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Advancements in Cyclostationary Technique for Cognitive Radio: An In-Depth Examination and Evaluation

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Abstract: In contemporary society, information communication has reached unprecedented levels, connecting individuals at all strata, from grassroots to the highest echelons. The integration of information technology and communication has become an intrinsic part of everyday life, catering to knowledge-based, entertainment-based, economical-based, and social-based data. As the volume of information data continues to grow, Information Communication Technology (ICT) plays a pivotal role in the lives of common individuals. However, the surge in users is met with the challenge of limited resources, specifically channel bandwidth for communication. This paper addresses the issue of communication channel utilization in the face of a rising number of users. To optimize and accommodate an increasing user base within the constraints of available channels, the proposed system introduces the Enhanced Cyclostationary technique for Cognitive Radio. This innovative approach aims to maximize the efficiency of communication channels, ensuring reliable connectivity for the expanding user population.

Keywords: *Cognitive Radio, Cyclostationary Technique, MATLAB, Primary User, Secondary User.*

1. Introduction:

Wireless communication serves as the backbone of modern information access systems, facilitating the transmission and reception of vital data. The fundamental medium for this communication is the spectrum of frequencies provided by various spectrums, including UHF, VHF, and HF. Each spectrum is allocated for specific reasons, forming the basis of diverse applications. However, the fragmentation of spectrums according to various applications has resulted in a growing challenge – the unavailability of channels for communication due to an increasing number of users. Users authorized to access specific channels are termed primary users, while unauthorized users are classified as secondary users. Historically, a conventional static spectrum approach was employed, where specific spectrums were allocated solely to primary users. The static approach, once effective, faced challenges as the number of users increased, exacerbating the scarcity of available spectrum. To address this, the dynamic spectrum allocation paradigm was introduced.

Dynamic spectrum allocation operates on the premise that if a primary user (licensed user) is not actively utilizing or occupying a spectrum for a specific period, the spectrum can be temporarily accessed by secondary users until the primary user resumes occupancy. This concept, known as the dynamic spectrum approach, significantly increases the utilization factor of available signals. In response to the need for automatic spectrum allocation, new techniques were introduced, namely Spectrum Sensing Algorithm and Spectrum Allocation Algorithm. This paper delves into these techniques, focusing on the proposed Enhanced Cyclostationary Spectrum Sensing algorithm. This advanced method integrates correlation and principal component analysis for enhanced results and effectiveness. The proposed algorithm utilizes major cyclic properties of signals to sense and allocate primary and secondary users. In contrast to conventional cyclostationary techniques, which solely rely on cyclic properties, the proposed system enhances the cyclostationary technique by incorporating principle component analysis. Additionally, the paper introduces novel approaches for detecting intruders within the spectrum. To implement the overall system, MATLAB software is employed, demonstrating the system's efficacy in terms of accuracy and response time. Quality parameter analysis, including probabilities of false alarm and probabilities of miss detection, is presented graphically, offering insights into the effectiveness of the proposed system.

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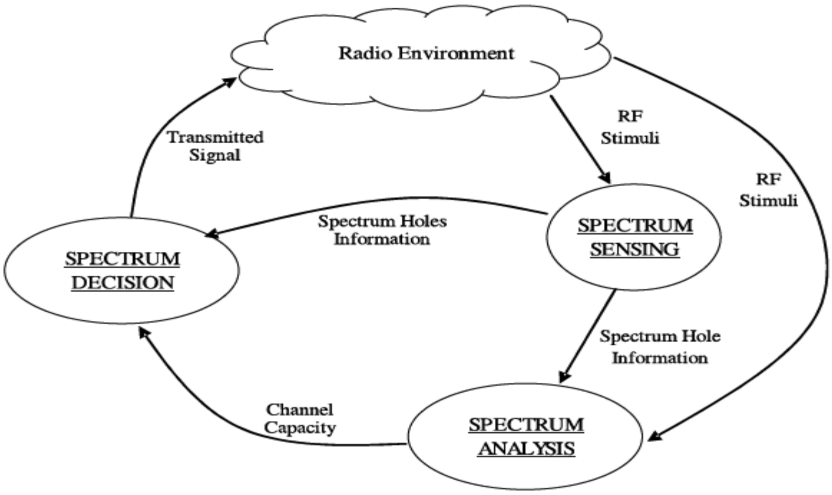

Fig 1:- Cognitive cycle

Cognitive Radio performs four key functions spectrum sensing, management, sharing & analysis. spectrum sensing continuously searches for unused spectrum, known as spectrum holes or white spaces, across Frequency, Time, Geographical Space, Code, and Phase. Involves measuring and being aware of various radio channel characteristics, interference, transmit power, and other environmental factors. Spectrum Management selects available white spaces or channels once spectrum holes are identified. Also utilize the detected spectrum for optimal communication. Spectrum Sharing allocates unused spectrum (spectrum holes) to secondary (cognitive) users as long as the primary user does not require it. Spectrum Mobility vacates the channel promptly when a licensed (primary) user is detected.

