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An Optimised SVD with SFLA & ABC for Spectrum Sensing in Cognitive Radio

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Abstract –**The aim of this study is to focus on spectrum sensing in cognitive radio which is a recently introduced technology in order to increase the spectrum efficiency. We studied the Singular value decomposition based signal detector and its advantages over the energy based signal detection. Soft thresholding technique for spectrum sensing is optimized using SFLA (Shuffled Frog Leaping) and Ant Bee Colony algorithm. Results shows that SFLA and ABC outperforms then SVD based signal detector to improve its performance, especially under low SNR simulation.**

Keywords – **Ant Bee Colony Algorithm, Cognitive Radio, SFLA, SNR, Spectrum Sensing, SVD.**

I. INTRODUCTION

The requirement for higher data rates is growing as an effect of evolution from voice to multimedia transmission. Since the spectrum is scarce and static frequency allocation schemes cannot fulfil the demand of increasing number of high data rate devices. Hence innovative concepts which can offer new ways to utilize the available spectrum are needed. Cognitive radio has emerged as tempting solution of the aforementioned problem which allows opportunistic usage of frequency bands that are not occupied by the licensed users [1]. Cognitive Radios use the radio spectrum owned by other users. They perform radio environment examination, identify the unutilized bands and assigns these spectrum holes to unlicensed secondary users ([2] [3]). In cognitive radio terminology Primary user refers to a user who is allocated the rights to use the spectrum. Secondary user refers to the users who try to use the frequency bands allocated to the primary user when the primary user is not using it. Spectrum Sensing, an essential component of the Cognitive Radio technology involves,

1. Identifying spectrum holes (white space) and,
2. When an identified spectrum hole is being used by the secondary users, to quickly detect the onset of primary transmission.

II. THE COGNITIVE RADIO NETWORK ARCHITECTURE

Existing wireless network architectures employ heterogeneity in terms of both spectrum policies and communication technologies. Moreover, some portion of the radio spectrum is licensed for different technologies and some bands remain unlicensed (called Industrial Scientific Medical (ISM) band). A clear description of Cognitive Radio Network architecture is essential for the development of communication protocols.

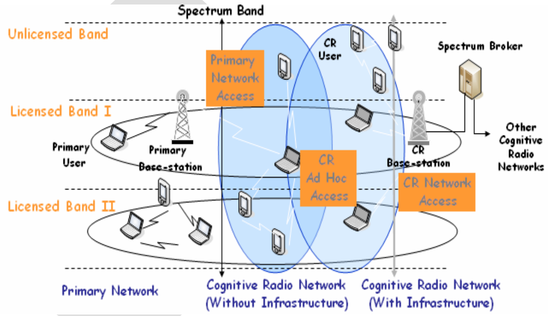

Fig. 1. Cognitive Radio Network Architecture [9]

The components of the Cognitive Radio network architecture, as shown in Figure 1, can be classified in two groups such as the primary network and the CR network. The basic elements of the primary and the CR network are defined as follows:

Primary Network

A network with rights for a specific radio spectrum band is called primary network. Examples include the common cellular network, WiMAX, CDMA and TV broadcast networks. The components of the primary network are as follows.

Primary User

A user of primary network which has a license to operate in a certain spectrum band. Primary user has access to the network via base-station. All of its services and operations are controlled by base-station. Hence, it should not be affected by any unlicensed user or user of any other network. Therefore, primary users do not need any change for coexistence with Cognitive Radio base-stations and Cognitive Radio users.

Cognitive Radio Network

A network where the spectrum access is allowed only in opportunistic manner and does not have license to operate in a desired band is called

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Cognitive Radio Network. It can be deployed both as an infrastructure network and an ad hoc network as shown in Figure 1. The components of a CR network are as follows:

Cognitive Radio User

Cognitive Radio user or secondary user has no spectrum license for its operation so some additional functionality is required to share the licensed spectrum band.

Cognitive Radio Base-Station

Cognitive radio base-station or secondary base-station is a fixed infrastructure component that provides a single hop connection to Cognitive Radio users without any license of radio spectrum. Cognitive Radio users can access the other networks with the help of this connection.

