SPECTRUM SENSING USING FUZZY LOGIC

IN

COGNITIVE RADIO

Submitted in partial fulfillment of the Degree of

BACHELOR OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

BY

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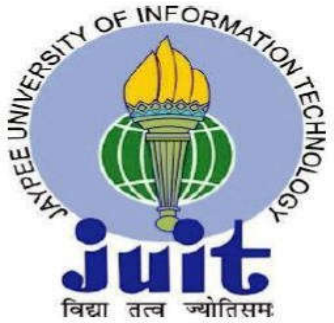

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CERTIFICATE

This is to ensure that venture report entitled "Spectrum Sensing in Cognitive Radio using Fuzzy Logic", put together by Ramneet Kaur and Siddharth Sharma in fractional satisfaction for the honor of level of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan, has been completed under my supervision.

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Ramneet Kaur (151045)

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ABSTRACT

Wireless communication was a technology that brought a revolution in the field of communication and with the arrival came the gush of customers in wireless network. Cognitive radio is an intelligent device , in literal meaning cognitive means intelligence, which means it has a knowledge about the surroundings and it works according to the surrounding. The need of latest technology like cognitive radio was raised because of the scarcity of the bandwidth that was being sensed in the tech field . Unused portions of bandwidth going waste or unused by the users , can be re-used was the main motive . cognitive radio helps to remove the problem of scarcity in a spectrum. This is done by allowing the secondary users to enter the spectrum.(The unoccupied and unused part of the spectrum).

Sensing the spectrum availability is the main challenge once the motive is decided Spectrum sensing refers to sensing whether the spectrum is available for secondary user without disturbing the primary user .There are various spectrum sensing techniques that are being applied to sense the availability . Energy detection method involves comparing the power of the received signal to the threshold calculated. other methods like cyclostationary filter and matched filter are used in order to find the same.

Each method for sensing the spectrum has its drawback and advantages. Fuzzy logic is applied for a better result detecting free spectrum . fuzzy is applied in two stage spectrum sensing techniques [3]. In between the region of two threshold lies the fuzzy region that is the confused region and fuzzy logic is applied to find better and improved results.

List of Symbols and Acronyms

γ_s SNR at Secondary User

l Length of the element of Antenna

c Speed of Light in Vacuum

σ Noise

SNR : Signal to Noise Ratio

RF : Radio Frequency

IEEE : Institute of Electrical and Electronics Engineers

CR : Cognitive Radio

VHF : Very High Frequency

UHF : Ultra High Frequency

DSA : Dynamic Spectrum Allocation

FCA : Fixed Channel Allocation

TVWS : Television White Spaces

QoS : Quality of Service

PU : Primary/Licensed User

SU : Secondary User

MF : Membership Function

FCC : Federal Communications Commission

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INTRODUCTION

Because of the developing interest of the remote correspondences exceptionally in the situation when we have restricted or under used assets, increasingly more spectrum assets are required which gives us the inspiration of Cognitive Radio. Cognitive radio is a versatile , Intelligent radio and system innovation that recognizes the accessible diverts in a remote spectrum. Intellectual Radio Systems includes Primary Users (PU) and Secondary Users (SU). In the event that the sign is unfit to recognize the nearness of PU it alludes to the SU, with the goal that it doesn't make any association the PU [1].

Out of all the biggest reason that tends to inefficiency in usage of the radio spectrum is the licensing scheme in the spectrum allocation. The traditional command - and – control model which is followed while distribution of spectrum holds a drawback that the radio spectrum allocated to the licensed user is not used by the unlicensed user for its further application and stays ideal when the licensed user is not using the spectrum .And the reason being the static and the inflexible allocation, we need to confined to a dedicated spectrum band operation ,which returns to a wastage in the efficient resource for use. Hence the adaptability of the transmission band with respect to different environment is compromised. So the focus of our tends to lie on the issue that the scarcity of the resources be met with availability.

CHAPTER 1

COGNITIVE RADIO

1.1 INTRODUCTION

Cognitive radio is another worldview of structuring remote correspondence frameworks which expects to improve the use of the Radio Frequency (RF) spectrum. The inspiration behind CR is the shortage of the accessible frequency spectrum, expanding request, brought about by the rising remote applications for remote users . The majority of the accessible radio spectrum has just been allotted to existing remote users, and just some frequency spectrum of it tends to be authorized to new remote applications. Regardless, an examination by the Spectrum Policy Task Force (SPTF) of the Federal Communications Commission (FCC) has demonstrated some results that some frequency groups are intensely utilized by licesensed user at specifically areas and at specific timings, however that there are additionally numerous frequency groups which are just mostly involved or to a great extent vacant , remain unused. For instance we have a case that of spectrum band distributed to cell organizes in the USA which achieve the most elevated usage amid working hours, however remain to a great extent empty from midnight until early morning.

Out of all the biggest reason that tends to inefficiency in usage of the radio spectrum is the licensing scheme in the spectrum allocation. The traditional command - and – control model which is followed while distribution of spectrum holds a drawback that the radio spectrum allocated to the licensed user is not used by the unlicensed user for its further application and stays ideal when the licensed user is not using the spectrum .And the reason being the static and the inflexible allocation, we need to confined to a dedicated spectrum band operation ,which returns to a wastage in the efficient resource for use. Hence the adaptability of the transmission band with respect to different environment is compromised. For instance, in the event that one spectrum band is vigorously utilized, the remote user can't change to work on another on the more utilized band.

The privilege to get to the spectrum is commonly characterized by tansmit power ,frequency,spectrum owner, space, sort of utilization, and the term of permit. Regularly, a permit is allocated to one licensee,

and the utilization of spectrum by this licensee must fit in with the detail in the permit (for example most extreme transmit control, area of base station). In the current spectrum permitting plan, the license can't change the kind of utilization or exchange the privilege to other licensee. This constrains the utilization of the recurrence spectrum and results in low use of the frequency spectrum. Basically, because of the present static spectrum licensing scheme, spectrum holes or spectrum holes arises. Spectrum holes are therefore characterized as frequency bands which are designated to, however in certain areas and at times not used by, licensed users, and, in this way, could be used by unlicensed user.

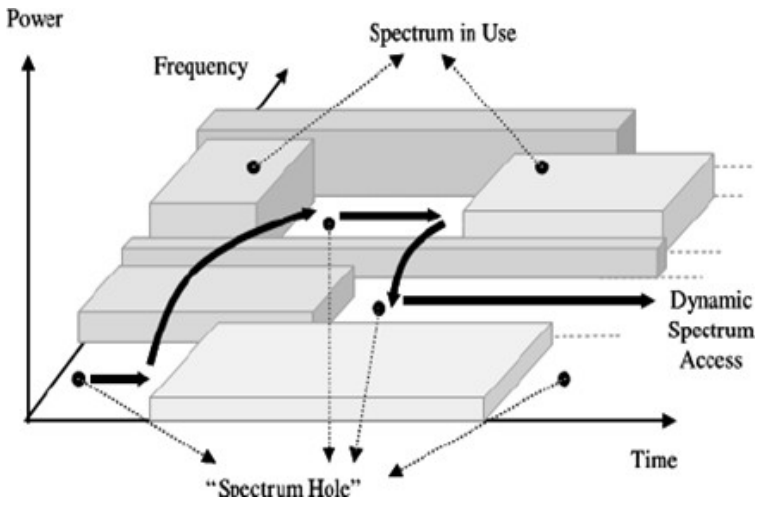


Figure 1.1 Spectrum Holes

The constraints in spectrum access because of the static spectrum authorizing plan can be outlined as pursues:

•Fixed sort of spectrum utilization: In the present spectrum authorizing plan, the kind of spectrum use can't be changed. For instance, a TV band which is apportioned to National Television System Committee (NTSC)- based simple TV can't be utilized by advanced TV communicate or broadband remote access innovations. Notwithstanding, this TV band could remain to a great extent unused in numerous areas because of satellite TV frameworks.

•Licensed for a huge district: When a spectrum is licensed, it is generally allotted to a specific client or remote specialist co-op in a huge locale (for example a whole city or state). In any case,

the remote specialist co-op may utilize the spectrum just in territories with a decent number of supporters, to pick up the most noteworthy rate of profitability. Thus, the dispensed recurrence spectrum stays unused in different regions, and different clients or specialist organizations are disallowed from getting to this spectrum.

•Large lump of licensed spectrum : A remote specialist organization is commonly licensed with a vast piece of radio spectrum (for example 50 MHz). For a specialist organization, it may not be conceivable to get permit for a little spectrum band to use in a specific territory for a brief timeframe to meet a transitory pinnacle traffic load. For instance, a cdma2000 cell specialist organization may require a spectrum with transmission capacity of 1.25MHz or 3.75MHz to give transitory remote access administration in a hotspot territory.

