Effect of Antenna Diversity in Cooperative Spectrum Sensing

Project report submitted in partial fulfilment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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MAY 2017

DECLARATION BY THE SCHOLAR

We hereby declare that the work reported in the B-Tech thesis entitled**“Effect of Antenna Diversity in Cooperative Spectrum Sensing**“,submitted at **Jaypee University of Information Technology, Waknaghat, India,** is an authentic record of our work carried out under the supervision of **Mr.ALOK KUMAR**. We have not submitted this work elsewhere for any other degree or diploma.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the B-Tech. thesis entitled **"Effect of Antenna Diversity in Cooperative Spectrum Sensing**", submitted by **ANKUR ANAND, MRIGANK SONI, SANTOSH KUMAR** at **Jaypee University of Information Technology, Waknaghat**, **India** is a bonafide record of their original work carried out under my supervision. This work has not been submitted elsewhere for any other degree or diploma.

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DATE:12/05/17

ACKNOWLEDGEMENT

Before Commencing, this report, we express our gratitude and appreciation to every single person associated with Jaypee University of Information Technology.

We express my gratitude to respected guide" **Mr.Alok kumar** " who provided me a life changing opportunity to work on this project, who helped me increase my knowledge about the image processing and also who has been utmost benign, affable and reasonable towards us, who shared his wonderful practical skills and helped me in understanding various concept.

Last but not least, we are grateful and indebted to my parents, teachers, mentor, friends and each single person who has in some way or the other helped me in making this treatise.

Thank you

ABSTRACT

We are in the age of next generation communication system in which we are using various techniques in which diversity is mainly used to improve the system performance .System performance is also improved with cooperation. Cognitive radio is used in next generation communication system. We see the effect of cooperative spectrum sensing which is used in Cognitive radio. Further we analysis the effect of various diversity techniques EGC, MRC, SC on cooperative sensing.

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CHAPTER 1

INTRODUCTION

Cooperation is a relatively new technique used for efficient usage of the available resources in the modern communication networks. Today most of the works being done for sensing are done by cooperation thanks to it’s ability to provide highly accurate results. Cooperation is being applied in advanced applications like Mobile communications, radio communications. Our goal is to study how the cooperative sensing capability of a cognitive radio can be improved by varying number of receiver antennas and how it gets affected by the diversity technique being used.

Spectrum Sensing is a function of CR to detect whether the spectrum is occupied or not. And when the spectrum is vacant, it provides the unlicensed user, access to the that spectrum until the licensed user doesn’t return to use it. The function of cognitive radios to detect when the spectrum is available to be used by unlicensed user is called spectrum sensing. There are different methods for sensing the spectrum. Among them, the Energy detection method is being utilized here.

The goal is to improve the detection capability of the cognitive radio, We will study how the probability of detection (of vacant spectrum) varies with the probability of false alarm at a fixed value of SNR and what will be the optimum point to work at. To increase the detection capability of the cognitive radios further, we will study how the SNR of the received signal can be increased if we change the number of receiver antennas on the cognitive radio. Studying it by using various diversity techniques gives us a fair idea of how to improve the spectrum sensing capabilities of the cognitive radio using multiple antennas.

As we change the number of receiving antennas, it’s very obvious that the signal received will be more accurate and error free as compared to the case when we use single antenna at the receiver side. Now the performance of the receiver part (in the cognitive radio) depends not only on the number of antennas but also the types of diversity we are using. Hence, we will observe in which of the case will the received signal will have maximum SNR in case of different diversity techniques are used .Then we study how the study of antenna diversity can be applied in the cooperative spectrum sensing.However, to understand all these, we need to understand what is cognitive radio and how does it work, what are it’s type, what is cooperative sensing and how can cooperative sensing be made more useful and effective using multiple antennas.

In the second chapter, cognitive radio is being introduced. How do the CRs work, it's components, it's abilities and it's essential functions. Then we study about spectrum sensing and it's types. We study about the factors affecting detection, misdetection of spectrum access by CRs and What affects the probability of false alarm.

The spectrum detection capability of CRs can be increased if it's signal receiving capability is increased. In the second chapter, we study what will be the optimum point to work at such that the probability of detection is high enough but the probability of false alarm is not so high. We study it at a fixed SNR(-10dB in this case).

In the third chapter, we observe how the SNR of the received signal varies with varying the number of receiver antennas on the CRs. Also how the Diversity techniques we use affect the SNR value of the received signal.

We start by studying about Diversity techniques, it's types, how it can be used into cognitive radio networks effectively and then about various techniques being used here (Equal Gain Combining, Maximal Ratio Combining).

CHAPTER 2

COGNITIVE RADIO

2.1 INTRODUCTION

Cognitive radio is a great technique to create wireless communications platforms that will target to increase the usage of the Radio frequency (RF) spectrum. The motivation for cognitive radio concept is the less availability of the usable frequency spectrum, greater demand, caused by the new wireless applications for mobile clients. Big part of the available radio spectrum has been given to existing wireless clients, however, and only small bits of it can be authorized to unlicensed wireless clients. Nonetheless, a study by the Spectrum Policy Task Force (SPTF) of the Federal Communications Commission (FCC) has inferenced that parts of frequency bands are majorly used by authorized clients in some locations and at definite times, but that there are also other frequency bands which are partially occupied or mostly vacant . For instance, spectrum bands given to cellular networks in the USA gets most of its traffic during the office hours of the day, but lie vacant largely at other times like during late night or early morning hours. The deciding factor that results in inefficient use of the radio spectrum is the spectrum allocating process itself. In contemporary spectrum licensing based on the command-and control model, where the radio spectrum is given toan authorized clients is not used, it cannot be used by unauthorized clients . Due to this non dynamic and static allocation, legacy wireless clients have to work only on a decided spectrum band, and is not able to adapt the transmission band according to the changing requirements.

The authority to use the spectrum is mostly defined by frequency, space, transmit power, spectrum owner , type of use, and the time period of the authorization. Generally, a license is given to one client, and the use of spectrum by this client must comply to the terms in the license. In the present spectrum authorizing scheme, the license cannot alter the kind of use or give the license to some other client . This contains the utilization of the frequency spectrum and outputs in low utilization of the frequency spectrum. importantly, due to the present static spectrum licensing , *spectrum holes* or spectrum opportunities (Figure 1.1) come up. Spectrum holes are defined as frequency bands that are given

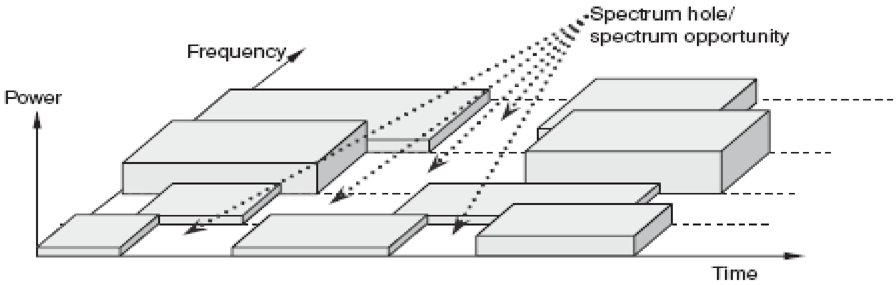

Fig 1.1 spectrum hole (spectrum opportunity)

to, but in some places and at some time intervals not utilized by, authorized clients, and, for that reason, could used by unauthorized clients. The problem in the access of spectrum is due to the static spectrum licensing scheme which can be summarized in the following manner:

• ***static way of spectrum utilization:*** By looking at the present spectrum allocation scheme, the type of usage of spectrum cannot be altered. For instance, a Television band used by the National Television System Committee (NTSC) based analog T V might not be utilizable by digital TV broadcasting Services. This band may remain most of the time unused in various places because of the presence of other TV clients.

• ***License for the usage of large area:*** Whenever any spectrum is authorized, it is generally given to a specific client which can be a wireless service provider across some geographically large area (e.g. whole city or province). Nevertheless , the wireless service provider would love to use the spectrum not only in places where a good quantity of subscribers are there, but also to gain the biggest return on their investment. As a result, the authorized frequency spectrum remains unutilized in rest of the areas, and rest of the clients or service providers are denied to access this spectrum.

• ***Major part of authorized spectrum:*** A wireless service provider is mostly authorized with a major chunk of a radio spectrum (e.g. 55 M Hz). Therefore, it wil not be possible to get license for a narrow spectrum band for the utilization of a specific area for a small period of time to meet the requirement of a short lived peak traffic load. For instance, a cdma 2000 cellular service giver may need a spectrum having a bandwidth of 1.35M Hz or 3.95MHz to give short term wireless access service in a hot spot place.

