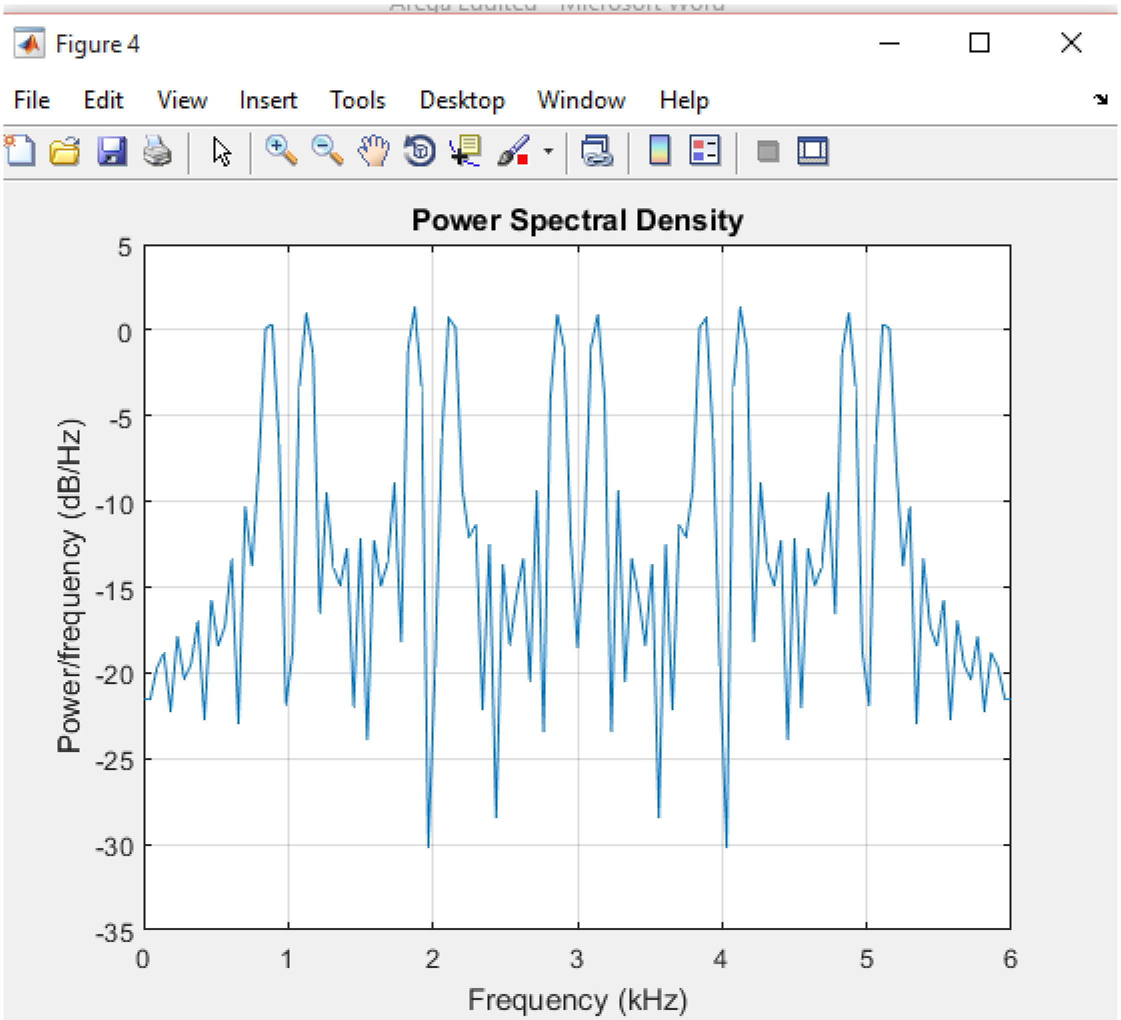


Figure 17 Attenuation of the Signal

5.7. Discussion

We've simulated the basics of a cognitive radio systems enabling dynamic spectrum access at run time. Mobile multimedia downloads emergency communications services, broadband wireless networking, "hot spot" services; multimedia wireless networking services are the best applications of Cognitive radio system. Cognitive radios are still in research pipelines as cognitive science is in its infancy. That's why we've tried to simulate the basics of cognitive radio technology to inform among Electrical & Electronic Engineers regarding the scope and applications of this tremendous new technology. By using MATLAB, we intend to come out with a simpler and efficient simulating technique. The consequences on the basis of power spectral density of the channel which can be used cognitively to find out the available gaps those can be assigned to new incoming users thus improving the overall channel's output.