Cognitive radio extends the software radio with radio-domain model-based reasoning about radio etiquettes. Radio etiquette is the set of RF bands, air interfaces, protocols, and spatial and temporal patterns that moderate the use of the radio spectrum [1]. Software radios are emerging as platforms for multiband multimode personal communications systems. It also provides an ideal platform for the realization of cognitive radio. Cognitive radio is a novel approach for improving the utilization of a precious natural resource: the radio electromagnetic spectrum [2]. The cognitive radio, built on a software-defined radio, is defined as an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding-by-building to learn from the environment and adapt to statistical variations in the input stimuli, with two primary objectives in mind: highly reliable communication whenever and wherever needed; efficient utilization of the radio spectrum. The spectrum sensing problem has gained new aspects with cognitive radio and opportunistic spectrum access concepts. Various aspects of spectrum sensing problem are studied from a cognitive radio perspective and multi-dimensional spectrum sensing concept is introduced [3]. A new method of spectrum sensing was proposed, which was based on the Eigenvalues of the covariance matrix of signals received at the secondary users. In particular, two sensing algorithms were suggested [4], one was based on the ratio of the maximum Eigenvalue to minimum Eigenvalue; the other was based on the ratio of the average Eigenvalue to minimum Eigenvalue. The proposed methods overcome the noise uncertainty problem, and can even perform better than the ideal energy detection when the signals to be detected are highly correlated. The methods can be used for various signal detection applications without requiring the knowledge of signal, channel and noise power.

In a wireless regional area networks (WRAN) network, the presence of a wireless microphone (WM) signal must be detected as a primary signal. However, energy detection method is not suitable for low SNR signal. So that Singular value decomposition (SVD)-based approach was used to sense and estimate a WM signal. This method gives better results than traditional energy detection [6].

- As is clear from the architecture description, above cognitive radio networks correspond to networks where a node needs to sense its surroundings to determine the proper free spectrum, possibly with help from other cognitive nodes, and simultaneously respecting the priority of the primary users. This is a highly dynamic and adaptive network. The cognitive task of sensing the spectrum is very much related to signal processing. In the functional framework above this is the responsibility of spectrum sensing component. Traffic performance related questions can be seen in the areas spectrum decision, sharing and mobility. Together all of these functions are responsible for guaranteeing an efficient usage of the wireless medium. To a large extent the performance related questions are similar to those already studied in wireless networking research. A specific feature brought by the cognitive environment is that the network must make the spectrum decision in a dynamic manner while taking into account the needs of the primary users. The objective of this survey is to characterize the various problem formulations where performance is addressed. To achieve this, we have adopted the following methodological categorization of the related literature: Optimization formulations, stochastic formulations, Game theory, Scaling laws, and Information theory.
- Spectrum sensing is one of the most challenging issues in cognitive radio systems. There are various spectrum sensing methods for cognitive radio such as, Energy detection, Eigenvalue based detection, Feature based detection, Cyclostationarity-based detection, and SVD based detection. Discussions about the above techniques and algorithms can be found in [3], [4]. Energy based detection method is a classical method of detection but it requires knowledge of

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noise power for signal detection and it gives poor performance under low SNR. Eigenvalue based detection method achieve both high probability of detection and low probability of false alarm with minimal knowledge of primary signal, [5]. The SVD based detection method is quite similar to Eigenvalue decomposition method. Among them SVD is very general that it can applied to any m×n matrix, while Eigenvalue decomposition method can only be applied to certain classes of square matrix. SVD has got several advantages compared to other decomposition methods [6] as it is more robust to numerical error; it exposes the geometric structure of a matrix an important aspect of many calculations. Since, in SVD decomposition methods the number of singular value depends on the number of rows, which indirectly depend upon the number of columns. So that in SVD based decomposition method it is very important to find optimal value of number of row and column.

III. System Model

Proposed SVD Algorithm

SVD plays an important role in signal processing and statistics, particularly in the area of a linear system. For a time series y (n) with n = 1, 2. . . N, commonly, we can construct a Henkel matrix with M = N -L+1 row and L columns as follows:

$$R = \begin{bmatrix} y(1) & y(2) & & y(L) \\ y(2) & y(3) & \cdots & y(L+1) \\ \vdots & \vdots & & \vdots \\ y(N-L+1) & y(N-L+2) & & y(N) \end{bmatrix} \quad (1)$$

Then R is an M × L matrix. Its elements can be found by substituting of y (n)