1.2 FUNCTIONS OF COGNITIVE RADIO

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

•Spectrum scrutiny: The data acquired from spectrum sensing is utilized then to calendar and plan spectrum access by the unlicensed clients. For this situation, the correspondence necessities of unlicensed clients are additionally used to enhance the transmission parameters. Real parts of spectrum management that is the spectrum access optimization , spectrum analysis. In spectrum examination, data from spectrum sensing is broke down to pick up information about the spectrum.

•Spectrum sensing: The objective of spectrum sensing is to decide the status of the spectrum and the action of the licensed users by occasionally sensing the objective frequency band. Spectrum sensing can be either concentrated or dispersed. In brought together spectrum sensing, a sensing controller (for example passageway or base station) detects the objective recurrence band, and the data in this manner acquired is imparted to different hubs in the framework Specifically, a cognitive radio handset recognizes an unused spectrum or spectrum openings (for example band,

area, and time) and furthermore decides the strategy for getting to it (for example transmit power and access span) without interfering with the transmission of a licensed user. Spectrum sensing can decrease the complex nature of client terminals, since all the sensing capacities are performed at the sensing controller. Be that as it may, unified spectrum sensing experiences area decent variety. For instance, the sensing controller will most likely be unable to distinguish an unlicensed client at the edge of the cell. In appropriated spectrum sharing, unlicensed clients perform spectrum sensing autonomously, and the spectrum sensing results can be either utilized by individual intellectual radios (for example non-helpful sensing) or imparted to different clients (for example agreeable sensing). But in all ways sensing acquires a

correspondence and handling overhead, the exactness of spectrum sensing is higher than that of non-helpful sensing.

1.3 COMPONENTS OF COGNITIVE RADIO

The real elements of cognitive radio, which are required to adjust the transmission parameters as per the evolving condition, can be spoken to through a "cognitive cycle". The various segments in a cognitive radio handset which actualize these functionalities are demonstrated as follows –

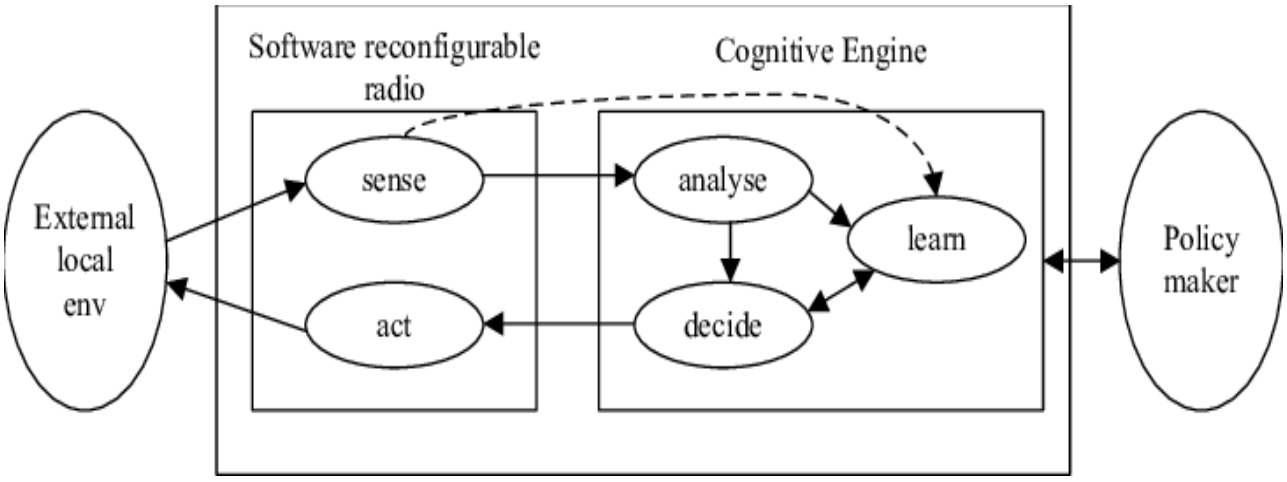


Figure 1.2 Components in a Cognitive Radio

•Transmitter/recipient: A product characterized radio-based remote handset is the significant part with the elements of information signal transmission and gathering. What's more, a remote collector is likewise used to watch the action on the recurrence spectrum (for example spectrum sensing). The handset parameters in the intellectual radio hub can be progressively changed as directed by higher layer conventions.

• Spectrum analyzer: The spectrum analyzer utilizes estimated sign to dissect the spectrum utilization (for example to identify the mark of a sign from a licensed client and to discover spectrum openings for unlicensed clients to get to). The spectrum analyzer must guarantee that the transmission of a licensed client isn't meddled with if an unlicensed client chooses to get to the spectrum. For this situation, different sign preparing procedures can be utilized to get spectrum utilization data.

•Knowledge extraction/getting the hang of: Learning and learning extraction utilize the data on spectrum use to comprehend the encompassing RF condition (for example the conduct of licensed clients). A learning base of the spectrum get to condition is fabricated and kept up, which is consequently used to streamline and adjust the transmission parameters to accomplish the ideal goal under different imperatives.

1.4 POTENTIAL APPLICATIONS OF COGNITIVE RADIO

Subjective radio ideas can be connected to an assortment of remote interchanges situations, a couple of which are portrayed underneath:

•Next age remote systems: Cognitive radio is relied upon to be a key innovation for cutting edge heterogeneous remote systems. Intellectual radio will give insight to both the client side and supplier side types of gear to deal with the air interface and system proficiently. At the client side, a cell phone with numerous air interfaces (for example WiFi, WiMAX, cell) can watch the status of the remote access systems (for example transmission quality, throughput, postponement, and blockage) and settle on a choice on choosing the entrance system to interface with. At the supplier side, radio asset from numerous systems can be streamlined for the given arrangement of versatile clients and their QoS prerequisites. In view of the portability and traffic

example of the clients, proficient burden adjusting components can be actualized at the specialist co-op's foundation to appropriate the traffic load among different accessible systems to diminish organize clog.

•Coexistence of various remote innovations: New remote advancements (for example IEEE 802.22-based WRANs) are being created to reuse the radio spectrum distributed to different remote administrations (for example Television administration). Subjective radio is an answer for give conjunction between these various advances and remote administrations. For instance, IEEE 802.22-based WRAN clients can entrepreneurially utilize the TV band when there is no TV client close-by or when a TV station isn't communicating. Spectrum sensing and spectrum the executives will be pivotal segments for IEEE 802.22 standard-based WRAN innovation to keep away from obstruction to TV clients and to expand throughput for the WRAN clients.

•e-Health administrations: Various sorts of remote advances are embraced in social insurance administrations to improve productivity of the patient consideration and medicinal services the board. Nonetheless, utilizing remote specialized gadgets in social insurance application is obliged by EMI (electromagnetic obstruction) and EMC (electromagnetic similarity) prerequisites. Since the restorative types of gear and bio-signal sensors are delicate to EMI, the transmit intensity of the remote gadgets must be deliberately controlled. Additionally, extraordinary biomedical gadgets (for example careful hardware, analytic and checking gadgets) use RF transmission. The spectrum use of these gadgets must be painstakingly picked to keep away from obstruction with one another. For this situation, subjective radio ideas can be connected. For instance, numerous remote restorative sensors are intended to work in the ISM (modern, logical, and medicinal) band, which can utilize subjective radio ideas to pick reasonable transmission groups to keep away from impedance.

CHAPTER-2

LITERATURE

REVIEW

In the present era, how important is the communication, transmission and broadcasting of information and data is , explaining the importance of it would be a waste of time . Radio frequency range is from 300 GHz to 9 kHz. The whole idea of transmitting a piece of information or data between a transmitter and receiver through a single or various chanel system , happen to occur over this frequency range . The band of frequency called Radio frequency with the help transmitter and antennas , can be used for several type of wireless communication, From cell phones to police scanners, from TV sets to garage-door openers, virtually every wireless device depends on access to the radio frequency wireless spectrum. As a result , the over usage of the spectrum of the radio frequency now results in the scarcity frequency range .As a growth of the applications ,the spectrum allocation has become very scarce.