Stop Spectrum use by unlicensed clients: In the present spectrum permitting plan, just an approved client is enabled the entrance to the dispensed radio range and unapproved clients are denied from getting to the range despite the fact that spectrum plan is vacant by the approved clients. For case, in a cell framework, there could be zones in a cell with no clients. In such a case, unapproved clients having short range wireless communications will not be having the capacity to get to the range, despite the fact that their transmission would not meddle with cellular clients. With a specific end goal to enhance the effectiveness and usage of the accessible range, these confinements are being helped by changing the range permitting plan. The thought is to make range get to more adaptable by enabling unapproved clients to get to the radio range under specific limitations. The fact that the legacy remote frameworks were expected to operate on a committed band of frequency, they are not ready to use the enhanced adaptability provided by this spectrum authorizing plan. In this manner, the idea of cognitive radio has been presented. The fundamental objective of cognitive radio is to give flexibility to remote transmission through dynamic spectrum access so that the execution of remote transmission can be optimized, and also improving the use of the recurrence range. The real functionalities of a cognitive radio framework incorporate range detecting, range administration, and range portability. Through range detecting, the data of the target radio range must be obtained with the goal that it can be used by the cognitive radio client. The spectrum detecting chunk of data is misused spectrum management function to examine the range openings and make decisions on spectrum access. On the off chance that the status of the target range changes, the spectrum portability function would control the change in operational recurrence bands to be used in the cognitive radio clients.

2.2 Software-defined radio

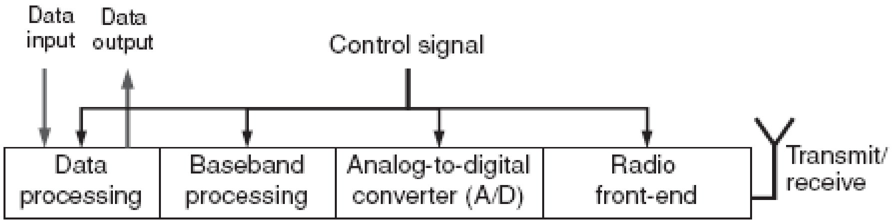

Fig 2.2.1SDR TRANSCEIVER

A software defined radio (SDR) is a reconfigurable remote communication framework in which the transmission parameters could be handled instantly. This flexibility capacity can be accomplished with the help of programming controllable flag preparing calculations. SDR is a key segment to actualizing cognitive radios. The fundamental elements of SDR are as per the following:

• ***Multiband operation***: SDR will bolster remote information transmissions over an alternate frequency spectrum utilized by various remote access frameworks (e.g. cell band, ISM band, television band).

• ***Multi standard support***: SDR will bolster diverse standards (e.g. GSM, WCDMA,cdma2000, WiMAX, WiFi). Additionally, different air interfaces inside a similar standard (e.g. IEEE 802.11a, 802.11b, 802.11g, or 802.11n in WiFi standard) can be upheld by SDR.

• ***Multiservice support***: SDR will bolster various sorts of services, e.g. cell communication or broadband remote Web access.

• ***Multichannel support:*** SDR will have the capacity to work (i.e. transmit and get) on numerous frequency bands simultaneously. The general structure of a SDR handset is shown in (Figure 2.2.1) While the majority of the segments in SDR (i.e. data processing, analog-to-digital converter, and baseband processing) are like those in customary handsets, the distinction is that each part can be controlled from the conventions in the upper layers or can be reconfigured by the cognitive radio module. In a SDR handset , the radio front-end gets analog signals from the receiving antenna. This analog signal is filtered by a bandpass filter to acquire the signal in the coveted frequency. This signal is enhanced and prepared to generate an in-stage (I) way and a quadrature (Q) way by moving the stage by $-\pi/2$. Both I and Q way signals are then converted over to digital data. The sampling rate of A/D must satisfy the states of Nyquist's testing hypothesis. In any case, the sampling rate ought to be limited to decrease the signal processing overhead. The sampling rate and the parameters of the analog and digital filters and in addition the signal processing calculations can be reconfigured as per the working frequency band and the wireless air interface technology. With SDR, the transmission parameters in a remote handset can be reconfigured as per the communication specifications and requirements:

• The radio transceiver parameters (e.g. the operational standard and frequency band) can be set before the system is delivered to the client. Be that as it may, the parameters can't be altered after the system is arranged. Albeit dynamic reconfiguration of the system is not upheld for this situation, one SDR handset model can be sold to numerous clients with various necessities.

• The radio transceiver parameters can be once in a while reconfigured (e.g. a few times amid the system's life time), for instance when the network structure changes or when another base station is included.

• The radio handset parameters can be changed on an association basis. For instance, when a client needs to start a remote Web connection, the transceiver can make a choice over the various wireless systems available (e.g. GSM, WiFi or WiMAX), in view of system accessibility, execution, and cost.

• The radio transceiver parameters can be dynamically changed on an availability premise. For instance, the transmission power can be adjusted when the level of impedance changes. The unapproved client(s) can change the working frequency band when the movement of the approved client(s) is distinguished.

Future cell phones will be intended to support various remote access advancements so that a portable client can have the adaptability to switch between various systems. In, a design approach was talked about for a SDR handset for multi standard cell phones. The space and power utilization and additionally the versatility of the equipment were distinguished as the significant design imperatives. A SDR platform, in particular, Kansas College Coordinated Radio (KUAR), was developed in. The stage comprises of a power supply, control processor, and a computerized leading band of programmable signal processor, analog to-digital and digital to-analog converters, RF handset, and receiving antennas. The radio front-end supports a working frequency of 5–6 GHz. The digital board is an implanted PC running on Linux. A field-programmable gate array (FPGA) is utilized as a part of this computerized board to give adaptability of actualizing the signal preparing calculation. For the product part, KUAR has radio control and administration programs, in particular Boot, Approach, Operations, and QoS. The Boot program is utilized to stack related radio modules utilized by different segments. The Operations and QoS projects are utilized to quantify organize parameters, e.g. the activity stack in the convention stacks and the RF condition of the system. The Operations program can likewise change the frequency band and the balance mode (e.g. QPSK, QAM-16, and QAM-64). The policy program is utilized to control the transmission parameters inside the administrative guidelines. This KUAR stage was utilized to execute a WiMAX 802.16a test transmitter and recipient. As of late, SDR stages to support a more extensive operational spectrum have been proposed. For instance, the collector was intended to go about as a signal conditioner for A/D converters so that a specific spectrum can be inspected proficiently.

This SDR stage supports a frequency spectrum of 800MHz to 5 GHz. Other usage and exploratory stages of programming characterized radio were produced.

2.3 Cognitive radio components and abilities

Cognitive radio, which is actualized in view of the software defined radio, gives instruments to dynamic range detecting, range administration, and range access for cognitive radio clients (e.g. unapproved clients). The expression "cognitive radio" was characterized as: "Cognitive radio is a smart remote communication framework that knows about its environment. This cognitive radio will gain from the surroundings and adjust its internal states to factual varieties in the current RF changes by altering the transmission parameters (e.g. frequency band, balance mode, and transmit control) progressively and [in an] on-line way." A cognitive radio system enable the user to set up interlinks among cognitive radio hubs/clients. The parameters of communication can be balanced by changes in the earth, topology, working conditions, or client prerequisites . The most important two principle goals of cognitive radio are to accomplish profoundly solid and very productive remote interchanges, and to enhance the use of the frequency range.

- **Cognitive radio engineering**

The convention design of Cognitive Radio Networks (CRN) is shown in Figure 2.3.1. If we look at the physical layer, the front-end of RF is actualized in view of Software defined radio (i.e. the SDR handset). The versatile conventions of the MAC, network, transport, and application layers tend to get the information about the varieties present in the cognitive radio arena. Specifically, the versatile protocols ought to take consideration of the movement action of essential clients, the transmission necessities of cognitive clients, and varieties in channel quality, and so on.

For the connection of all modules, a cognitive radio control is to be used to set up the interfaces for the SDR handset, versatile conventions, and remote applications and administrations. The present cognitive radio module utilizes smart calculations to handle the deliberate flag with the help of physical layer, and get data of transmission necessities from the applications to control the convention parameters in the distinctive layers.

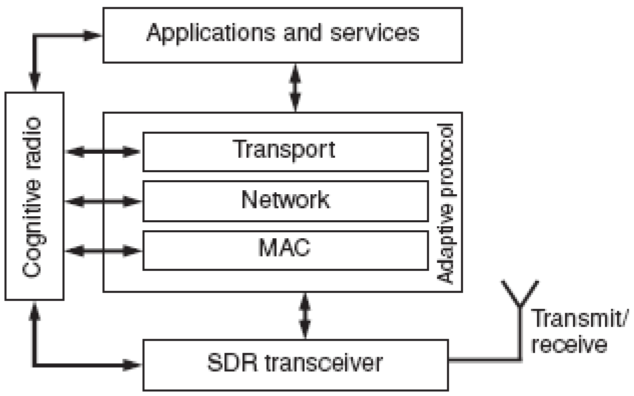

Fig 2.3.1 cognitive radio protocol stack

2.4 Functionalities of cognitive radio

The main functions of cognitive radio networks is to support intelligent and efficient dynamic spectrum access are as follows:

• ***Spectrum sensing:*** This function is aimed to decide the spectrum status. Specifically, a CR handset identifies an unused spectrum or spectrum opening (i.e. band, area, and time) and furthermore decides the strategy for getting to it without meddling with the transmission of an approved client. Spectrum sensing can be of two kinds: centralized and appropriated. In case of centralized spectrum sensing,there is a base station that detect the frequency band, and the data acquired is sent to different hubs in the network. In distributed spectrum sharing, spectrum sensing is done autonomously by unapproved clients, and the results can be either used by individual CRs (also called non-cooperative sensing) or shared with different clients (i.e. cooperative sensing).