R_{ml} = y (m+l-1), m = 1, 2…M and l = 1, 2…L Using SVD, R can be factorized as

R = $U\sum V^H$

U and V is an M × M and L × L unitary matrix, respectively. The columns of U and V are called left and right singular vectors, respectively. The $\sum$ = diag $(\lambda_1, \lambda_2 \dots \lambda_m)$ is a diagonal matrix whose nonnegative entries are the square roots of the positive eigenvalue of R^HR or RR^H. These nonnegative entries are called the singular values of R and they are arranged in a decreasing manner with the largest number in the upper left-hand corner of the matrix. The $[\,]^H$ denotes the Hermitian transpose of a matrix.

Whenever no primary signal or other signal is present, the received signal y (n) includes only AWGN contribution such that its singular values are similar and close to zero. When other signals are active whose power is higher than a threshold, there will exist several dominant singular values to represent these signals. As a result, the signal can be detected by examining the presence of dominant singular values [7].

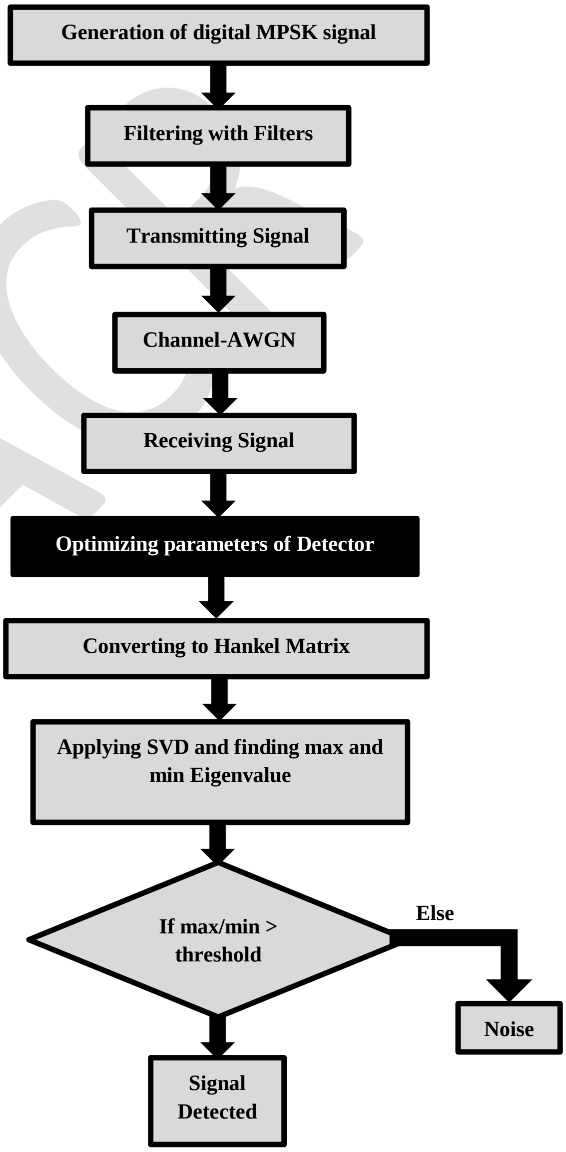

Fig. 2 Flow diagram for proposed work with soft thresholding optimization Algorithm

Threshold Determination

Decision threshold and probability of false alarm are derived based on limiting distribution of eigenvalues

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based on random matrix theory. The decision statistic for the maximum minimum eigenvalue (MME) detection is defined as the ratio of maximum to minimum eigenvalues of received signal covariance matrix as follows:

$$T_Y = \lambda_{max}/\lambda_{min} \qquad (2)$$

Based on decision statistic as in the above equation, the detection threshold, g, must be estimated for a required probability of false alarm. To define the threshold in terms of P_{fa} or vice versa, the density of the test statistic, T_Y, is required. The density can be found asymptotically i.e. both the threshold values and the probabilities of detection and false alarm are derived based on asymptotical (limiting) distributions of eigenvalues that is mathematically tractable and less complicated.