In such scenario, CR has been a relief which tackles with the problem of spectrum scarcity. Cognitive radio works on the principle of CR device relies on a cycle of observation, analysis, and decision and an opportunistic access to the available bandwidth. Hence the CR device has to sense the presense of primary user and then opportunistically transmits whenever a frequency/time slot is vacant. Considering the spectrum utilization at various bands , there is an clear opportunity to use them again in future. By the priority of users in the usage of the frequency band in the CR , there are two type of users namely , Primary users often termed as licensed user and secondary users. Usually the SU's are allowed to use the frequency spectrum so that they do not overlay with PU's or cause any disturbance for the primary user.There are various methods of spectrum sensing done by cognitive radio . Sensing can be done methods namely, Energy detection method ,Matched filter, Cyclostationary based detection, Fuzzy based detection . Each method has its own drawback and advantages. Fuzzy based detection is the latest detection method that is being implemented and has great advantages over the other methods . because fuzzy theory helps dealing with the the uncertain noise and conditions , when RF environment is changing too fast .Fuzzy logic is implemented at the FC (fusion centre) . Single threshold is also considered for detection . where a single threshold is decided and presense and absence of primary user is decided on the basis of that .whereas in double threshold method lemda1 and lemda2 ,two threshold are calculated and the region between them is considered as confused region or fuzzy region .The decision at Fuzzy region is taken by FLD (fuzzy logic detector) .While calculating the thresholds , there are n Number of samples taken .

Spectrum sensing in part CR identifies the presence of PU. In cooperative sensing , data from neighbouring CR terminals is considered and final decision is taken . Phase one , each nodes

gives a decision of spectrum LOW, medium, high. And in phase two ,performs cooperative sensing by taking the decision by the corresponding nodes also.

The data fusion centre , fuzzy logic is implemented . It considers the SNR of the corresponding CR's . In Each CR the value of power transmitted over a certain bandwidth is recorded and SNR also. To make a decision the value of own SNR and power is taken and neighboring two CR's power is taken into consideration. The membership function low , high, medium is used. Fuzzy logic is implemented so to improve the sensing results , however there is a drawback that time is more consumed .but as far as our results of detection of whether a primary ,licensed user is present or absent are more accurate ,so that the the band of frequency can be considered to reuse ,it is worth it.

CHAPTER 3

SPECTRUM SENSING

Practically speaking, the unlicensed clients, additionally called optional clients (SUs), need to persistently screen the exercises of the licensed clients, likewise called essential clients (PUs), to discover the spectrum Holes (SHs), which is characterized as the spectrum groups that can be utilized by the SUs without interfering with the PUs. This system is called spectrum sensing.

Spectrum in strict significance implies something used to order anything as far as its position or a size of two extraordinary focuses (like in Rainbow, created by detachment of the segments of light by their various edges ,degrees of refraction ,as indicated by wavelength).

3.1 SINGLE STAGE SPECTRUM SENSING

Single stage spectrum sensing includes estimation at first stage which is additionally trailed by decision stage. For a signal transmitted by PU, the secondary user needs to separate between the accompanying speculations.

$$y(n) = \begin{Bmatrix} w(n), H_0, PU\ Signal\ is\ absent \\ w(n) + h(n), H_1, PU\ Signal\ is\ present \end{Bmatrix}$$

Equation – 3.1

In ordinary discovery plot, Test measurements is determined and contrasted and a fixed limit as appeared in fig3.1.If test measurement is more noteworthy than Threshold ,H1 is proclaimed generally H0 is announced.

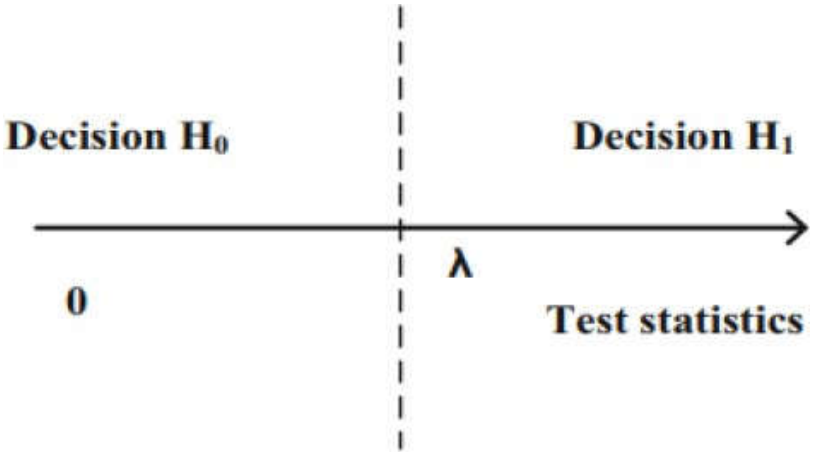


Figure 3.1 single threshold

For all intents and purposes managing when essential client is permitted to a channel is attenuated with commotion factors which circumscribely gets connected with vitality factors and is decided over its scope of limit.

Additionally the Energy which is not exactly the limit goes for credibility vitality test ,over the scope of Fuzzy Logic locator which takes the choice over its range of approximated vitality.

3.2 DOUBLE STAGE SPECTRUM SENSING

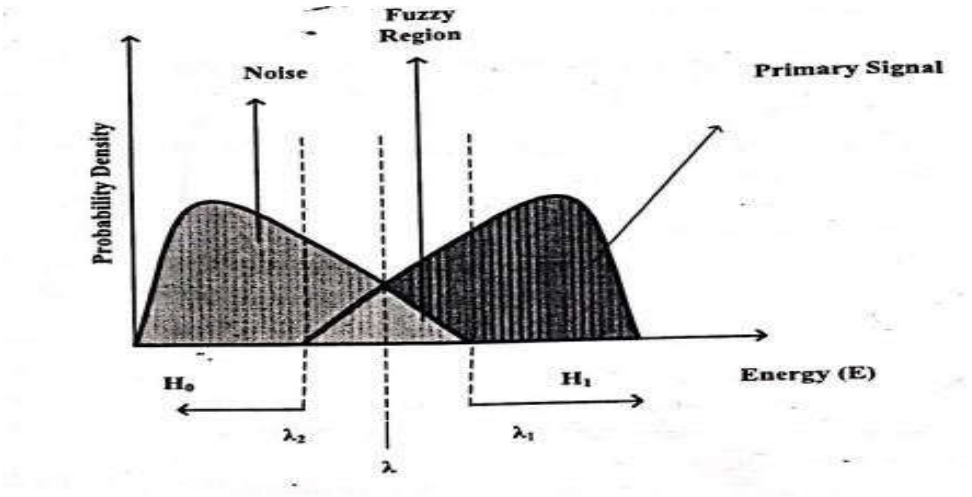
Double stage spectrum sensing includes estimation at various stages which is further pursued by decision stage. For a signal transmitted by PU , due to the presence of multi-vitality edge over what the fuzzy logic is to be implemented.

In ordinary recognition conspire, Test insights is determined and contrasted and a fixed limit as appeared in fig3.1.If test measurement is more noteworthy than Threshold,H1 is declared generally H0 is proclaimed.

Be that as it may, for this situation because of various limit it is hard to institutionalize the presence as yes or no. So we go for the Fuzzy Logic choice table to recognize its essence.

For all intents and purposes managing when essential client is permitted to a channel is attenuated with clamor factors which circumscribely gets connected with vitality factors and is chosen over its scope of limit. Additionally the Energy is detected over PSD Estimator and where it is additionally checked with credibility _PSD ,if the vitality surpasses the second edge , where as ,in the other case its straight forwardly sent through PSD Estimator for basic leadership.

Figure 3.2 Double threshold detection



3.3 LOCAL SPECTRUM SENSING TECHNIQUES

3.3.1 MATCHED FILTER DETECTOR

The ideal path for any signal recognition is a matched channel , since it augments gotten signal-to- clamor proportion. Be that as it may, a matched channel adequately requires demodulation of an essential client signal. This implies psychological radio has from the earlier information of essential client signal. The matched sifting finder requires short sensing time to accomplish great recognition execution. In any case, it needs information of the transmit signal by PU that may not be known at the SUs. In this manner, the matched sifting method isn't appropriate when transmit flag by the PUS are obscure to the SUs. Nonetheless, a critical disadvantage of a matched channel is that an intellectual radio would require a committed collector for each essential client class.

3.3.2 ENERGY DETECTOR

The Energy Detector is the most widely recognized spectrum sensing technique. The choice insights of the Energy Detector are characterized as the normal vitality of the watched tests. The choice is made by contrasting Y and an edge, γ. In the event that $Y \geq \gamma$, the SU settles on a choice that the PU signal is available (H1); else, it proclaims that the PU signal is missing (H0). The Energy Detector is anything but difficult to execute and requires no earlier data about the PU signal. Be that as it may, the vulnerability of clamor control forces principal impediments on the presentation of the vitality finder . Beneath an SNR edge, a solid recognition can't be accomplished by expanding the sensing term. This SNR limit for the identifier is called SNR divider . With the assistance of the PU signal data, the SNR divider can be moderated, however it can't be disposed of . In addition, the vitality finder can't recognize the PU signal from the clamor and other obstruction signals, which may prompt a high false alert likelihood.