• ***Spectrum examination:*** The data which is acquired from spectrum sensing is utilized for the creation and planning of spectrum access by unapproved clients. For this situation, the communication prerequisites of unapproved clients are mostly used to streamline the transmission parameters. Real parts of spectrum management can be recapitulated as spectrum examination and spectrum access advancement. In spectrum examination, data from spectrum sensing is broken down to get information about the spectrum openings (e.g. impedance estimation, term of accessibility, and shot of impact with an approved client because of sensing blunder). At that point, a choice to get the information about the spectrum (e.g. frequency, transfer speed, tweak mode, transmit power, area, and time span) is made by improving the framework execution given the coveted target (e.g. amplify the throughput of the unapproved clients) and limitations (e.g. keep up the obstruction brought on to approved clients underneath the aimed limit).

• ***Spectrum access:*** After making a choice on spectrum access in light of spectrum's investigation done previously, spectrum gaps are taken aback by the unapproved clients. Spectrum access is performed in light of a cognitive medium access control (Macintosh) convention, which means to stay away from crash with approved clients and furthermore with other unapproved clients.

• ***Spectrum mobility:*** Spectrum versatility is a capacity identified with the changing of working frequency band of cognitive radio clients. If we look at the point when an approved client begins getting to a radio channel which is as of now being utilized by an unapproved client, the unapproved client could change to a spectrum band which is sitting without moving to any direction. This change in working frequency band is expressed to be as spectrum handoff. In spite of spectrum handoff, the convention parameters at the diverse layers of the convention stacks must be acclimated to coordinate the new working frequency band. It must attempt to guarantee that the information transmission with the help of unapproved client can be proceeded in the new spectrum band.

2.5 Dynamic spectrum access

It can be characterized as some component so as to alter the spectrum resources utilization in a continuous way in by looking at the changing environment and goals (e.g. accessible channel and sort of uses), changes of radio state (such as status of battery, transmission mode and area), and to change the condition and outside limitations of the spectrum(e.g. radio spread, operational approach).

There are three noteworthy models of dynamic spectrum access to be presented later, in particular- of common use, shared-utilization, and elite utilize models. In the common use model, the spectrum is open to access all the clients. This model as of now is being used in the ISM band. In the shared utilize model, approved clients (i.e. essential clients) are allotted the frequency groups which are sharply required by the unapproved clients (i.e. cognitive clients) when they are not involved by the important clients. In the selective utilize model, an approved client could give access of a specific frequency band to an unapproved client for a specific period of time mentioned early .

With opportunistic spectrum access, a cognitive client can misuse unused in-band fragments without making obstruction the dynamic essential clients. There are two methodologies for sharp spectrum access: spectrum underlay and spectrum overlay. The spectrum underlay approach obliges the transmission energy of cognitive clients so that they

Fig 1.5.1 cognitive cycle

work underneath the interference temperature farthest point of essential clients. One approach is transmitting the signals in a wide frequency band so that we can get higher information rate even when the transmission power is low. It will depend on the worst case scenario assuming that the essential clients transmit constantly. Subsequently, it doesn't abuse spectrum blank spaces (i.e. spectrum gaps). Limitations on the transmission control by cognitive clients aint a matter of concern in case of the spectrum overlay approach. It enables cognitive clients to recognize and abuse the spectrum gaps which are characterized in space, time, and frequency. This approach is good with the current spectrum distribution, and, using these lines, the legacy frameworks can keep on operating without influenced by the cognitive radio clients in the future.

At the point when every one of the systems in a heterogeneous domain have cognitive versatile abilities (i.e. every single existing together system have level with motivating forces to adjust), it is alluded to be as symmetric sharing. Then again, when there is at least one system without cognitive/versatile abilities (e.g. concurrence of legacy innovation with cognitive radio innovation, conjunction of effective 802.11 systems with low-control 802.15.4 systems, this is alluded to as uneven spectrum sharing.

2.6 Spectrum sensing

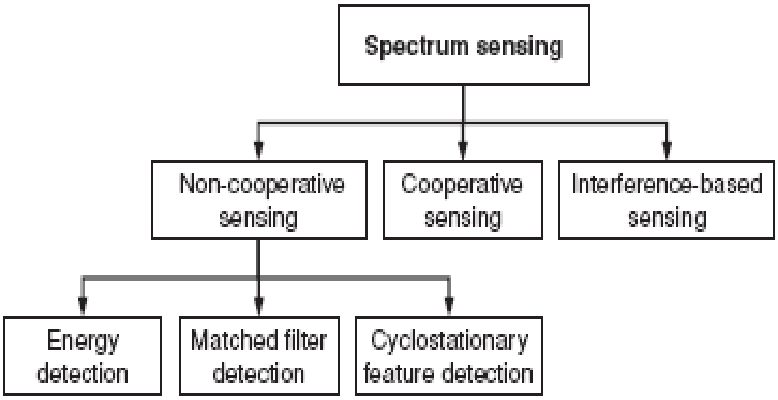

Fig 2.7.1spectrum sensing

The function of CRs to sense whether the given spectrum is vacant or not is called spectrum sensing. Broadly, It can be classified as cooperative and non-cooperative sensing:

2.7 Types of spectrum sensing

2.7.1 Cooperative sensing

An unauthorized transmitter may not always be able to detect the signal from an authorized transmitter due to its geographic separation and channel fading. For example, the transmitter and receiver of the unauthorized client cannot detect the signal

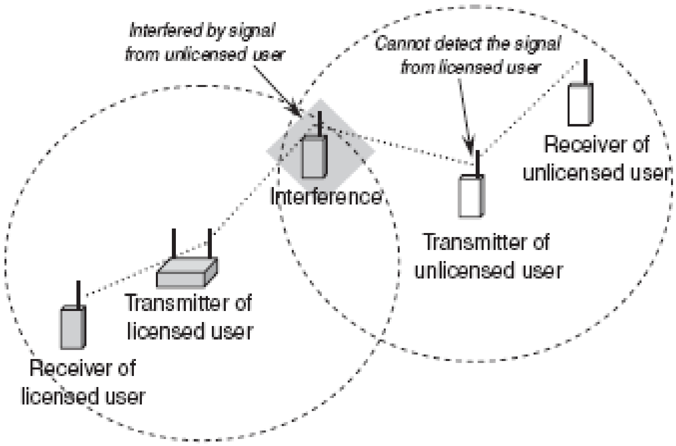

Fig 2.7.2 Hidden node problem

from the transmitter of the approved client since they are out-of-range. This is alluded to as the hidden node issue. For this situation, when the transmitter of the unapproved client transmits, it will meddle with the receiver of the approved client.

To tackle the concealed hub issue in non-cooperative transmitter sensing, cooperative spectrum sensing can be utilized. In cooperative detecting, spectrum sensing data from different unapproved clients are traded among each other to distinguish the nearness of approved clients. The cooperative spectrum sensing design can be either unified or dispersed. Utilizing cooperative trade of spectrum detecting data, the shrouded hub issue can be explained and the detection chance can be essentially enhanced in a vigorously shadowed condition. Be that as it may, this incurs a more prominent communication and calculation overhead contrasted to non-cooperative sensing. For cooperative detecting, two unique systems can be sent to perform spectrum sensing and signal, separately.

For this situation, the sensor network gathers spectrum usage data of approved clients which can be handled by a central controller. At that point a spectrum use guide is made and circulated to the operational system of unapproved clients for streamlining the spectrum signal. Promote exchange on communitarian detecting will be given in next part.

2.7.2 Non cooprative sensing

In this case, cognitive users sense their environment individually and utilizes the result itself without sharing it with other CRs in the network

$$x(t) = \begin{cases} n(t),\ H_0 \\ h * s(t) + n(t),\ H_1 \end{cases} \qquad (1)$$

Here x(t) is the received signal of an unapproved client, s(t) is the transmitted signal of the approved client, n(t) is the added substance white Gaussian noise (AWGN), and h is the channel pick up. Here, H0 and H1 are characterized as the speculations of not having and having a signal from an approved client in the objective frequency band, respectively.

Concept of two hypothesis in Energy Detection method

Spectrum sensing is an important component of cognitive radio system. As a general rule it is the initial step that requires to be performed for correspondence to be taking place. It can be essentially reduced to a recognizable proof issue, demonstrated as per a speculation test. The detecting gear need to just select for one of the 2 speculations

$$\begin{aligned} H1&: x(n) = s(n) + w(n) \\ H0&: x(n) = w(n) \end{aligned} \qquad \textbf{(2)}$$

Where
s(n)-signal that was transmitted by primary user.
x(n)-the signal that was received by the secondary users.
w (n)-the additive white Gaussian noise including variances .