CHAPTER SIX

CONCLUSION AND RECOMUNDATION

6. Conclusion

Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services. We've shown the simulation of a radio frequency spectrum sensing in Cognitive Radio System by using MATLAB where maximum utilization and efficiency of the frequency spectrum have been ensured and the noisy signal has also been attenuated.

REFERENCE

[1]. Md. Jakir Hossain and Md. Shahidullah Kawsar "Simulation of Cognitive Radio System"

[2]. Detection of Vacant Frequency Bands in Cognitive Radio "by Rehan Ahmed and Yasir Arfat Ghous at Blekinge Institute of Technology May 2010".

[3]. Simulation of Cognitive Radio System by using Automatic Insertion of Primary Users BY Priyangu Shaya Sarmah, Digital Electronics and Communication Systems VTU, CPGS, Bengaluru Region.

[4] Joseph Mitola III, Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio, PhD dissertation, Royal Institute of Technology (KTH) Stockholm, Sweden, 8 May, 2000.

[5] Spectral Efficiency of Cognitive Radio System; Majed Haddad, Aawatif Menouni Hayar and M´erouane Debbah.

[6] Experiments in Cognitive Radio and Dynamic Spectrum Access using An Ontology-Rule Hybrid Architecture; Allen Ginsberg, Jeffrey D. Poston, and William D. Horne.

[7] Cognitive Radio Technology A Study for Ofcom – Summary Report

[8] Cognitive Radio: A Flexible Wireless Platform for Transceiver Optimization: Alexander M. Wyglinski, the University of Kansas