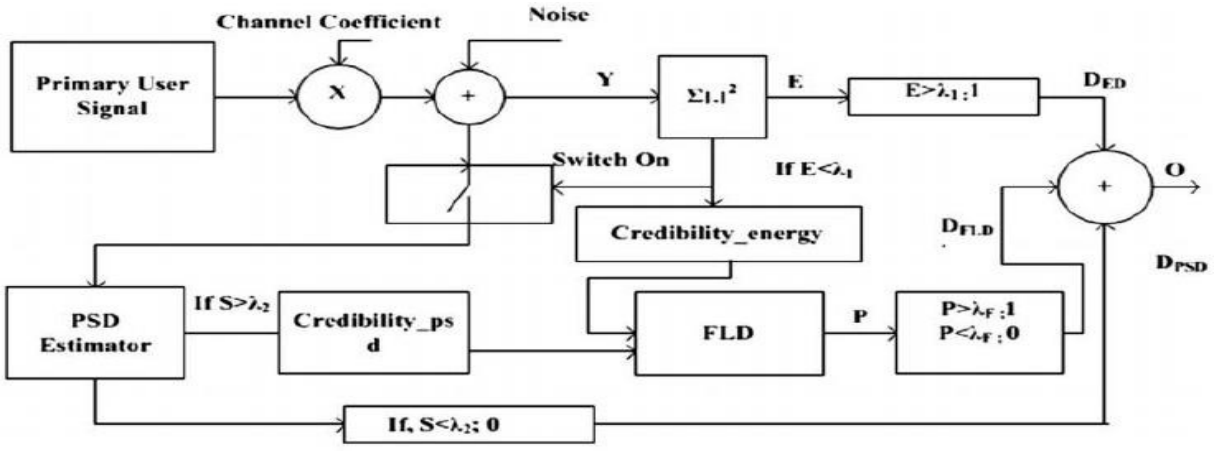


Figure 3.3 Credibility energy

3.3.3 CYCLOSTATIONARY FEATURE DETECTION

Cyclostationary finder is one of the component identifiers that use the cyclostationary highlight of the sign for spectrum sensing. By and large, include locator can recognize commotion from

the PU flag and can be utilized for identifying powerless sign at an extremely low SNR district, where the vitality discovery and matched separating discovery are not appropriate.

In, a Cyclostationary Feature Detection (SFD) has been proposed to identify low SNR TV broadcasting signals. The fundamental system of the SFD is to relate the period gram of the got sign with the chose otherworldly highlights of a specific transmission plot.

To catch the upsides of the Energy Detector and the cyclostationary identifier while staying away from the drawbacks of them, a crossover design, partner them two, for spectrum sensing has been proposed in. It comprises of two phases: a vitality recognition arrange that mirrors the vulnerability of the commotion and a cyclostationary discovery organize that works when the vitality location fizzles. The proposed cross breed engineering can identify the sign proficiently.

3.4 COOPERATIVE SENSING

Subjective radio agreeable spectrum sensing happens when a gathering or system of intellectual radios share the sense data they gain. This gives a superior image of the spectrum utilization over the zone where the psychological radios are found. Spectrum sensing can be accomplished by vitality location, it was simple executed and had honorable execution. Yet, of late, it was seen that the got sign quality could be blurred at specific areas due to Multipath fading and shadowing impact.

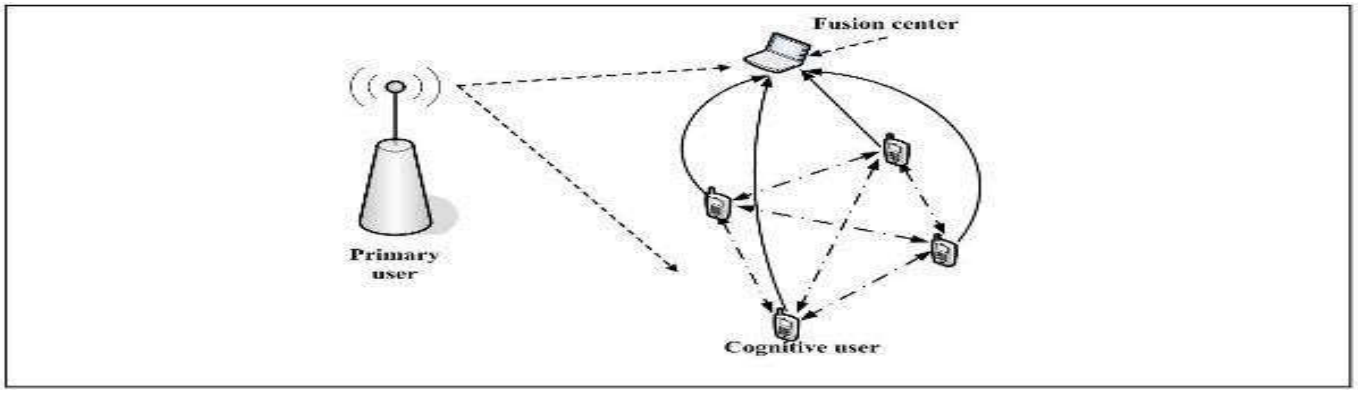


Fig.3.4 Co-operative sensing

Multipath Fading – Signals travel different path but arrive at a certain same time , they may cancel each other effect .This is referred a s multipath fading . The relative strengths of the signals may decrease and effect the signal output.

Shadowing Effect – The power of the received signal degrades because of the objects that are in between of the transmitter and receiver , degrading the signal strength. As a result, there is a deviation from the original signal strength.

3.5 SPECTRUM SENSING USING FUZZY LOGIC

3.5.1 THE PROPOSED SCHEME

Spectrum sensing part in Cognitive Radio Systems recognizes the nearness of the PU. A geological region comprising of a solitary PU and an arbitrary number of CR terminals are considered. It is expected that all the CR terminals are inside the satisfactory range from the essential client. In helpful spectrum sensing, information from a couple of CR terminals are utilized in an official conclusion making process. Here in the main stage every hub gives a choice on the spectrum status as Low, Medium or High. In the second stage it plays out the agreeable sensing by taking the choice from neighboring hubs moreover. In the information combination process for basic leadership, Fuzzy Logic is utilized. Fundamental commitment of this strategy is it considers the SNR at every collector additionally in settling on a choice.

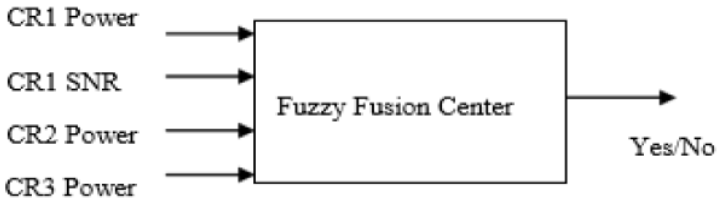


Figure 3.5 Fuzzy fusion centre

Every CR terminal consistently watches the intensity of the sign being transmitted inside a particular transmission capacity and records information on the SNR esteem too.

For a CR to settle on a choice, it thinks about its own information on power and SNR, and power from two of the closest neighbors. In this way an aggregate of four information sources are considered for basic leadership. Model of a fluffy combination focus .For fuzzification of intensity and SNR, three 18 enrollment capacities are characterized for the two parameters. The enrollment capacities speak to three dimensions, LOW, MEDIUM and HIGH . These dimensions are characterized dependent on information investigation signal power and SNR, which had been made preceding reenactment.

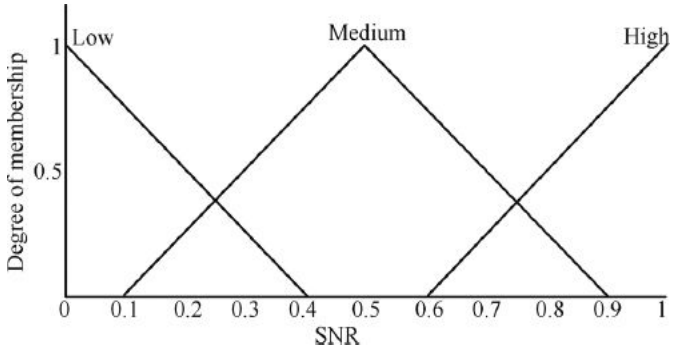


Figure 3.6 MF[SNR]

Nonetheless, the yield is a paired parameter which signifies the nearness of the PU by 1 and nonappearance of the PU by 0 .Also the working of the principle is such that the output so obtained will be 1,if the SNR and the power obtained from the CR is high ,irrespective of the data on power that has been collected from the neighboring CR's.