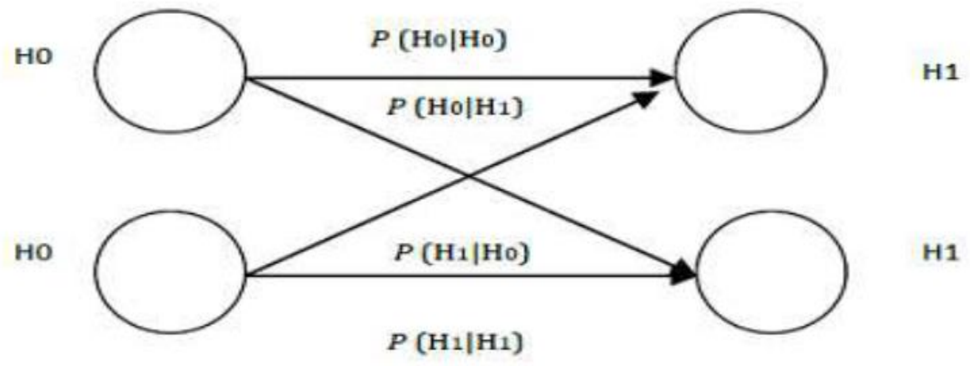

Fig 3.2.1 hypothesis problem model

As appeared in fig 3. 2.1 above Theory H0 demonstrates non attendance of essential client and that the recurrence band of intrigue just has clamor while H1 focuses towards nearness of essential client.

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Thus by looking at the two state hypotheses, numbers of important cases can be described as follows :-

- H1 is TRUE only if primary client is present.this is known as **Chance of Detection (Pd).**

- H0 is TRUE if primary client is present.This is known as **Chance of Miss-Detection (Pm).**

- H1 is true TRUE in case of absence of primary client.This is known as **Chance of False Alarm (Pf).**

The chance of detection is of major concern because it provides the prospect of properly sensing for the presence of commissioned shoppers within the waveband. likelihood of miss detection is simply the complement of detection likelihood. The goal of the sensing schemes is to maximise the detection likelihood for a coffee likelihood of warning.

Matched filter detection or coherent detection:

Fig 2.7.3 matched filter detection

Matched filter detection for the most part is used to recognize a signal by looking at a known signal (i.e. a layout) with the info signal. A matched filter will augment with the SNR that have been received for the deliberate signal. In this manner, if the data of the signal from an approved client is known as matched filter. It is an ideal locator in stationary Gaussian noise. Since a format is utilized only for signal detection, a matched filter requires small time to work. Be that as it may, if this format is not accessible, the execution of spectrum sensing data bases altogether. Matched filter detection is reasonable when the transmission of an approved client has pilot, prefaces, synchronization word or spreading codes, which could be utilized to build the layout for spectrum sensing.

• ***Transmitter energy detection****:*

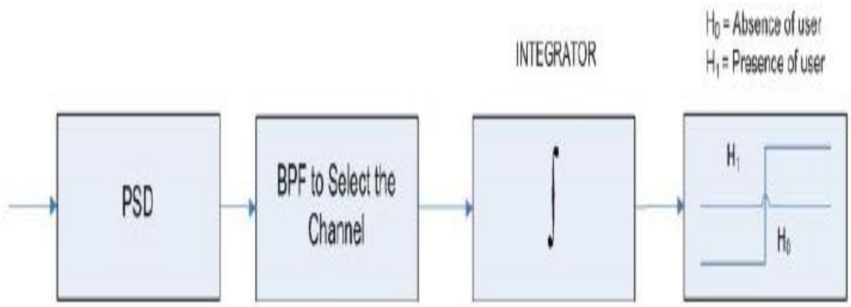

Fig 2.7.4 Energy detection

Energy detection is the ideal technique for spectrum sensing when the data from an approved client is inaccessible. On account of energy location, the output motion from a bandpass filter is squared and matched over the observation interval. A choice calculation contrasts the integrator yield with a threshold to choose whether an approved client will exist or not. As a rule, the energy discovery execution weakens (e.g. Pm increments) when the SNR diminishes. The two deficiencies of energy detection are to be described as follows: (1) It is defense less to the vulnerability of noise power, and (2) it can just distinguish the nearness of the signal yet can't separate the kind of signal (e.g. signals from cognitive clients having a similar channel with the essential client). Along these lines, the detection error would be high in nearness of signal sources other than the approved client.

- ***Cyclostationary feature detection:***

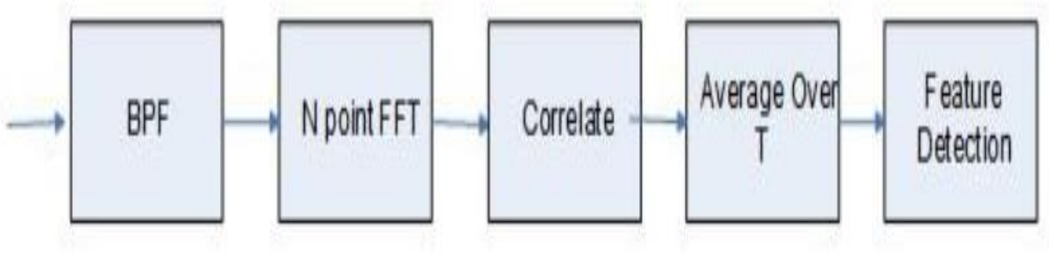

Fig 2.7.5 cyclostationary feature detection

The sent signal from an approved client for the most part have a consistent pattern. This intermittent pattern is called as cyclostationarity, and can be utilized to identify the nearness of an approved client. A signal is called as cyclostationary if the autocorrelation happens to be a periodic function. With this intermittent pattern, the transmitted signal from an approved client can be recognized from noise, which is a wide-sense stationary signal without connection. cyclostationary detection can give a more precise sensing result and it is more invulnerable to varieties in noise control. Be that as it may, the detection is always intricate and requires long observation periods to acquire the sensing result. With a specific end goal to enhance the general execution of spectrum sensing, numerous location techniques can be incorporated in a solitary unapproved framework (e.g.

quick and fine sensing. For instance, energy discovery can be utilized to play out a speedy output of an extensive variety of spectrum bands. The outcomes from energy detection can be utilized to dispose of the spectrum bands with high energy densities (e.g. because of the transmission of approved clients). At that point, include recognition can be connected to a couple competitor bands with low energy densities to look for the exceptional components of a signal from an approved client.

2.8 Spectrum Sensing with the help of Hard Decision Fusion Scheme

The requirement for an omnipresent remote scheme is developing by the multiplication of versatile interactive media specialized gadgets. Thus, greater part of the accessible spectrums as of now have been approved. It along these lines creates the impression that there is almost no space in including any type of new administrations. Additionally looking into this have demonstrated that the greater part of the approved spectrum is to a great extent under-used and can be utilized in the coming time.

A radio is needed along these spectral lines that can distinguish and sense radio spectrum, and briefly observe spectrums available for use and utilize them. This can show higher data transfer capacity and decrease the need for the use of centralized spectrum association. This can be made viable by a radio that can figure out the choices autonomously. Cognitive radios involves the possibility to do all this. They can bounce through all the spectrum gaps that aren't used to expand the spectrum skill.

CRs have the ability to propel spectral compatibility by sensing the environment and, by keeping in mind that our end goal is to give environment of service to the client to whom the spectrum was allocated primarily, filling holes that were found of the unused approved spectrum with the help of their own particular transmissions. Exact spectrum recognition is the main worry for the CR system. In that case it is suggested to use a versatile transmission in vacant spectral bands. Also it shouldn't cause impedance for any of the important (primary) client. The transmissions by the approved clients must be recognized and observed without failure. Also the principle reason for versatile transmission is actually the detection of exact location of empty spectral bands. To get most extreme throughput without making any hindrance to the essential client's nature of service. Hence, a dependable spectrum sensing method is required. Energy detection demonstrates effortlessness and appears to be a workable spectrum sensing procedure. In order to enhance the spectrum sensing for Cognitive Radio network (CRN), Cooperative sensing is proposed to eradicate these issues of spectrum sensing, such as-blurring,shadowing, and beneficiary instability issues.