2. System Development & Execution:

In order to improve the conventional cyclostationary technique, the proposed system introduces a sophisticated approach. Within this system, significant cyclic properties are identified, and their energy values are correlated with the ongoing signal. This identification of crucial cyclic properties is accomplished through a component of principle component analysis. The proposed system is depicted in Figure 2

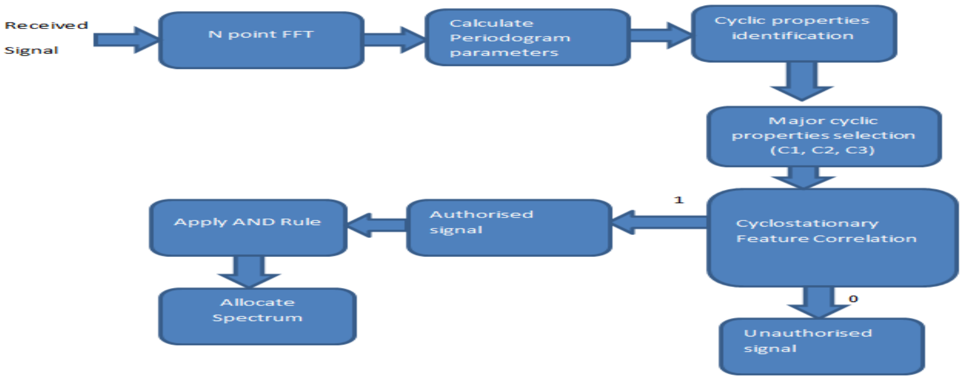

Fig 2: Flowchart for execution using cyclostationary detection method

As depicted in Figure 3, the enhanced technique incorporates the conventional cyclo-stationary method, selecting significant cyclic components (C1, C2, C3) for feature correlation using principle component analysis. This augmentation results in a more efficient and effective technique.

To implement the cognitive radio in MATLAB, follow these steps: firstly install MATLAB R2013a 8.1.0.604 &Save the code in the local MATLAB directory.

To simulate the cognitive radio go to Navigate to New > Graphical User Interface > Open Existing GUI.

Browse the local directory, open the .fig file, and press the Run Figure button to display the simulated GUI.

In the GUI control panel press the "All Primary User Present" button, displaying six windows on the axis, indicating the presence of primary users with peaks at their carrier frequencies. Turn a Primary User OFF by using the empty band detection button, specifying the user state as 'Y' for present or 'N' for absent. The subplot shows a line for absent users, indicating noise only when users are absent.

Insert the first secondary user by pressing the "Insert First Secondary User" button on the control panel.

After that press "Insert Second Secondary User" for the second secondary user to search for an empty band when two primary users are absent. For effective spectrum utilization perform dynamic spectrum allocation by pressing the "1st PU wants to Use SU1" button & release the band used by Primary User 1 and search for a vacant band. If found, it is occupied by Secondary User 1.

There are two panels on the GUI show the state of Primary Users and Secondary User, In that primary User panel indicates whether they are ON or OFF & secondary User panel shows whether they are searching for a band or which band is occupied by the secondary user.

For evaluating PFD Detection performance, three push buttons in the control panel are utilized, with the callback linked to the file name. This same process is applied for assessing performance matrices, comparing PFD detection, and analyzing using the AND rule method. The push button labelled "Detect the Primary User in low SNR" is employed to compare the detection of the Primary User (PU) using both Energy Detection (ED) and Cyclostationary Detection (CD) methods. Leveraging the cognitive radio base station's knowledge of all Secondary User (SU) modulating frequencies, the PFD detection excels in effectively distinguishing between PU and SU. This functionality is exemplified by a dedicated push button that distinctly separates PU and SU.