Power CR-1	SNR CR-1	Power CR-2	Power CR-3	Output
Low	Low	Low	Low	No
Low	Low	Medium	High	No
Medium	Low	Medium	Low	No
Medium	High	High	High	Yes
High	Medium	Low	Medium	Yes
High	High	High	High	Yes

Table 3.1 Fuzzy rule base

The fluffy guideline base contains of IF THEN provisions which is structured so that the hubs possess choice will get more significance than its neighbors'. For instance, on the off chance that the CR terminal distinguishes high power and high SNR, at that point the yield is 1 regardless of the information on power that has been gathered from the neighbors.The standard base is characterized for all the conceivable mix of sources of info. With four information sources three potential dimensions for each contribution, there are 81 potential blends. A piece of the standard base is appeared table.

CHAPTER 4

FUZZY LOGIC

4.1 FUZZY SET

Customary set hypothesis has a fresh idea of enrollment: a component either has a place with a set or it doesn't. Fuzzy set hypothesis contrasts from conventional set hypothesis in that halfway enrollment is permitted. This level of enrollment is generally alluded to as the participation esteem and is spoken to utilizing a genuine incentive in [0, 1], where 0 and 1 relate to full non-enrollment and enrollment, separately.

4.2 FUZZY LOGIC

Fuzzy logic was proposed as a strategy to stretch out paired logic to cover the issue of thinking under vulnerability. Fuzzy logic can be utilized to settle on choices by utilizing deficient ,surmised, and ambiguous data. To put it plainly, rather than utilizing muddled scientific definitions, fuzzy logic utilizes human-reasonable fuzzy sets and induction rules (for example IF,THEN, ELSE, AND, OR, NOT) to acquire the arrangement that fulfills the ideal framework goals. Predicates in fuzzy logic can have incomplete degrees of truth, similarly as components can have halfway enrollment in fuzzy set hypothesis. The evaluation of truth of a predicate is spoken to utilizing a genuine number in [0, 1]. The evaluation of truth of a conventional predicate P in the structure "x is An" is given by $\mu P = \mu A(x)$. The customary logic administrators ¬ (NOT), v (OR), and ^ (AND) are re-imagined regarding how they alter reality estimation of the predicate(s) to which they are connected so as to deliver reality estimation of the last articulation.

4.3 FUZZY DESIGN IMPLIMENTATION SKELTON

The First endeavor made to idea of fuzzy logic was made by Lotfi Zedeh. He revealed the idea and system of semantic factors. Here we use Mamdani model in order to oversee and control the various parameters of cognitive radio utilizing fuzzy tasks. Thus we have two strategy to handle the issue ie. fuzzy logic base framework and other is non fuzzy logic base framework. In fuzzy logic structure, we have three stages:-

1. Comprehend physical framework.

2. Control necessity.

3. Plan the controller by utilizing fuzzy principles which incorporates the recreation of the structure and execution of configuration on further dimension.

4.4 FUZZY LOGIC PROCESS

4.4.1 FUZZYFICATION.

4.4.2 DEFUZZYFICATION.

4.4.3 MEMBERSHIP FUNCTION DOMAIN.

4.4.4 LINGUISTIC VARIABLE AND RULES

4.4.5 FUZZY LOGIC INFERENCE SYSTEM

4.4.1 FUZZYFICATION

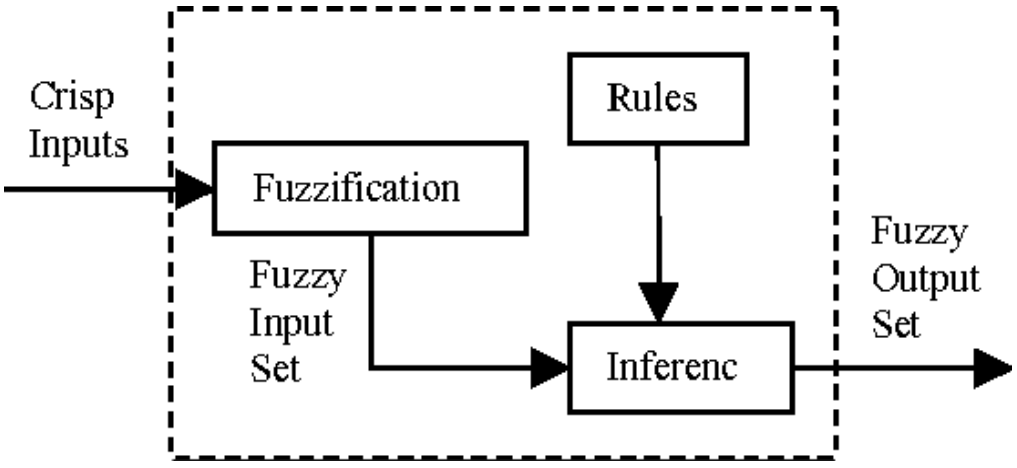


Figure 4.1 Fuzzification

Fuzzy logic depends on the thoughts of fuzzy set hypothesis and fuzzy set participation regularly found in normal (e.g., verbally expressed) language rather it is a way to deal with vulnerability that consolidates genuine qualities [0… 1] and logic tasks.

This procedure is completed for each information variable at each induction cycle, by assessing the enrollment estimation of each trait describing it.

4.4.2 DEFUZZIFICATION

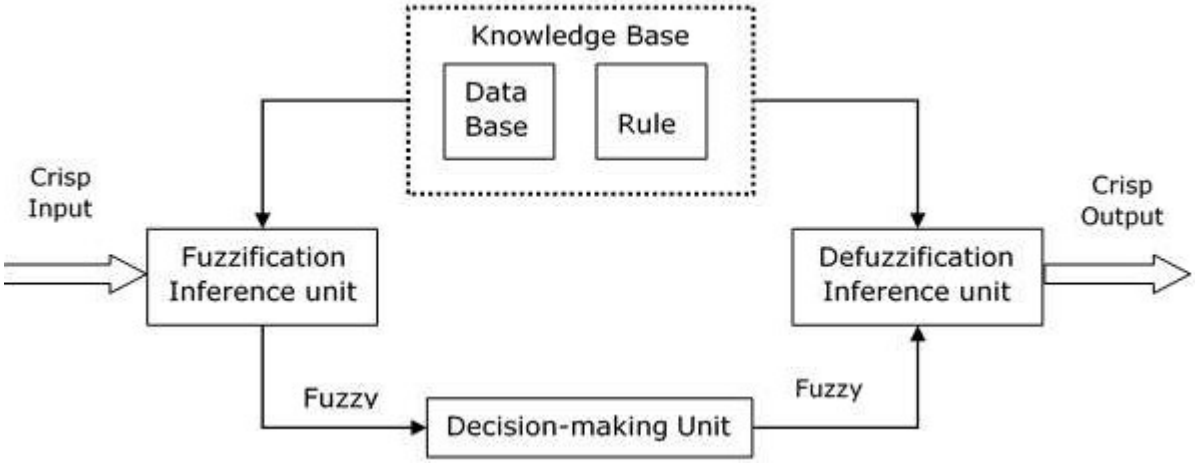


Figure 4.2 Defuzzified output

The standard assessment and basic leadership process has delivered, for each yield variable, a participation work μC(c) speaking to the suitability of each yield esteem c. Defuzzyfication is the way toward deciding a proper fresh incentive to be utilized as the genuine yield. A standout amongst the most generally utilized procedures for this intention is the focal point of region strategy, wherein the yield is resolved from the focal point of gravity of the participation work from the result of the arrangement of guidelines. Let Θ = {c | μC(c) > 0} indicate a lot of yields c with enrollment esteem bigger than zero, the proper fresh incentive at the yield of the fuzzy logic surmising framework is determined as pursues:

$$C = c\mu c(c)$$

4.4.3 MEMBERSHIP FUNCTION DOMAIN

The enrollment capacity of a fuzzy set extending its incentive from 0 to 1 measures the degree or the evaluation of participation of the component of the fuzzy set. The going qualities are with the end goal that the esteem 0 accentuation that the component isn't the individual from the Fuzzy set while the esteem 1 of the participation work accentuation that it is completely an individual from the Fuzzy set. Additionally the mid going estimations of the fuzzy set accentuation that it has a place with the set in part.