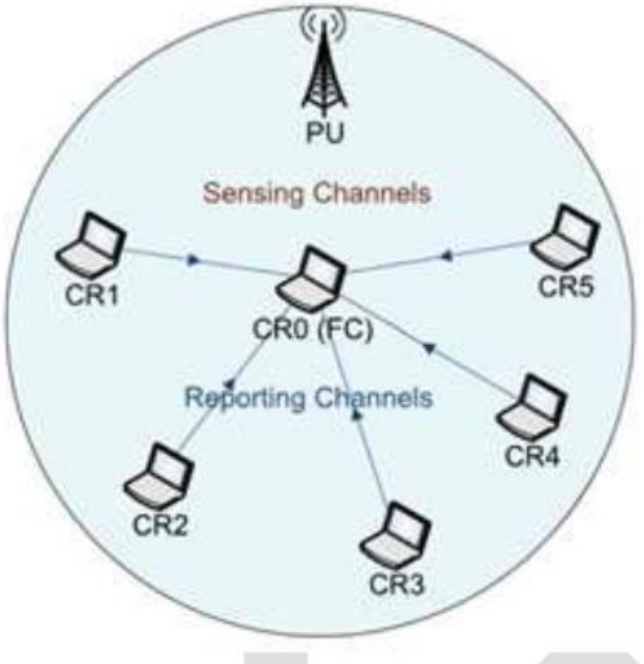

Fig 2.8.1 centralized cooperative spectrum sensing

In the arduous call combination theme, close selections of the hubs area unit sent to the leader. the elemental advantage of this strategy is that the means that it wants restricted information measure. The calculation for this set up is as per the subsequent. every hub ab initio performs neighbourhood spectrum detective work and settles on a twofold call on whether or not a symbol of intrigue is accessible or not by different the detected energy and a limit. All hubs send their one-bit call outcome to the chief node. At that time, an officer call on the closeness of the signal of interest is settled on by the chief. the placement likelihood Pd, miss recognition likelihood pm and warning likelihood Pf over AWGN diverts is communicated in following way:

$$\boldsymbol{P_{d,k}} = \boldsymbol{Q_m}(\sqrt{\boldsymbol{2y}}, \sqrt{\boldsymbol{\lambda}}) \quad \textbf{(3)}$$

$$\boldsymbol{P_{m,k}} = \mathbf{1} - \boldsymbol{P_{d,k}} \quad \textbf{(4)}$$

$$\boldsymbol{P_{f,k}} = \frac{\Gamma(\boldsymbol{m}, \boldsymbol{\lambda}/\mathbf{2})}{\Gamma(\boldsymbol{m})} \quad \textbf{(5)}$$

Where y is the signal to noise ratio (SNR), m=TW is the time data transfer capacity , Qm(- ,-) is the summed up Marcum Q work, Γ (.) and Γ (.,.) are finished and deficient gamma works separately.

There are three guidelines utilized by the decision taker for the last decision are currently talked about

2.8.1 Logical- OR Rule

In this method, if any 1 of the neighborhood decisions sent to the chief is a consistent one , an official decision settled on by the leader is one (i.e. chief chooses that the signal of intrigue is available). Helpful recognition chance Qd, agreeable false caution chance Qf and Agreeable miss identification chance Qmd are characterized as

$$\boldsymbol{Q_{d,or}} = \mathbf{1} - \prod_{\boldsymbol{k}=\mathbf{1}}^{\boldsymbol{k}} (\mathbf{1} - \boldsymbol{Pd}, \boldsymbol{k}) \quad \textbf{(6)}$$

$$\boldsymbol{Q_{f,or}} = \mathbf{1} - \prod_{\boldsymbol{k}=\mathbf{1}}^{\boldsymbol{k}} (\mathbf{1} - \boldsymbol{Pf}, \boldsymbol{k}) \quad \textbf{(7)}$$

$$Q_{md,or} = 1 - Q_{d,or} \qquad (8)$$

2.8.2 **Logical-AND Rule**

In this rule, if the greater part of the neighborhood decisions sent to the chief are one (i.e., the majority of the hubs choose that the signal of intrigue is available), a ultimate conclusion settled on by the leader is one (i.e., chief chooses that the signal of intrigue is available).

$$Q_{d,and} = \prod_{k=1}^{k} Pd,k \qquad (9)$$

$$Q_{f,and} = \prod_{k=1}^{k} Pf,k \qquad (10)$$

$$Q_{md,and} = 1 - Q_{d,and} \qquad (11)$$

2.8.3 **Majority Rule**

In this rule, if one by two or more of the local decisions forwarded to the decision maker are 1, the final decision made by the decision maker is one .

CHAPTER 3
ANTENNA DIVERSITY

3.1 Introduction:

Antenna diversity is a kind of wireless diversity scheme which uses two or more than two antenna to increases the reliability of the wireless link. Especially increase of urban and indoor environments, there is absence of (LOS) b\n transmitter and receiver. Rather the signal is reflected in different direction before received at the receiver.

It is specially important in removing the multipath reflection . since large no of antennas provide a receiver many observation of the signal. Every antenna would have a different kind of obstacle. Hence, if any antenna experiences fad , other has a sufficient signal. Ultimately this type of arrangement will provide robust mechanism. Although it is basically seen in receiving system analog had proven important for transmission diversity.

There are different types of antenna techniques namely : spatial techniques, pattern diversity, polarization diversity, transmit diversity, adaptive diversity

Since , above mentioned techniques need processing also ,therefore there are following types of processing techniques: switching, selecting, combining and dynamic control

APPLICATIONS:

-Mobile phone towers: we use two antennas one for transmitter and other for receiving

-Used in wi-fi networking to avoid multipath reflections.

We are using 3 different diversity techniques here essentially.

Those are- Selection Combining, Equal Gain Combining, Maximal Ratio Combining,.

3.2 COMBINING TECHNIQUES

3.2.1 SELECTION COMBINING

Diversity combining technique is the technique applied to combining multiple received signal of a diversity reception device into a single improved signal. In the performance analysis of cooperative diversity techniques, maximum set of information is considered. In order to select the relaying link that has the highest gain among all the diversity branches we are considering the selection combining schemes. Any additional gain diminishes rapidly with the increasing number of channels. This is a more efficient technique than switched combining In this scheme, two strategies are considered:) the combiner selects the relaying branch with highest SNR (γr). ii) the relay with highest min(γs, γr) is selected. We are considering two hypotheses Ho and H1.

Ho: absence of primary users.

H1: presence of primary users.

Instead of SNR, channel gain is used to determine the two hypotheses. If Y denotes the signal power at the output combiner, then the mean value of Y for a given g can be

expressed as

$$E\,Y/g = \begin{cases} \boldsymbol{\sigma yo} = N_0(1 + Ascg)H_0 \\ \boldsymbol{\sigma yo} = N_0(1 + (1 + \boldsymbol{\gamma sc})Ascg)H_0 \end{cases} \qquad \textbf{(12)}$$

Sometimes more than one combining technique is used for example, lucky imaging uses selection combining to choose the best 10% images, followed by equal-gain combining of the selected images. Other signal combination techniques have been designed for noise reduction and have found applications in single molecule biophysics and chemo metrics among others.

3.2.2 EQUAL GAIN COMBINING:

In equal gain combining we first co-phase the signals on individual branches and then combine them with equal magnitude Coefficient on branch l.
Instantaneous bit energy to noise ratio for i^{th} receive antenna in the presence of channel hi is given by:

$$\boldsymbol{\gamma_i = \frac{|h_i|^2 E_b}{N_0}} \qquad \textbf{(13)}$$

3.2.3 MAXIMAL RATIO COMBINING

In broadcast communications, maximal-ratio combining (MRC) is a strategy for differences combining in which: the inputs from each channel are included, the gain of each channel is made corresponding to the rms signal level and contrarily relative to the mean square noise level in that channel and distinctive proportionality constants are utilized for each channel. It is otherwise called proportion squared combining and forecast joining. Maximal proportion consolidating is the ideal combiner for autonomous AWGN channels. MRC can reestablish a signal to its unique shape.

In numerous performances examination calculation of entirety of the squared envelopes of the faded signals over several fading signals over diversity paths uses MRC schemes.MRC collector measures its info motion with their channel insights and is known to be of elite.

$$\boldsymbol{\gamma} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \frac{|\boldsymbol{h_i}|^2 \boldsymbol{E_b}}{\boldsymbol{N_0}} \qquad (14)$$

$$= N\gamma_i$$

3.3 SINGLE ANTENNA CR'S

For single antennas on the receiver's end, we discuss the variation in Pd and Pf with changing the number of antennas. Additive White Gaussian Noise Channel obeys Gaussian distribution of zero (mean and variance) hence, on calculating energy En , the distribution is altered. an follows the central chi-square distribution with degrees of freedom having L real components and imaginary components) and under this hypothesis H1, follows non-central chi-square distribution with the non-centrality parameter and the degrees of freedoms and the SNR all equal. Gaussian distribution don't get affected by IDFT and DFT blocks.
In case of single antennas, there is only one antenna on both the transmitter and the receiver end.
So, the case of antennas diversity doesn't arise here. However, due to this reason we have to compromise with the performance. It's very likely to receive a slightly distorted signal(especially when the transmitter and the receiver don't lie in the Line of Sight)

3.4 MULTIPLE ANTENNA CR'S

Now we discuss the Spectrum Sensing efficiency for multiple antenna on the CRs. From *n*-th subcarrier, the *m*-th antenna, the L samples that are received is given by:

$$r_n^m(l) = \begin{cases} G_n^m(l),\ H_0 \\ S_n^m[l] + G_n^m[l]H_1 \end{cases} \qquad (15)$$

Here
Ho denotes that *n*-th subcarrier is vacant.
H1 denotes *n*-th subcarrier is occupied.