3. Simulation Result & Discussion

MATLAB was utilized to verify the effectiveness of the cognitive cyclostationary detector. Setting up a cognitive radio system included configuring 6 primary users, 2 secondary users, and 6 intruders. The initial stage involves launching the Cyclostationary process, specifically concentrating on correlating two signals. This initial phase is dedicated to identifying authorized signals through correlation analysis.

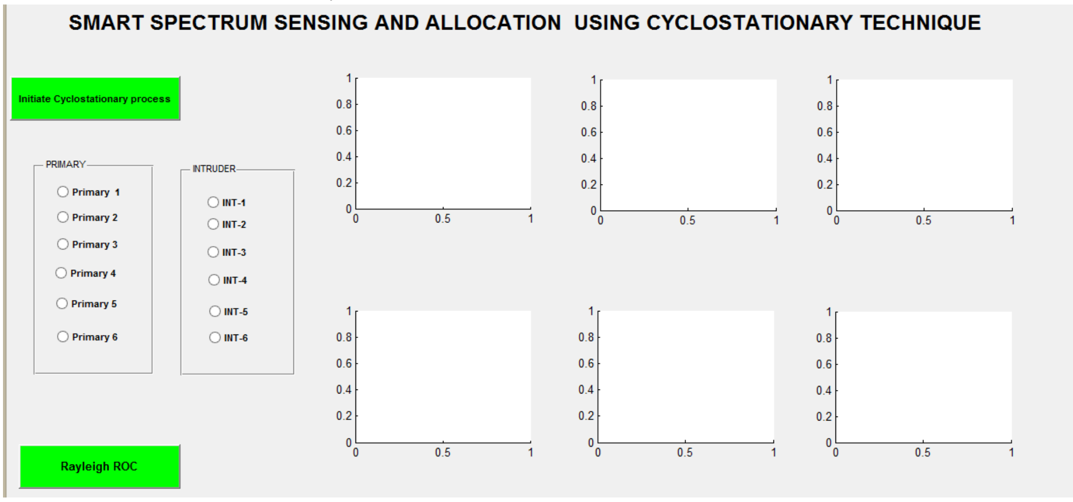

Fig 3 : Initialization of Cyclostationary Technique

After the initialization phase, the subsequent step entails the individual allocation of channels for primary users. This allocation process utilizes cyclic autocorrelation and periodogram analysis. The sequential assignment of channels for primary users begins with user 1 and continues through user 6.

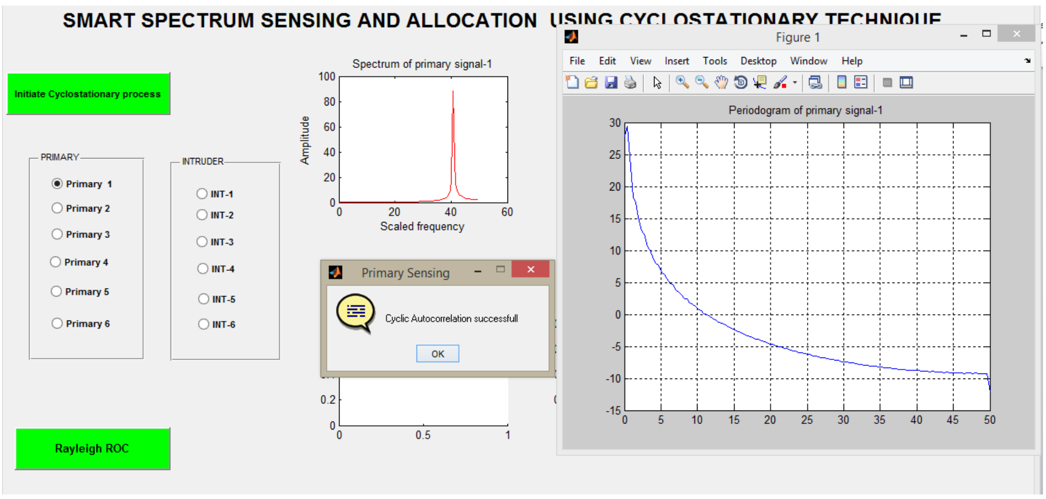

Fig 4: Channel allocation to Primary user one.

If an additional primary user vacates its channel, priority is granted to Secondary Signal 1 for data transfer and spectrum allocation. As illustrated below, when Primary Users 1, 2, and 3 abandon their respective channels, Secondary Signal 1 seamlessly occupies the channel that was previously utilized by Primary User 1.