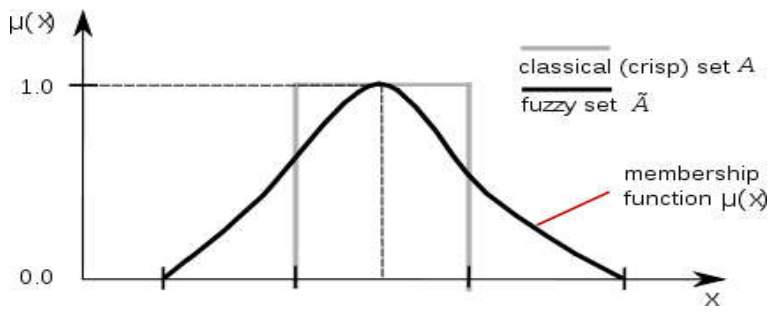


Figure 4.3 Membership function

4.4.4 LINGUISTIC VARIABLE AND RULES

Many fresh correlations are not expected to coordinate accurately a solitary esteem: fuzzy examinations are accessible to tackle the quandary. The fresh uniformity examination is supplanted with a fuzzy correlation that represents a scope of information. We base an examination on three information esteems: the correlation point, go until the correlation has fizzled, and the present variable esteem. Delta is the separation to an esteem where the present correlation stops to be significant. Etymological factors give a characteristic smooth progress between contending rules depicting various methodologies.

4.4.5 FUZZY LOGIC INFERENCE SYSTEM

The straightforward engineering of a fuzzy logic derivation framework is described in figure as referenced beneath. The further modules creating a fuzzy logic induction framework are depicted in the remainder of this subsection.

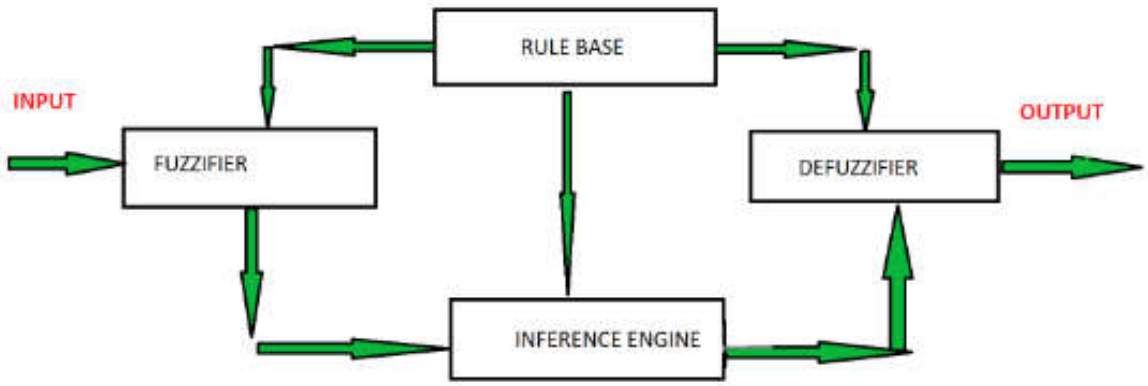


Figure 4.4 Fuzzy interface system

4.5.1 KNOWLEDGE BASE

The information base describes the connection between fresh information/yield parameters and their fuzzy portrayal comprehended by the fuzzy logic deduction framework. Each info/yield variable is portrayed by the accompanying things in the information base:

• Its universe.

• The arrangement of etymological traits that make its subjective portrayal.

• For each name, the enrollment work characterizing it.

Moreover, the information base gives a lot of surmising rules for the deduction motor.

These standards is built in type of "On the off chance that –" explanation dependent on the experience of specialists.

4.5.2 RULE-BASED INFERENCE ENGINE

The core of a fuzzy logic deduction framework is made out of a lot of IF-THEN standards used to decide the estimation of the yield factors. On the off chance that conditions are made utilizing the predicates and logic administrators, while THEN proclamations are usually predicates demonstrating the fuzzy characteristic that is progressively suitable for the yield factors included.

The procedure of guideline assessment is simpler to clarify by a model. Let A, B be input factors, and C be a yield variable. Let A, B and C be spoken to by the phonetic traits A1 and A2, B1 and B2, and C1 and C2, individually. Assume we have the accompanying guideline set:

• Rule 1: IF (An is A1) and (B is B1) THEN (C is C1).

• Rule 2: IF (An is A2) or (B is B2) THEN (C is C2).

At long last, let an and b be the present fresh qualities for An and B. As a matter of first importance, reality esteem for each standard is determined as pursues:

$$\alpha_1 = A_1 a^{\mu B_1 b}$$

At that point an adjusted enrollment work is determined for the induction yield suggested by each standard by taking the base (fuzzy ^ administrator) of its participation work and reality estimation of the IF statement:

$$C_1 = a_1{}^{C_2}$$

$$C_2 = a_2{}^{C_2}$$

At last, the participation work for the choice yield of variable C is determined by taking the most extreme (fuzzy v administrator) of the adjusted enrollment of all choice activities alluding to C:

$$C = C_1 V \mu C_2$$

The above deduction technique is called max-min surmising strategy.

4.6 FUZZY LOGIC CONTROLLER (FLC)

So as to finish the methodology to settle on choice, in fuzzy logic hypothesis, we use "Fuzzy Logic Controller" (FLC) to execute this capacity. Basically, FLC is a lot of controlling standards. We can utilize these guidelines to settle on the yield of choice. A general FLC comprises of four modules: a fuzzy guideline base, a fuzzy induction motor and a fuzzification/defuzzifucation module. A FLC works by rehashing a cycle of five stages executed by these four modules. Initially, estimations are got of all factors that speak to applicable states of the controlled procedure.

Next, these estimations are changed over into fitting fuzzy sets to express estimation vulnerabilities. This progression is called fuzzification. The fuzzified estimations are then utilized by the induction motor to assess control rules put away in the fuzzy guideline base. The aftereffect of this assessment is a few fuzzy sets characterized on the universe of talk of potential activities. This fuzzy set is then changed over, in the last advance of the cycle, into a fresh esteem. This change is called defuzzification. The defuzzified values speak to moves made by the FLC in individual control cycles.

Basically, the fuzzy logic controller is a calculation which can change over the semantic control technique dependent on master learning into a programmed control methodology. Particularly the philosophy of FLC seems valuable when the procedures are unreasonably confused for

investigation by the conventional quantitative systems. In the CR organize, accessible wellsprings of data are deciphered quantitatively, inaccurate or uncertainly, the utilization of fuzzy logic controller can take care of these difficult issues.

4.7 ADVANTAGES OVER DISADVANTAGES OF FUZZY

- This framework can work with a data sources whether it is uncertain, contorted or boisterous information data.
- It gives an effective answer for complex issues in all fields of life as it takes after human thinking and basic leadership.
- The calculations can be portrayed with little information, so the memory required is comparatively low for the execution.

But the most draped disadvantage of fuzzy application is that fuzzy logic is based on the loose or approximated information available so, precision in this case is always undermined ,moreover the time processing for the decision process is much higher in this.

CHAPTER 5:

RESULTS AND CONCLUSION

Software used-MATLAB2019a

Following are the results obtained while working on the project .

1. Threshold is calculated using matlab functions .

   Figure1 depicts graph between Pf and thresh (calculated using random function).