In case of Energy Gain Combining, diversity technique energy for antennas of the CR from 1 to M and the –nth subcarrier is given as:

$$\sum_{m=1}^{M}\sum_{l=1}^{L}[\,|r_n^m[l]|^2 \qquad \textbf{(16)}$$

Where M square measure the amount of antennas the metallic element is provided with.
Now the SNR of the signal gets increased when the SNRs of different antennas get added in the slightest degree in M branches.So,

$$\gamma_t = \sum_{m=1}^{M}\gamma_m \qquad (17)$$

3.5 Potential Application

3.5.1 Cluster based cooperative Spectrum Sensing

First of all we need to address the question- why did the need for cluster based spectrum sensing arose.

In case of non-cooperative based sensing, we can use a lot of cooperative users and this doesn't pose any as such difficulty to handle. However, It's not the case with cooperative spectrum sensing methods. The reason being, each and every user in cooperation need to share the decisions with other cooperative users in it's network.

Hence, as the number of cooperative users increases in the network, so does the amount of decisions made by cooperative users(one made by each user).And all those decisions are shared with each and every user. So, a lot of decisions reach each and every cooperative radio user. With increased number of signals to operate on, it results in excessive overhead for those users. To sort it out, clustering is an optimal solution. What we do is we group the cooperative users into different clusters based on location(there can be various other reasons).Now the cooperative users inside a cluster share information only with the cluster head that is chosen by themselves. The cooperative user having the maximum gain in a cluster is often chosen as the cluster head of that specific Cluster. The cluster head makes the final decision for that cluster head by gathering all the information it gets from the cluster members.

Similarly there are many clusters. Together ,they choose a main head. The cluster heads of each cluster shares it’s decision with the main head which makes the final decision (whether the spectrum is vacant or occupied).Once the decision is made. It is shared with all the cluster heads which is then shared with the members of their respective cluster. In this way cooperation happens in the cluster based spectrum sensing. We often use hard decision rule to make decision at any of the cluster heads or the main head.

Hence our first project is on the hard decision rule(especially AND & OR rule).

Now, the result can be improved even further if sub clustering is done as second level of clustering. This is called two level clustering.

Now in case more than 1 antenna are used on different cognitive users. For example inside a cluster one of the cognitive users has only one antenna while 3 cooperative users have 5 antennas. The remaining 2 users have 3 antennas. Now those having same number of antennas are termed commonly as Virtual Sub cluster. Hence we can say the cognitive users having 3 antennas in Cluster1, are grouped as Virtual Subcluster1.Those with 1 antenna as VSC2 and those with 5 as VSC3.

Each of the virtual sub clusters is assigned certain weights for their decision. The cognitive users inside the cluster (From all virtual sub clusters) send their decisions to the cluster heads. Those cluster heads make a final decision based on the weight of the decision of the virtual sub clusters. Generally, the more the antennas, more the weight assigned to the decision. Nearer the cluster, more the weight assigned to it’s decision.

Hence, multiple antennas get used in this case. Because multiple antennas are being used, a lot of questions arise.

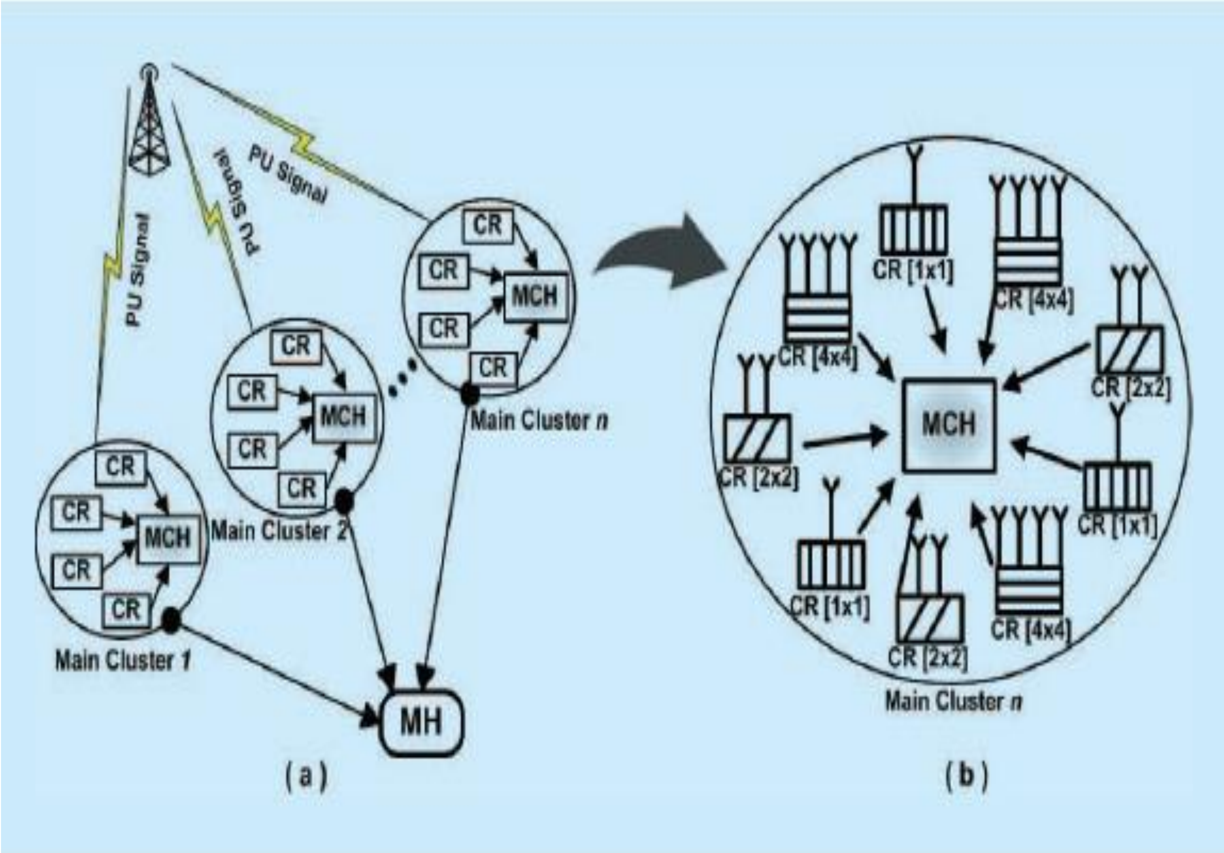

Fig 3.5.1 (a) system model (b) main cluster

CHAPTER -4

SIMULATIONS & RESULTS

Parameters	**Attributes**
Channel	AWGN
No.of transmitter antenna	1
No. of receiver antenna	Varies from 1 to 20
SNR value used	-10 dB

4.1 ROC curve in case of Hard decision rules.(Spectrum Sensing by Energy Detection)

Here we have studied the detection performance of our scheme by simulation on matlab using complementary ROC graphs. We have demonstrated the performance of the energy detection
we have demonstrated the variation of probability of detection with respect to the probability of false alarm using the hard decision rules –AND decision rule. We are comparing the performance of AND decision rule with the theoretical value obtained by OR decision rule by using the Monte Carlo techniques that uses 1000 repetitions.
For the theoretical value, the no. of chosen clients are different than those being obtained through simulation using assumptions mentioned above.

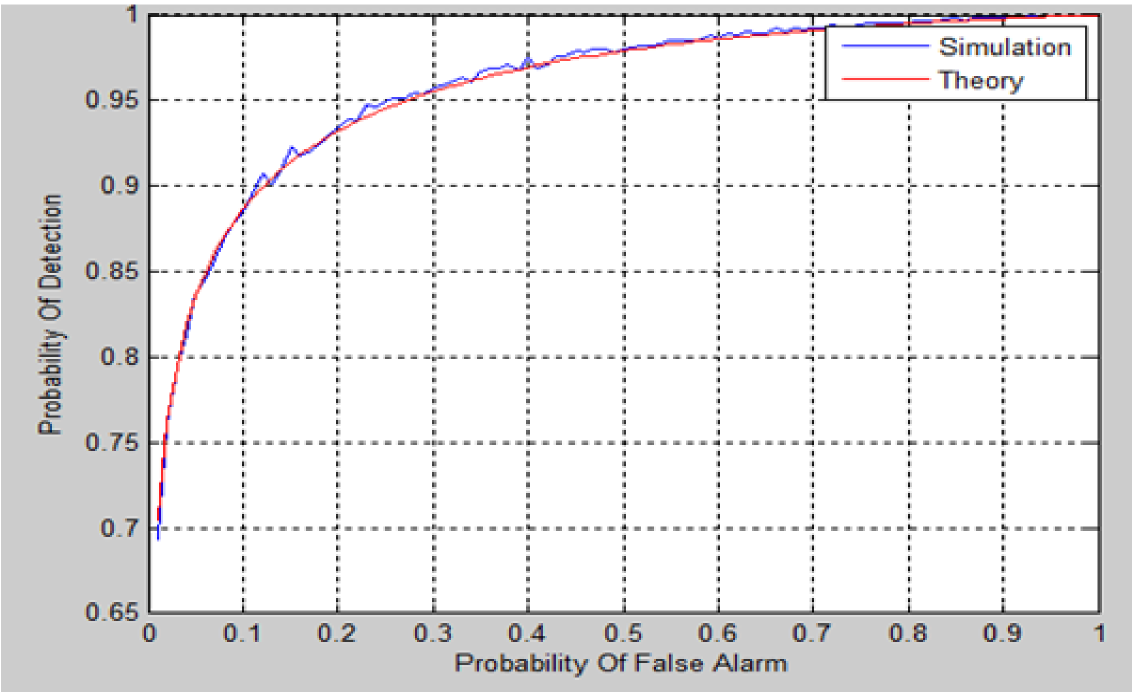

Fig 4.1.1 Complementary ROC curve under AWGN channel for single node (i.e. without cooperation).