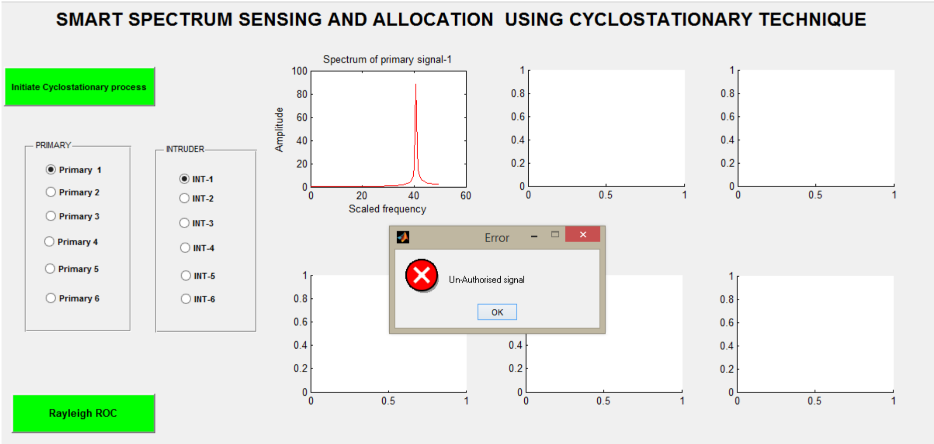

Fig 5.3: Intruder as Unauthorized signal.

The intruder, characterized as a noise signal, is a form of signal that must be prevented from entering the spectrum. It represents an unauthorized signal, and its presence within the spectrum poses a security risk. In this project, any attempt by an unauthorized signal or user to intrude is countered by the cyclic autocorrelation technique, employing the Peak Matching technique. As illustrated in Figure 4, the cyclostationary technique promptly recognizes Intruder 1 as an unauthorized signal. This conceptual approach aligns with the principles of Cognitive Radio.

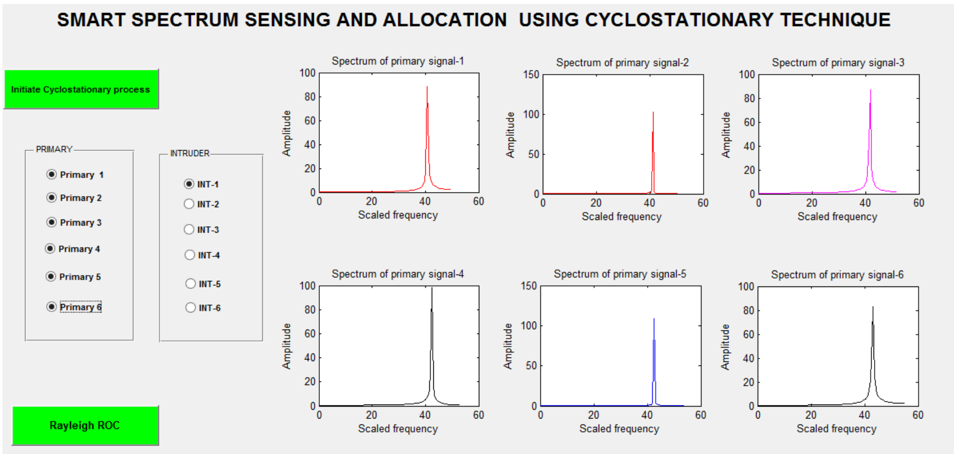

Fig 4: Channel allocation to all six Primary users.

When a specific channel is vacated by a primary user, the secondary user can employ that channel for data transfer until the primary signal returns to the spectrum. In this context, signals are prioritized based on their data transfer requirements. As illustrated in Figure, when Primary User 4 exits its channel, Secondary Signal 2 seamlessly takes over the same channel that was previously utilized by Primary User 4. This illustrates the core objective of Cognitive Radio, showcasing efficient spectrum utilization for both primary and secondary users.