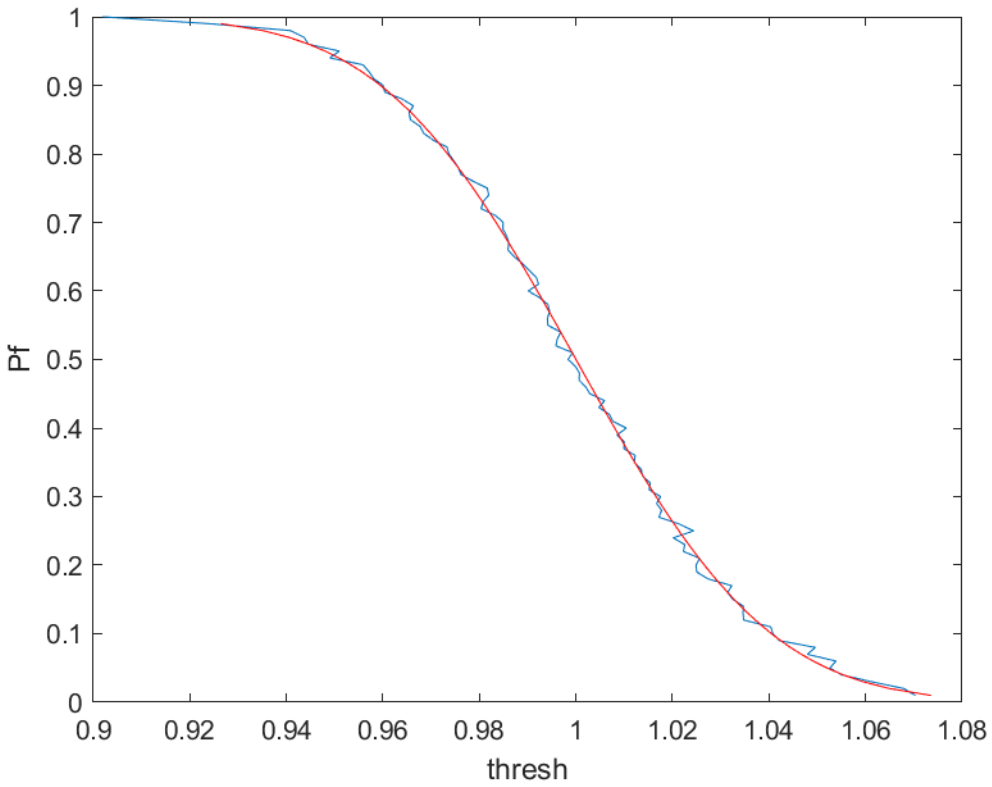
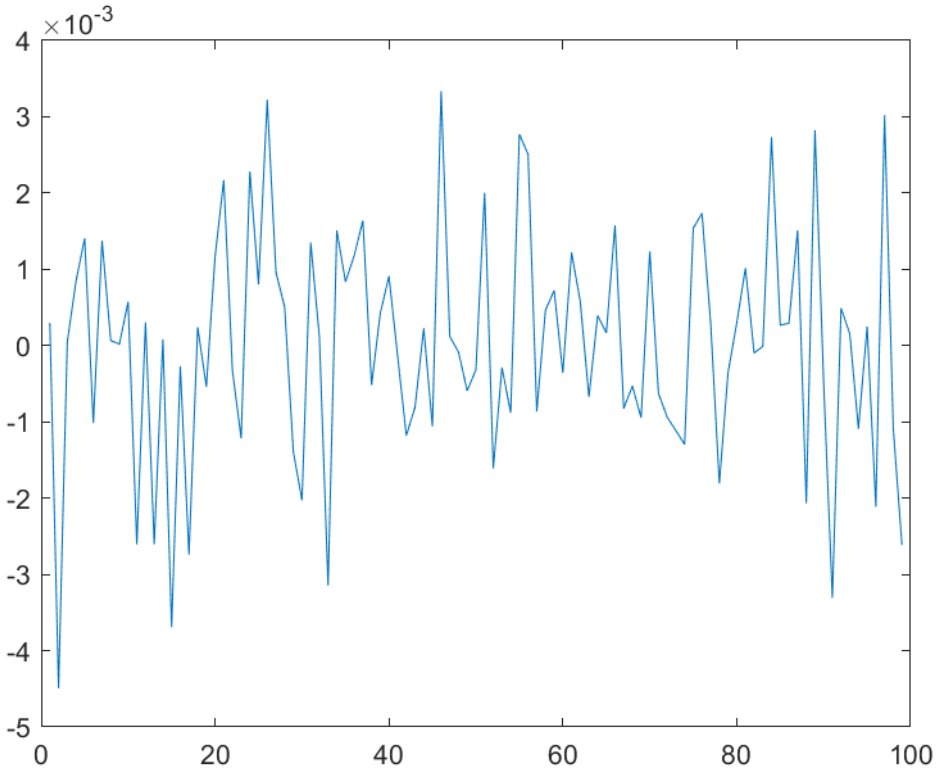
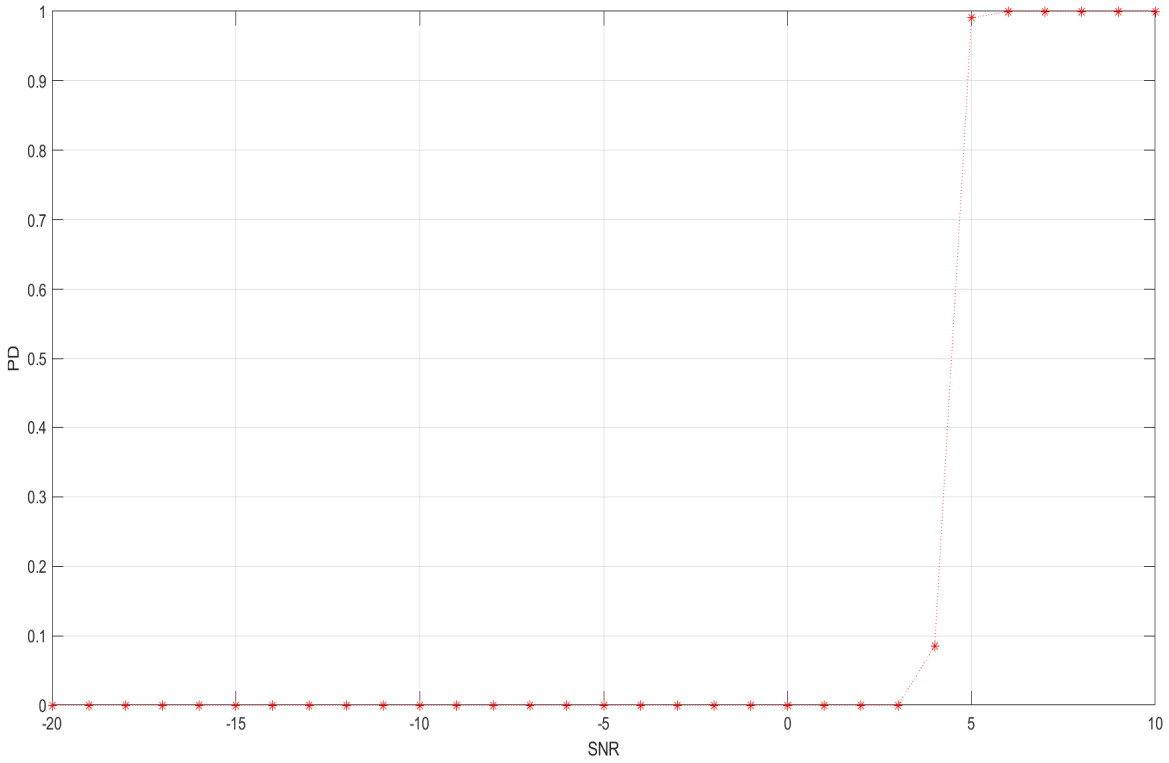


Figure 2 depicts the difference between the thresh1 and thresh .
Thresh is the threshold calculated using random function and thresh1 is calculated using the theoretical formula using Q function.