An asymptotic formula of signal detection threshold in term of desired probability of false alarm for MME has been proposed in. The detection threshold in terms of desired probability of false alarm is calculated by using the results of the theorem in and, as follows (in our case, M = 1):

$$\gamma_{mme} = \left((\sqrt{N_s} + \sqrt{L})^2/(\sqrt{N_s} + \sqrt{L})^2\right) \times \left(1 + \frac{(\sqrt{N_s}+\sqrt{L})^{\frac{2}{3}}}{(N_s L)} . F_1^{-1}(1 - P_{fa})\right) \qquad (3)$$

Where F_1^{-1} 1 denotes the inverse of cumulative distribution function (CDF) of the Tracy-Widom distribution of order 1.

The threshold definition is formulated based on deterministic asymptotic values of the minimum and maximum eigenvalues of the covariance matrix, R, when the number of samples, Ns is very large. As shown in the equation, it is defined only in terms of number of samples, N_s, level of covariance matrix, L and the desired probability of false alarm, P_{fa}

Previous method:

- Select number of columns of a covariance matrix, L such that k < L < N-k, where N is the number of sampling points and k is the number of dominant singular values. here, k = 2 and L = 16
- Factorized the covariance matrix.
- Obtain the maximum and minimum eigenvalue of the covariance matrix which are $\lambda_{\max}$ and $\lambda_{\min}$.
- Compute threshold value γ. The threshold value determination will be highlighted in the next section.
- Compare the ratio with the threshold. If $\lambda_{\max}/\lambda_{\min} > \gamma$, the signal is present, otherwise, the signal is not present.

B) ABC:

A. Pseudo code of the ABC Algorithm

1. Initialize the population of solutions x_{ij}
2. Evaluate the population
3. Cycle=1
4. Repeat
5. Produce new solutions (food source positions) v_{ij} in the neighbourhood of x_{ij} for the employed bees and evaluate them.
6. Put on the greedy selection process between xi and v_i
7. Compute the probability values Pi for the solutions xi by means of their fitness values. In order to calculate the fitness values of solutions

$$\begin{bmatrix} \frac{1}{1+f_i} & if\ f_i \geq 0 \\ 1 + abs(f_i) & if\ f_i < 0 \end{bmatrix} \qquad (4)$$

   Normalize p_i values into [0, 1]
8. Produce the new solutions (new positions) v_i for the onlookers from the solutions x_i, selected depending on p_i, and evaluate them
9. Put on the greedy selection process for the onlookers between x_i and v_i
10. Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution xi for the scout using the equation

$$x_{ij} = min_j + rand(0,1) * (max_j - min_j) \qquad (5)$$

11. Memorize the best food source position (solution) achieved so far
12. cycle=cycle+1
   Until cycle= Maximum Cycle Number (MCN)

C) SFLA: The SFL algorithm, in essence, combines the benefits of the genetic-based MAs and the social behaviour-based PSO algorithms. In the SFL, the population consists of a set of frogs (solutions) that is partitioned into subsets referred to as memeplexes. The different memeplexes are considered as different cultures of frogs, each performing a local search. Within each memeplexes, the individual frogs hold ideas, that can be influenced by the ideas of other frogs, and evolve through a process of memetic evolution. After a defined number of memetic evolution steps, ideas are passed among memeplexes in a shuffling process. The local search and the shuffling processes continue until defined convergence criteria are satisfied [6].As described in

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the pseudocode of Appendix A, an initial population of P frogs is created randomly. For S-dimensional problems (S variables), a frog i is represented as Xi = (xi1, xi2,…, xiS). Afterwards, the frogs are sorted in a descending order according to their fitness. Then, the entire population is divided into m memeplexes, each containing n frogs (P m×n). In this process, the first frog goes to the first memeplex, the second frog goes to the second memeplex, frog m goes to the mth memeplex, and frog m+1 goes back to the first memeplex, etc. Within each memeplex, the frogs with the best and the worst fitnesses are identified as Xb and Xw, respectively. Also, the frog with the global best fitness is identified as Xg. Then, a process similar to PSO is applied to improve only the frog with the worst fitness (not all frogs) in each cycle. Accordingly, the position of the frog with the worst fitness is adjusted as follows: Change in frog position (Di) = rand( )× (Xb Xw) (10) New position Xw= current position Xw + Di (11) Dmax≥Di≥-Dmax Where rand( ) is a random number between 0 and 1 and Dmax is the maximum allowed change in a frog's position. If this process produces a better solution, it replaces the worst frog, otherwise the calculations in (10) and (11) are repeated but with respect to the global best frog (Xg replaces Xb). If no improvement becomes possible in this case, then a new solution is randomly generated to replace that frog. The calculations then continue for a specific number of iterations [6]. Accordingly, the main parameters of SFL are: number of frogs P, number of memeplexes, number of generation for each memeplex before shuffling, number of shuffling iterations, and maximum step size. 5. SFLA Procedure The SFLA-based approach for solving the optimal placement and sizing of distributed generation problem to minimize the loss and improve the voltage profile takes the following steps: In SFLA, each possible solution Xi = (xi1, xi2,…, xiS) that in this paper Xi=l1,l2,…,lbus,x1,x2,…,xpower limit Where, l is the number of DG location candidates and x is the number of capacity types of DGs are is considered as a frog. The steps of the algorithm are as follows:

Step 1: Create an initial population of P frogs generated randomly. SFLA_Population =[X1,X2,…,Xp]p×n Where, P=m×n, N is the number of DG, m is the number of memplexes and n is the number of frogs in memplex.

Step 2: Sort the population increasingly and divide the frogs into m memplexes each holding n frogs such that P=m×n. The division is done with the first frog going to the first memplex, second one going to the second memplex, the mth frog to the mth memplex and the m+lth frog back to the first memplex. Fig.3 illustrates this memeplex partitioning process.

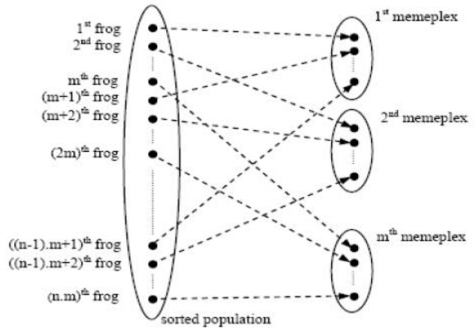

Fig. 3: Membership portioning

Step 3: Within each constructed memeplex, the frogs are infected by other frogs' ideas; hence they experience a me-metic evolution. Memetic evolution improves the quality of the meme of an individual and enhances the individual frog's performance towards a goal. Below are details of memetic evolutions for each memeplex:

Step 3-1: Set m1=0 where m1 counts the number of memeplexes and will be compared with the total number of memeplexes m. Set y1=0 where y1 counts the number of evolutionary steps and will be compared with the maximum number of steps (ymax), to be completed within each meme-plex. Step 3-2: Set m1=m1+1 Step 3-3: Set y1=y1+1 Step 3-4: For each memplex, the frogs with the best fitness and worst fitness are identified as Xw and Xb respectively. Also the frog with the global best fitness Xg is identified, and then the position of the worst frog Xw for the memplex is adjusted such as (10) and (11). Fig.4 demonstrates the original frog leaping rule.

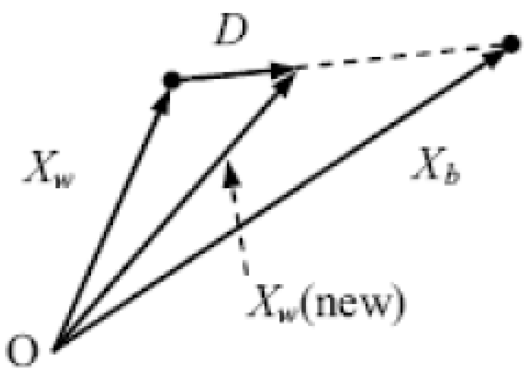

Fig. 4: The original frog leaping rule

If the evolutions produce a better frog (solution), it re-places the older frog, otherwise Xb is replaced by Xg in (10) and the process is repeated. If no improvement becomes possible in this case a random frog is generated which re-places the old frog. Step 3-5: If m1<m, return to step3-2. If

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y1<ymax, return to step 3-3, otherwise go to step 2. Step 4: Check the convergence. If the convergence criteria are satisfied stop, otherwise consider the new population as the initial population and return to the step2. The best solution found in the search process is considered as the output results of the algorithm.

Optimization with ABC and SFLA Algorithm

1. Optimize the value of L by ABC and SFLA.
2. Factorized the covariance matrix.
3. Obtain the maximum and minimum eigenvalue of the covariance matrix which are $\lambda_{\max}$ and $\lambda_{\min}$.
4. Compute threshold valueγ. The threshold value determination will be highlighted in the next section.
5. Compare the ratio with the threshold. If $\lambda_{\max}/\lambda_{\min} > \gamma$, the signal is present, otherwise, the signal is not present.