Appendix

Implementation of the Code

```
t = 0:0.00001:0.001;
% we've taken 5 carrier frequencies Fc1 = 1000, Fc2 = 2000, Fc3 = 3000, Fc4=4000 & Fc5 =
5000 % keeping the user message/data signal frequency as 1000.
Fc1 = 1000;
Fc2 = 2000;
Fc3 = 3000;
Fc4 = 4000;
Fc5 = 5000;
Fs = 12000;
y1 = 1; y2 = 0; y3 = 0; y4 = 0; y5 = 0; Y6 = 0;
x1 = cos(2*pi*1000*t); % every user's base band data signal
% once user 1's data arrive, it is modulated at the first carrier Fc1, similarly as the 2nd user's
% data arrives; it is modulated at the 2nd carrier Fc2, so on till fifth user is assigned the Fc5
% band. If any user's data isn't present his frequency band remains empty which is called a
% Spectral Hole.
in_p = input('Do you want to enter first primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y1 = ammod(x1,Fc1,Fs);
end
in_p = input('Do you want to enter second primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y2 = ammod(x1,Fc2,Fs);
end
in_p = input('Do you want to enter third primary user Y/N: ','s');
if(in_p == 'Y' ||in_p == 'y')
y3 = ammod(x1,Fc3,Fs);
end
in_p = input('Do you want to enter fourth primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
```

```
y4 = ammod(x1,Fc4,Fs);
end
in_p = input('Do you want to enter fifth primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y5 = ammod(x1,Fc5,Fs);
end
% once all the assignment is complete we add all the signals to create a carrier signal
% which will be analyzed for empty slots as the channel.
y7 = y1 + y2 + y3 + y4 + y5;
while(1)
% Now we'll estimate the power spectral density of our carrier signal using the periodogram();
% function and the values are stored in an array Pxx. Pxx is the distribution of power per unit
% frequency. This value is then stored in a dsp data object and then plotted.
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs');
plot(Hpsd);
% Hs = DSPDATA.<DATAOBJECT>(...) returns a DSP data object,
% Hs, of type specified by DATAOBJECT. Some common data objects are
% msspectrum - Mean-square Spectrum (MSS) data object
% psd - Power Spectral Density (PSD) data object
% pseudospectrum - Pseudo Spectrum data object
in_p = input('\nDo you want to enter another primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
tp=0;
% we've obtained five points for all users in the array Pxx which multiplied by 10000 should be
% above 8000 if there's no spectral hole. //this just an observation which is working so far, the %
technical aspects will be addressed later in the presentation.
chek1 = Pxx(25)*10000;
chek2 = Pxx(46)*10000;
chek3 = Pxx(62)*10000;
chek4 = Pxx(89)*10000;
```

```
chek5 = Pxx(105)*10000;
% now if there is a new user entering the channel, we’ll check the array Pxx, at certain location
% and assign user the first spectral gap as coded below
if(chek1 < 8000)
disp('Assigned to User 1 as it was not present.');
y1 = ammod(x1,Fc1,Fs);
elseif (chek2 < 8000)
disp('Assigned to User 2 as it was not present.');
y2 = ammod(x1,Fc2,Fs);
elseif(chek3 < 8000)
disp('Assigned to User 3 as it was not present.');
y3 = ammod(x1,Fc3,Fs);
elseif(chek4 < 8000)
disp('Assigned to User 4 as it was not present.');
y4 = ammod(x1,Fc4,Fs);
elseif(chek5 < 8000)
disp('Assigned to User 5 as it was not present.');
y5 = ammod(x1,Fc5,Fs);
else
disp('all user slots in use. try again later,');
tp=1;
end
figure
y7 = y1 + y2 + y3 + y4 + y5 ;
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
if(tp==1)
% then we’ve the slot emptying algorithm which will empty the already occupied bands by
% asking user to choose a slot and executing the following code.
inp_t=input('Do you want to empty a slot: ','s');
```

```
if(inp_t=='Y'||inp_t=='y')
inp_t=input('Which slot do you want to empty for your entry: ','s');
switch(inp_t)
case ('1')
y1=0;
disp('slot1 is fired');
y7 = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs',Fs); %#ok<*DPPSD>
plot(Hpsd);
case('2')
y2=0;
disp('slot2 is fired');
y7 = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('3')
y3=0;
disp('slot3 is fired');
% then we repeat the above plotting procedure that was done after the assignments.
% To add noise to our signal I’ve used the simpler awgn(); function.
y7 = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('4')
y4=0;
disp('slot4 is fired');
y7 = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y7);
```

```
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('5')
y5=0;
disp('slot5 is fired');
y7 = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y7);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
 otherwise
   disp('Invalid slot entered');
end
end
end
inp_t=input('Do you want to add noise: ','s');
if(inp_t=='y'||inp_t=='Y')
d = input('Enter the SNR in dB: ');
figure
Y6 = awgn(y7,d);
Pxx1 = periodogram(Y6);
Hpsd = dspdata.psd(Pxx1,'Fs',Fs);
plot(Hpsd);
end
% to attenuate our signal the system asks for the percentage of attenuation required followed %
by the plot of the attenuated carrier signal. The percentage divided by hundred is subtracted %
from 1 and the remaining number is multiplied with the signal.
temp = input('Do you want to attenuate the signals? [Y/N]: ','s');
if(temp == 'Y' || temp == 'y')
aF = input('Enter the percentage to attenuate the signal: ');
figure
tem = aF/100;
```

```
tm = 1-tem;
Z = y7.*tm;
disp('attenuating');
grid;
plot(Z);
Pxx4 = periodogram(Z);
Hpsd = dspdata.psd(Pxx4,'Fs',Fs);
plot(Hpsd);
end
end
temp = input('Do you want to re-run the program? [Y/N]: ','s');
if(temp == 'Y' || temp == 'y')
disp('\n\nEnter the users again.\n\n');
else
break;
end
end
```

Block Diagram of Simulation Test