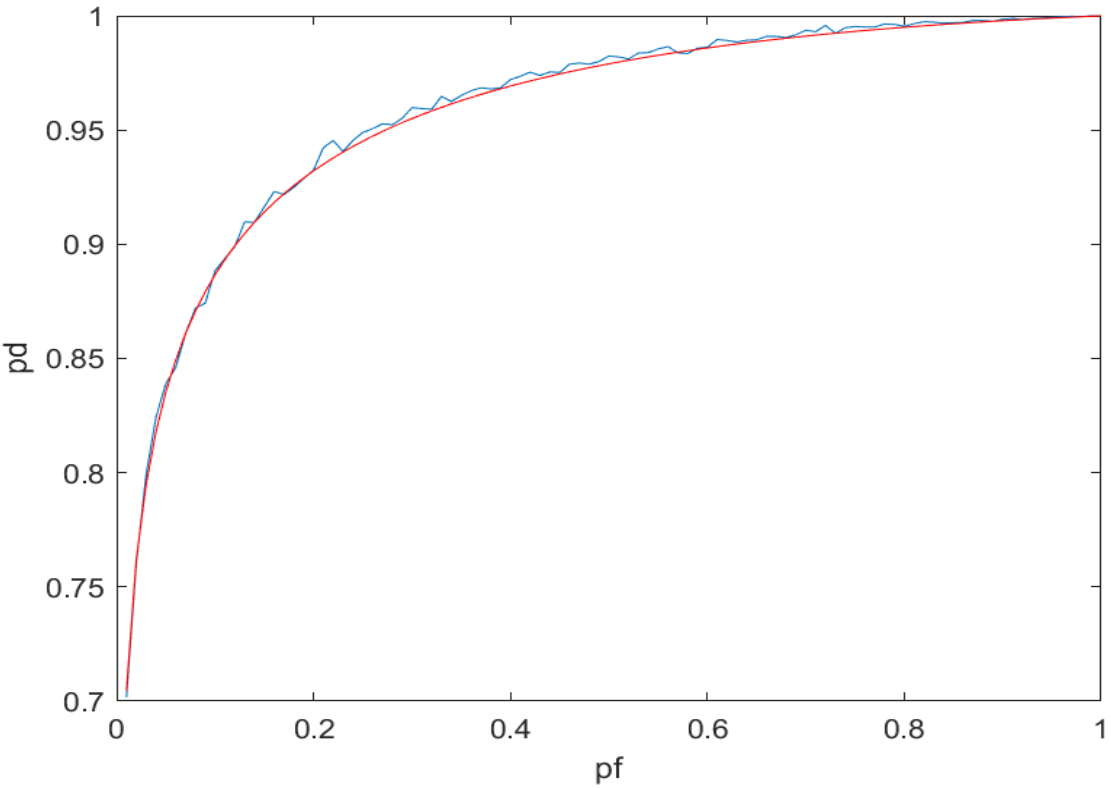


2. Plot between SNR and Pd (probabibilty of detection) , where pf=0.1 ,standard for cognitive radio system

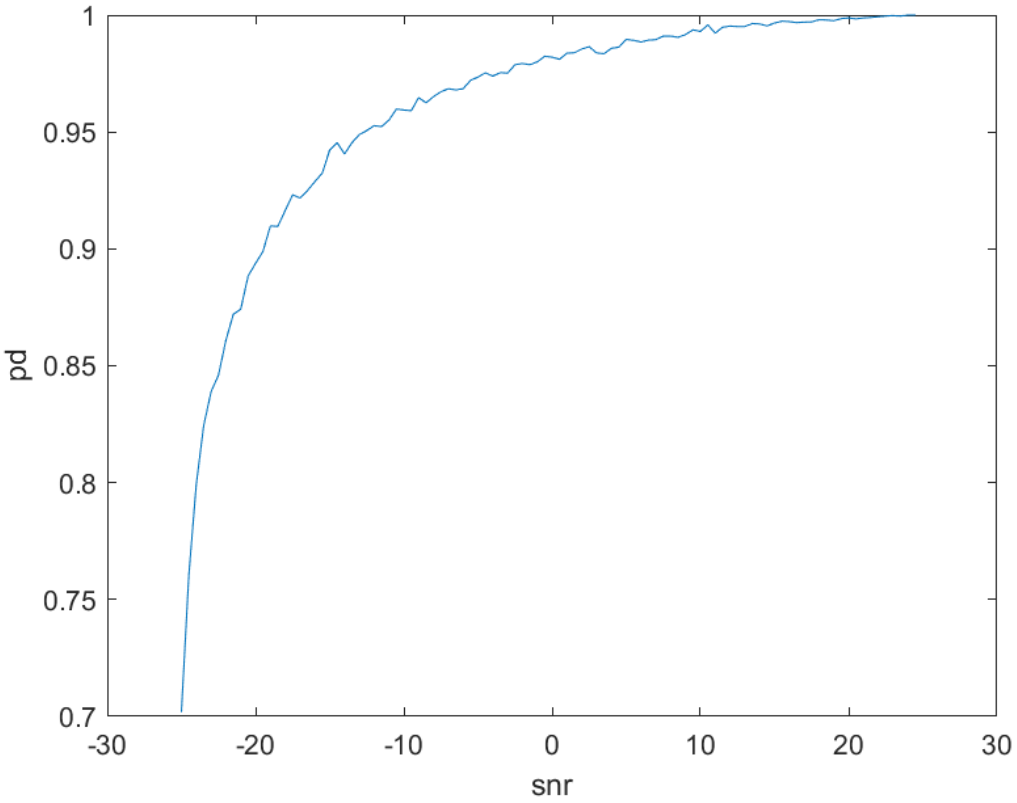
   Value of SNR is taken as [-20 to 10]



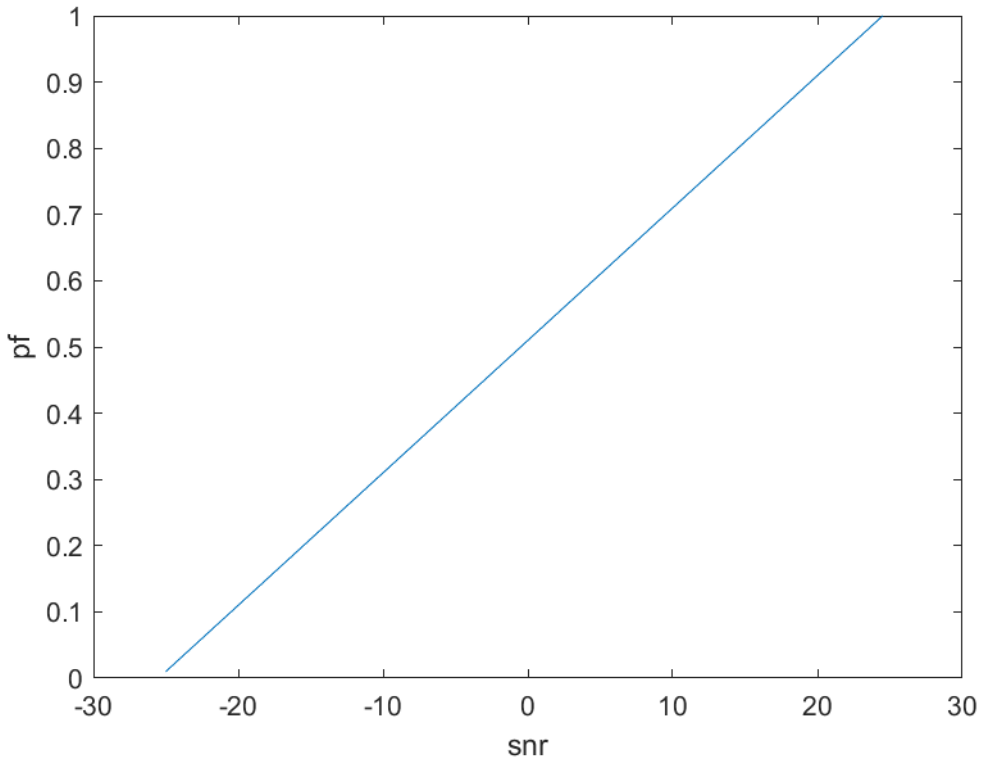
3.Plot between (pf vs pd) ,taking constant value of SNR = -10



3. Plot between Pd vs SNR



4. Plot between Pf vs SNR



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APPENDIX

MATLAB CODE FOR RESULT -1

```
clc
close all
clear all
L = 1000;
iter = 1000;
Pf = 0.01:0.01:1;
for tt = 1:length(Pf)
    tt;
for kk=1:iter
 n=(randn(1,L)+j*randn(1,L))./(sqrt(2));
 y = n;
 energy = abs(y).^2;
 energy_fin(kk) =(1/L).*sum(energy);
end
 energy_desc = sort(energy_fin,'descend');
 thresh(tt) = energy_desc(ceil(Pf(tt)*iter));
end
figure(1)
plot(thresh, Pf)
hold on
xlabel('thresh');
ylabel('Pf')
%%
thresh1 = (qfuncinv(Pf)./sqrt(L))+ 1;
plot(thresh1, Pf, 'r')
hold on
figure(2)
y=thresh1-thresh;
plot(y)
```

MATLAB CODE FOR RESULT-2

```
close all;
clear all;
N=1000;
M=10000;
SNR_dB=-20:10;
SNR= 10.^(SNR_dB./10); %real SNR
for m=1:length(SNR)
i=0;
pf=0.1;
for kk=1:M
n=randn(1,N);
s=sqrt(SNR(m)).*randn(1,N);
y=s+n;
energy=abs(y).^2;
energy_fin=(1/N).*sum(energy);
 thresh_c=qfuncinv(pf./sqrt(N))+ 1;
if(energy_fin>=thresh_c)
i=i+1;
end
end
Pd(m)=i/M;
end
figure (1)
plot(SNR_dB,Pd,'r*:')
grid on
xlabel('SNR');
ylabel('PD');
```

MATLAB CODE FOR RESULT- 3

```
clc
close all
clear all
L = 1000;
snr_dB =-10;
snr = 10.^(snr_dB./10);
Pf = 0.01:0.01:1;
 for m = 1:length(Pf)
    m
    i = 0;
for kk=1:10000
 n = randn(1,L);
 s = sqrt(snr).*randn(1,L);
 y = s + n;
 energy = abs(y).^2;
 energy_fin =(1/L).*sum(energy);
 thresh(m) = (qfuncinv(Pf(m))./sqrt(L))+ 1;
 if(energy_fin >= thresh(m))
     i = i+1;
 end
end
Pd(m) = i/kk;
end
plot(Pf, Pd)
xlabel('pf');
ylabel('pd');
 hold on
 thresh = (qfuncinv(Pf)./sqrt(L))+ 1;
Pd_the = qfunc(((thresh - (snr + 1)).*sqrt(L))./(sqrt(2).*(snr + 1)));
figure (1)
plot(Pf, Pd_the, 'r')
hold on
snr1 = -25:0.5:24.8;
figure (2)
plot (snr1, Pf)
xlabel('snr');
ylabel('pf');
figure (3)
plot (snr1, Pd)
xlabel('snr');
ylabel('pd');
```