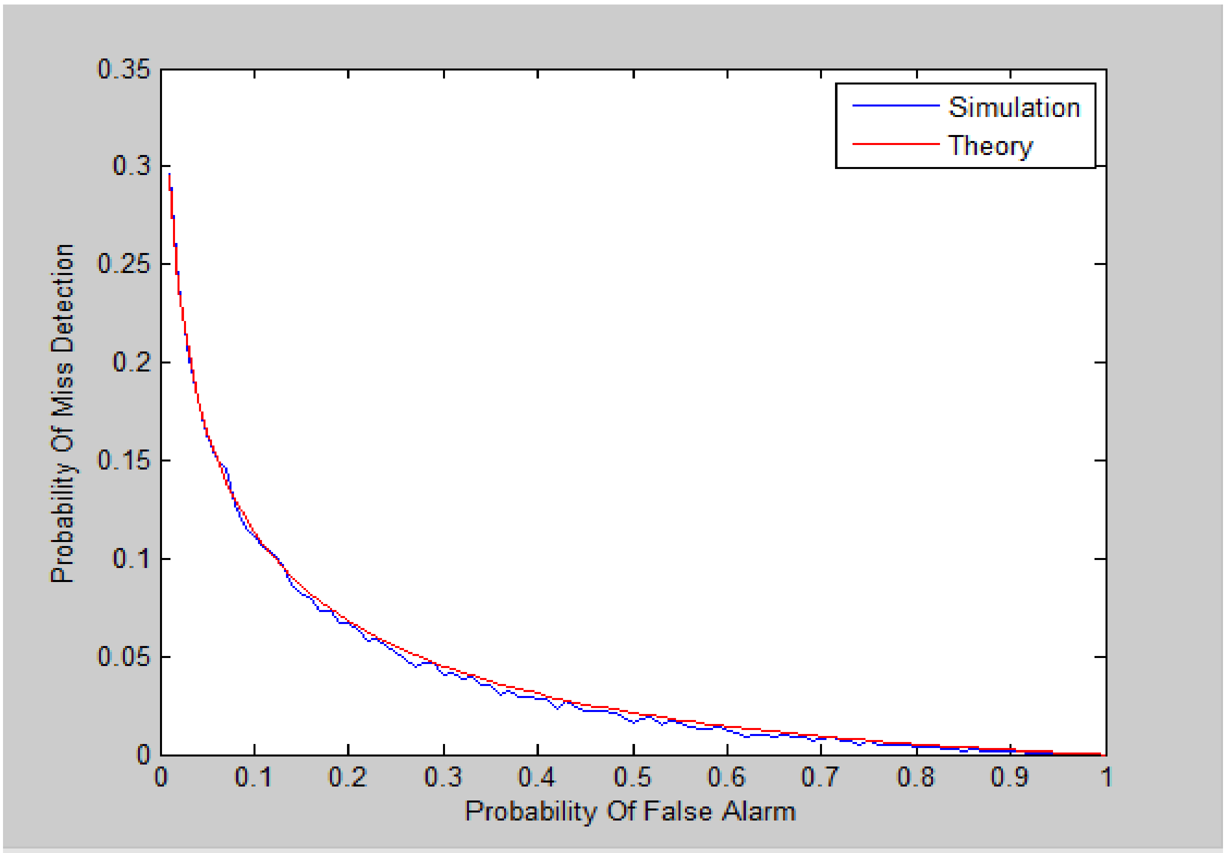

Fig 4.1.2 comparing the complementary curve of hard decision logical _OR' rule with the theoretical part of hard rule

4.2 Variation in SNR for multiple antennas by using different Diversity techniques

Here, we are observing the value of SNR if we use different antenna diversity schemes.As mentioned above, we are using multiple antennas(varies from 1 to 20) on the receiver end,only one antenna on the transmitter end,the channel used is AWGN and different diversity techniques to find an optimum SNR level for use.

As we increase the number of antennas form 1 to 20 on the receiver's end, we observe the variation in the value of SNR. It's obvious that as the number of receiving antennas are increasing the SNR of the received signal should increase.
However, the value of SNR changes if we change the diversity technique we are using.
In the first case we are using Selection Combining to find out how the SNR value changes with the change in number of receiving antennas.
Similarly, in the second case, we are using Maximal Ratio Combining to find out how they change with respect to the change in no. of receiving antennas.
And finally we are using Equal Gain Combining for the same variation and observe the result as follows.

Selection combining

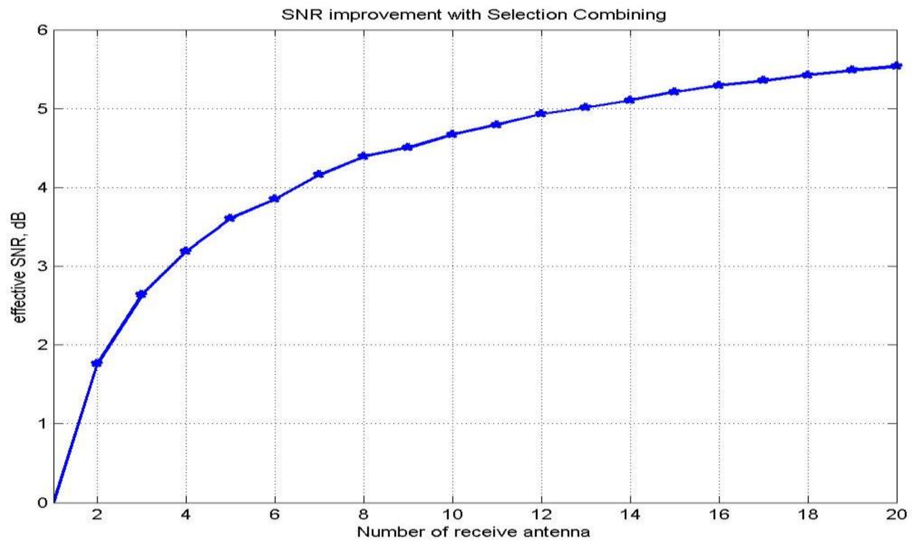

Fig 4.2.1 SNR versus Number of received antenna

In fig 4.2.1 we have illustrated the variation of SNR value of received signal with increasing number of received antennas in case of selection combining

Maximal ratio combining

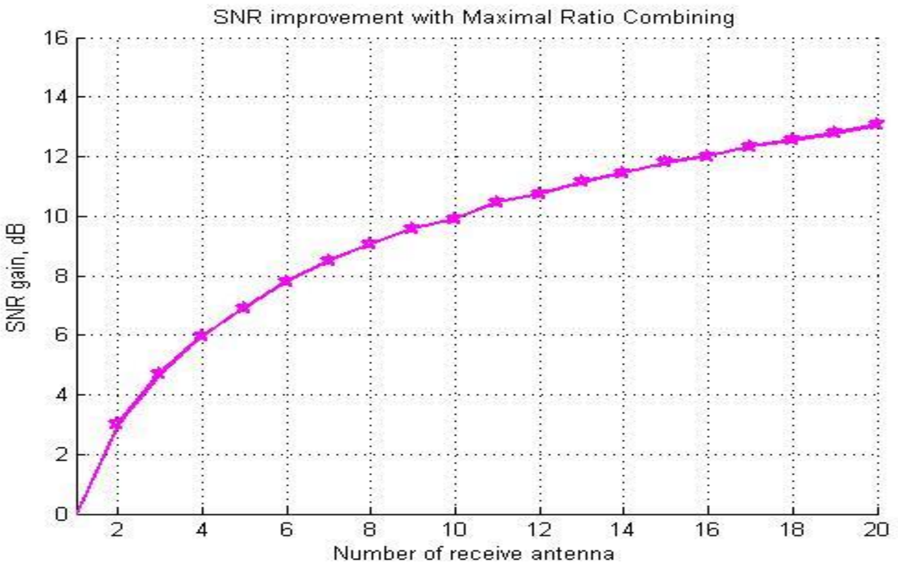

Fig 4.2.2 SNR versus Number of received antenna

In fig. 4.2.2, we have illustrated the variation of SNR value of received signal with increasing number of received antennas in case of maximal ratio combining