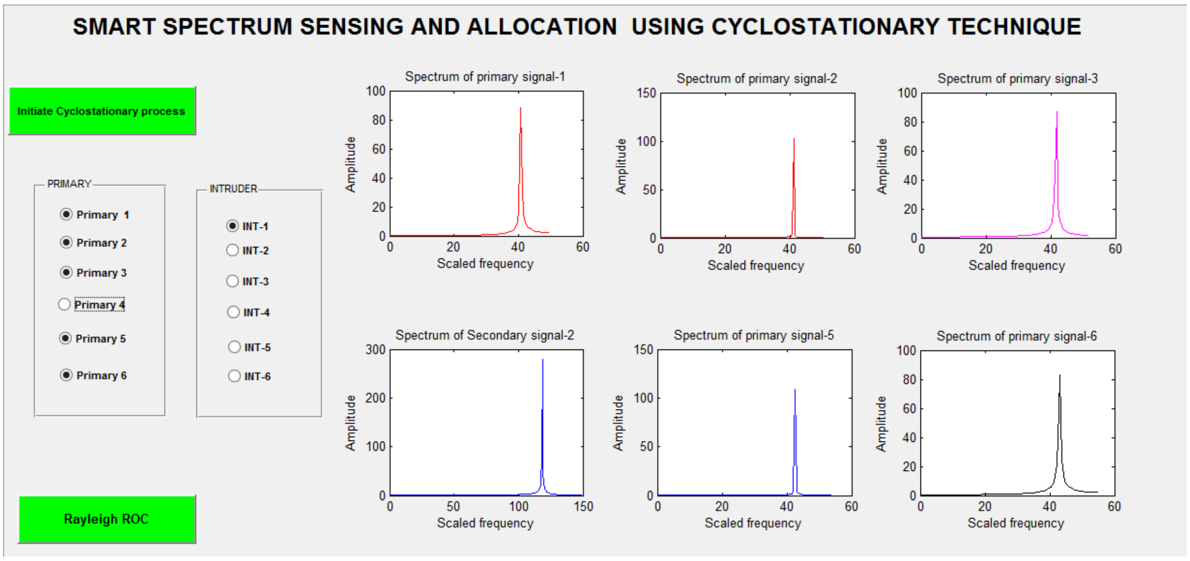

Fig 5: Channel allocation to secondary signal.

In this process, channels have been allocated to six primary users, and the introduction of an intruder signal has been examined. The demonstration effectively characterizes the intruder as an unauthorized signal, enhancing spectrum security. Additionally, two unlicensed secondary signals have been generated. The core objective of Cognitive Radio is the prioritized allocation of channels, a principle implemented through MATLAB. Sensing based on priority is applied to both primary and secondary signals, resulting in their assignment to various channels with distinct frequencies.

Following this, we generated a graph depicting the relationship between Miss Detection and False Alarm rates. Miss Detection signifies the probability of a signal not being correctly identified, while False Alarm represents the probability of erroneously identifying an intruder as a primary signal. The system achieves an accuracy of up to 90%, leading to low probabilities for both Miss Detection and False Alarm in the cyclostationary technique. Thus, the successful implementation of this system is evident.