IV. Simulation And Results

Simulation Parameters:
Modulation Scheme:- MPSK:M=8
Signals:-
1. Rectangular Pulse
2. Raised cosine
3. Root Raised cosine

SNR Range: - -16 to -4 db
P_fa: - 0.01-0.1
Environment: - AWGN.

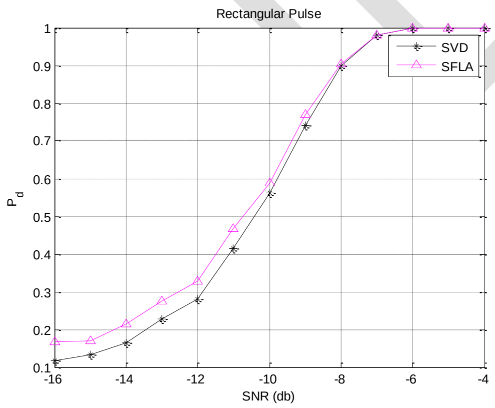

Fig. 5: simulation result of SVD and Shuffeled Frog Leaping for Rectangular pulse

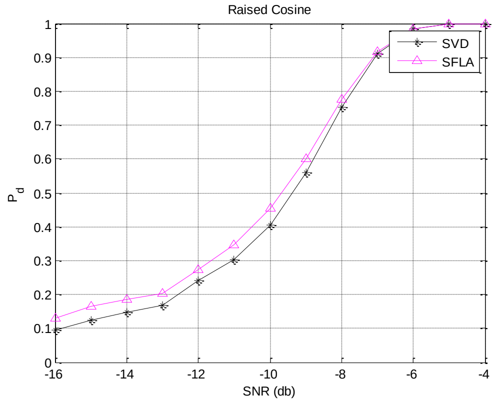

Fig. 6: simulation result of SVD and Shuffled Frog Leaping for Raised cosine pulse

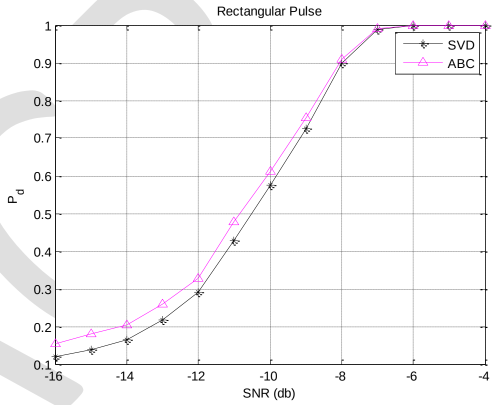

Fig. 7: Simulation result of SVD and ABC for Rectangular pulse

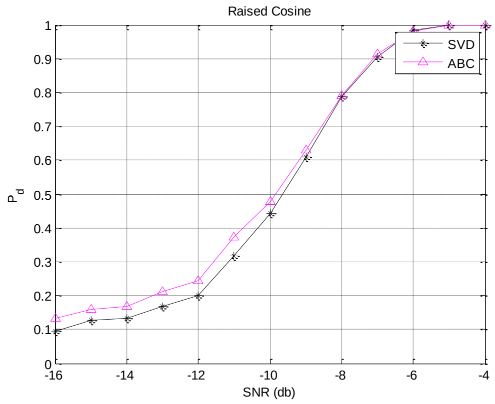

Fig. 8: Simulation result of SVD and ABC for Raised cosine pulse

V. Conclusion

Spectrum is a very valuable resource in wireless communication systems, and it has been a focal point for research and development efforts over the last several decades. Cognitive radio, which is one of the efforts to utilize the available spectrum more efficiently through opportunistic spectrum usage, has become an exciting and promising concept. One of the important elements of cognitive radio is sensing the available spectrum opportunities. In this

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paper, we implemented a SFLA-SVD, ABC-SVD-based approach to detect common signals in today's digital communication system. As expected genetic algorithm has shown its effectiveness on the entire work. The simulation results show the impact of SFLA, ABC on the SVD based method. The detection probability is improved in low SNR zone of simulation which conclude itself that the implementation of this work in reality may make the system more reliable and effective.

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