Equal gain combining

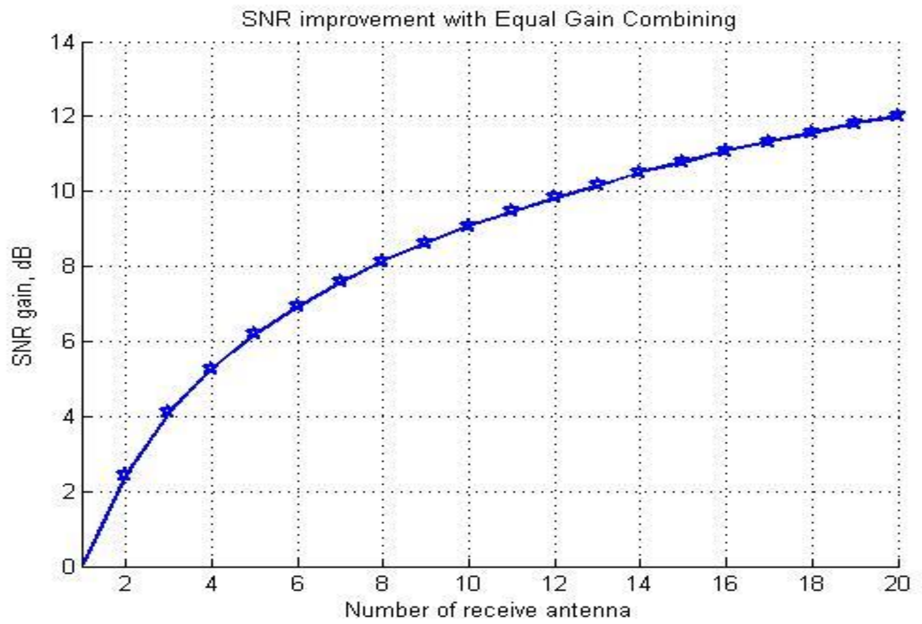

Fig 4.2.3 SNR versus Number of received antenna

In fig. 4.2.3 we illustrate the effect of received antenna on SNR(in dB) for EGC. SNR is increase as we increase the number of antenna.

<u>Comparison</u>

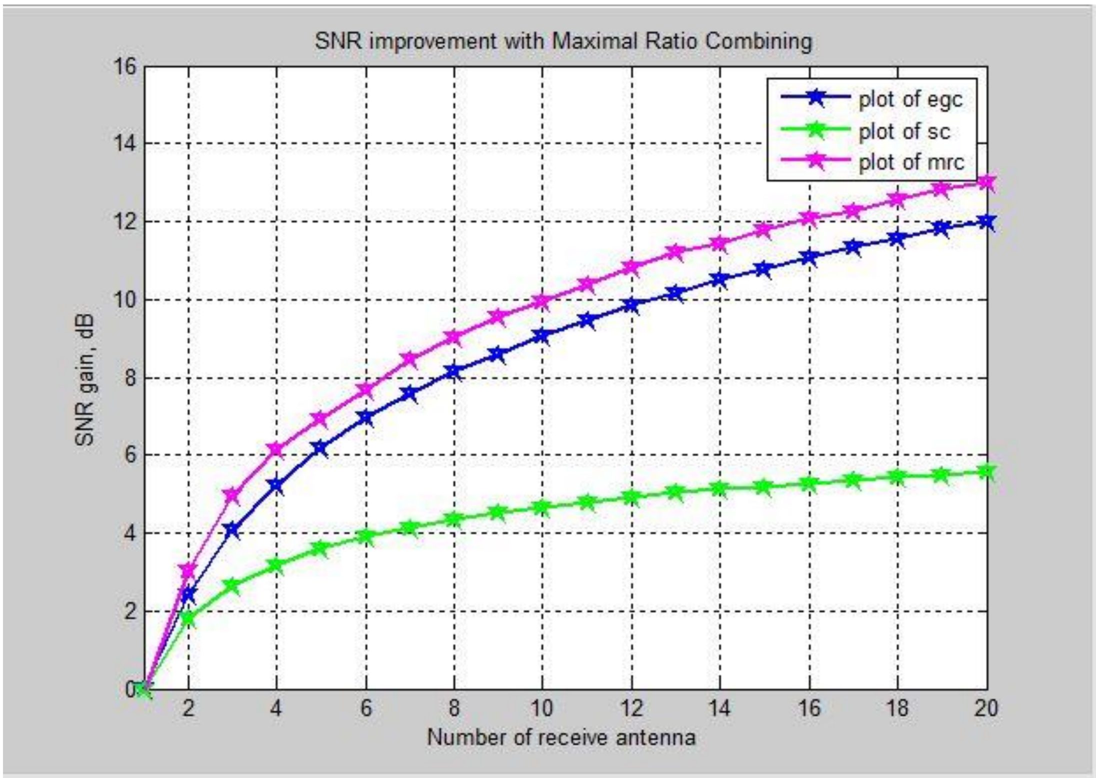

Fig 4.2.4 SNR gain comparison between diversity techniques with varying number of received antennas.

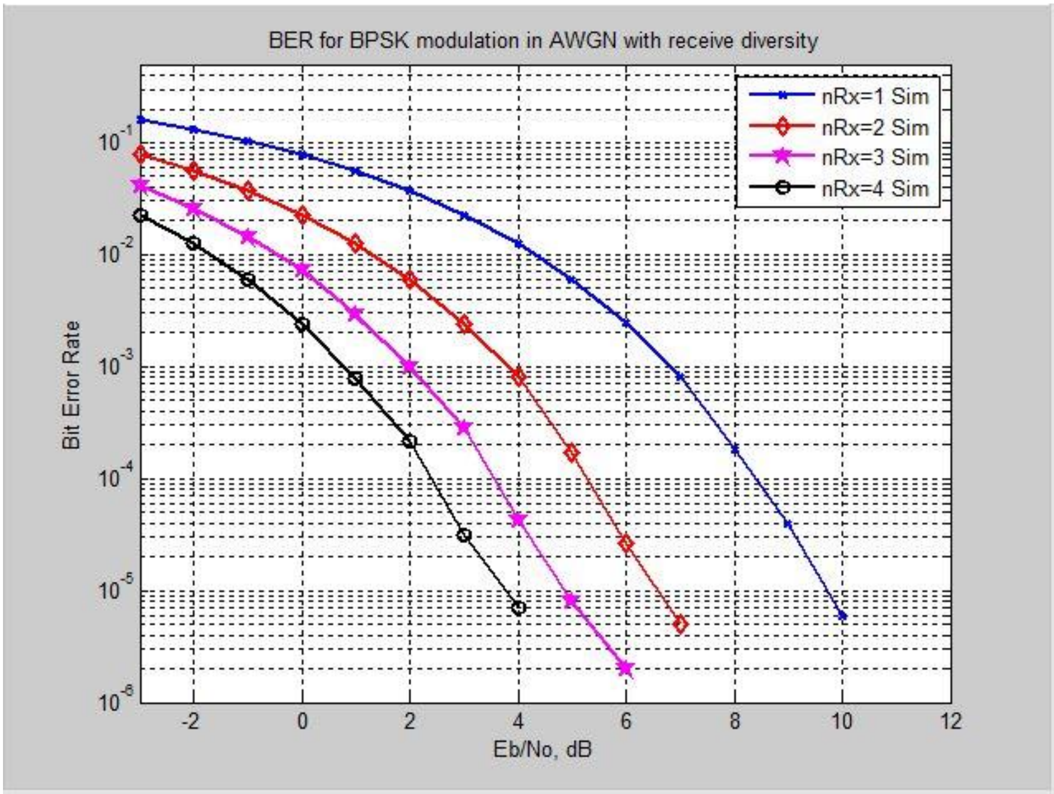

Fig 4.2.5 variation of BER of received signal with increasing number of received antennas.

Conclusion

By studying the variation of Probability of detection with respect to Probability of false alarm,we concluded that at a fixed SNR value,the Probability of detection is inversely proportional to the Probability of false alarm in a case of energy detection method.But what if we increase the SNR value,then we are able to get a higher detection probability while the false alarm probability is still low.We increased the SNR value of received signal by apllying multiple antennas on the receiver end.We applied three diversity techniques namely EGC, MRC and SC.By studying all these three diversity techniques and the variation of net SNR on varying the number of receiving antennas, we concluded that the Selection Combining performed the poorest among the lost in the circumstances provided. Maximal Ration Combining proved itself to be most beneficial as the SNR values remained the highest when we used this diversity technique among the lot. Equal Gain Combining was pretty close to MRC as the SNR value we got using this technique wasn't very less from what we got using MRC.

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