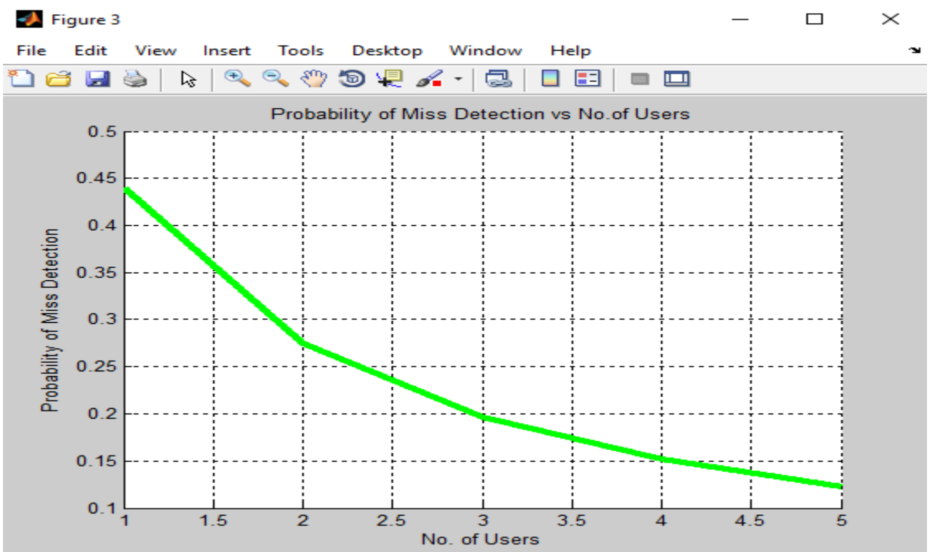

Fig : Probability of miss detection vs no of user

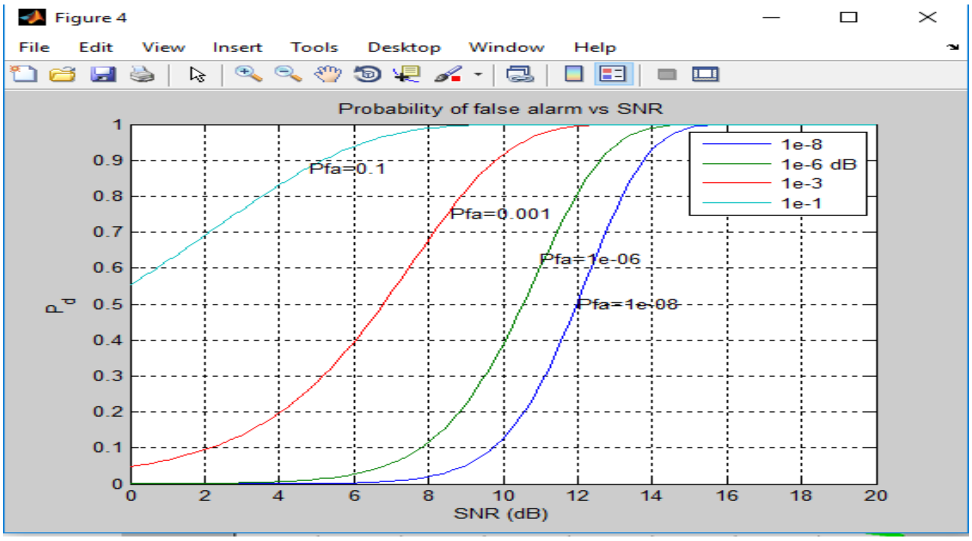

Fig : Probability of false alarm vs SNR

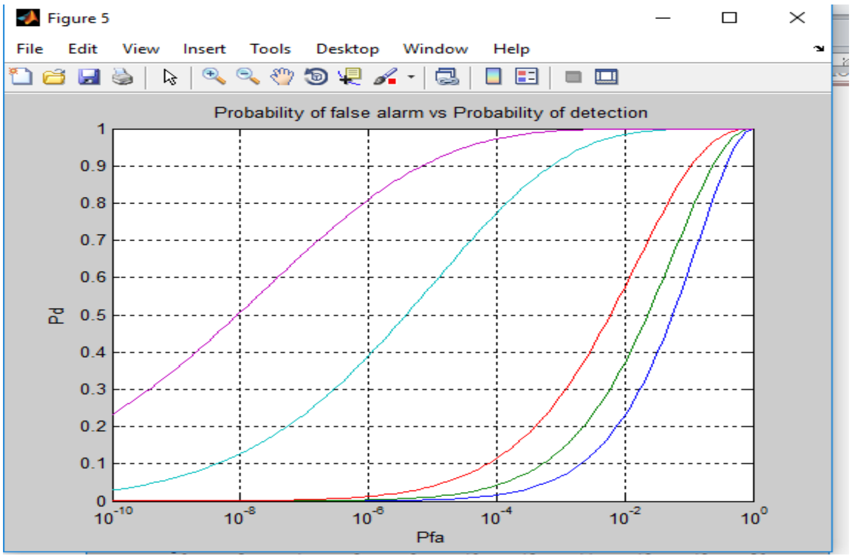

Fig : Probability of false alarm vs probability of detection

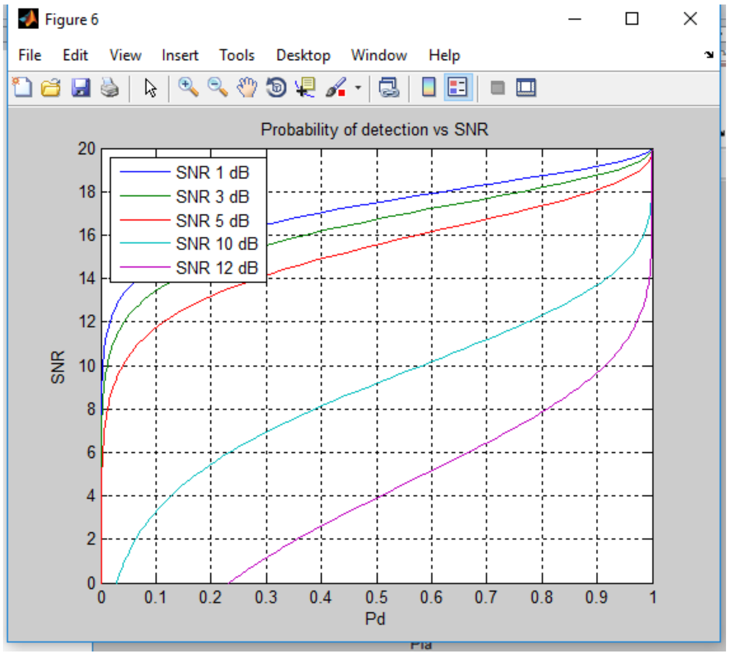

Fig : Probability of detection vs SNR

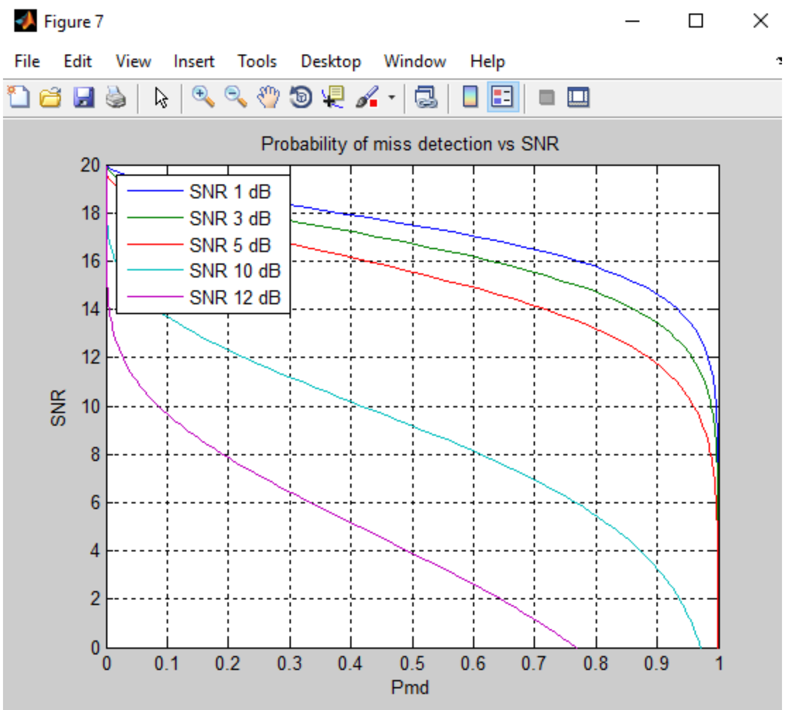

Fig : Probability of miss detection vs SNR

In order to optimize the utilization of the wireless spectrum, cognitive radios were introduced, designed to exploit available spectrum gaps opportunistically. Spectrum sensing is a crucial component of cognitive radio systems, and various sensing techniques are employed for this purpose. This paper focuses on Energy Detection, Matched Filter Detection, and Cyclostationary Feature Detection as spectrum sensing techniques.

Energy Detection offers the advantage of not requiring prior knowledge about primary users. However, its performance is less effective at low Signal-to-Noise Ratio (SNR) values, necessitating a minimum SNR for reliable operation. The results presented in the paper reveal that Energy Detection starts functioning at -7 dB SNR.

Matched Filter Detection surpasses Energy Detection, initiating operation at a lower SNR of -30 dB. Cyclostationary Feature Detection emerges as superior to both previous detection techniques, delivering better results at the lowest SNR values, particularly below -30 dB. The results demonstrate that the performance of Energy Detection improves with increasing SNR, with the "probability of primary detection" increasing from zero at -14 dB to 100% at +8 dB. Correspondingly, the "probability of false detection" decreases from 100% to zero.

4. Conclusion:

The utilization of the enhanced cyclostationary technique with principle component analysis, incorporating the selection of cyclic properties and subsequent energy calculation over these chosen cyclic properties, has demonstrated increased effectiveness in achieving precise spectrum sensing. This hybrid approach minimizes the probability of miss detection during spectrum sensing by leveraging the strengths of both cyclostationary and energy level detection techniques. Through the integration of the advantages inherent in these conventional techniques, the enhanced cyclostationary technique concurrently deals with and alleviates the limitations associated with each method. Subsequent to the spectrum sensing algorithm, a spectrum allocation algorithm based on the AND rule is also put forth.

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