*Article*

# Spectrum Sensing Using Cooperative Matched Filter Detector in Cognitive Radio

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**Abstract:** The vast rise in the number of Internet-connected devices necessitates a more accessible spectrum. As a result, Cognitive Radio was already proposed as a solution to the problem of restricted spectrum resources by utilizing available spectrum which is assigned to primary users. This method allows the secondary user to utilize the spectrum whenever the primary user is not using it, and it does so without intruding with the primary user. Whenever the secondary user detects the spectrum, it faced some issues, such as complexity in sensing leading to a lack of noise value, and the primary user is hidden to all secondary users. In order to tackle these challenges, an adaptive threshold matched filter detector and a cooperative matched filter detector are utilized in this paper to detect the spectrum. The probability of detection (Pd), probability of miss detection (Pm), and probability of false alarm (Pf) are the metrics used to assess sensing accuracy. To simulate suggested detectors, the MATLAB R2020a software was utilized. In comparison to earlier studies, the simulation conclusions reveal that the detection process starts with lower SNR values.

**Keywords:** Cognitive Radio; MATLAB; WSN; Spectrum; Radio Frequency

## 1. Introduction

Over time, the hardware industry grows to make human life easier, which leads to an increase in the number of devices connected to the Internet. This affects the speed of sending and receiving data and productivity due to a large number of devices. So, the use of cognitive radio objects to take advantage of unused spectrum that is already owned by primary user (PU) and solve the problem of spectrum scarcity should be investigated.

Cognitive radio (CR) is an intelligent technology that recognizes its surroundings in all cases. It is improving the use of the spectrum and reducing its scarcity. This happens when enabling a secondary user (SU) to use the idle spectrum that is unused by PU [1], as shown in Figure (1).

As seen in Figure (2), the primary tasks of CR are spectrum sensing, spectrum sharing, spectrum mobility, and spectrum management. Spectrum sensing involves performing a spectrum scanner to determine whether there are parts of the spectrum that are unused by PU so that they can be reused by SUs. This should be done conditionally, whereas PU is not affected [2,3].

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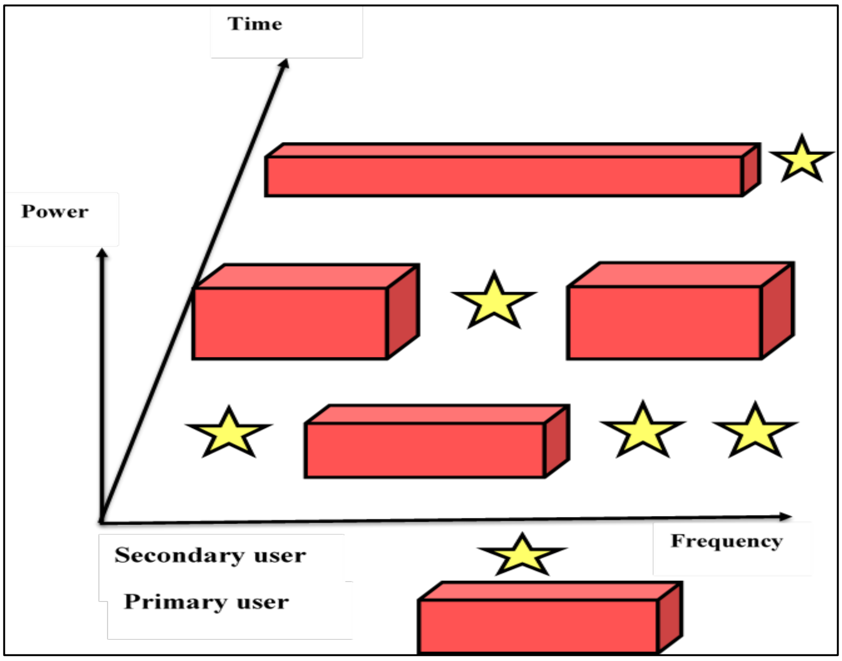


**Figure 1.** The cognitive radio behavior

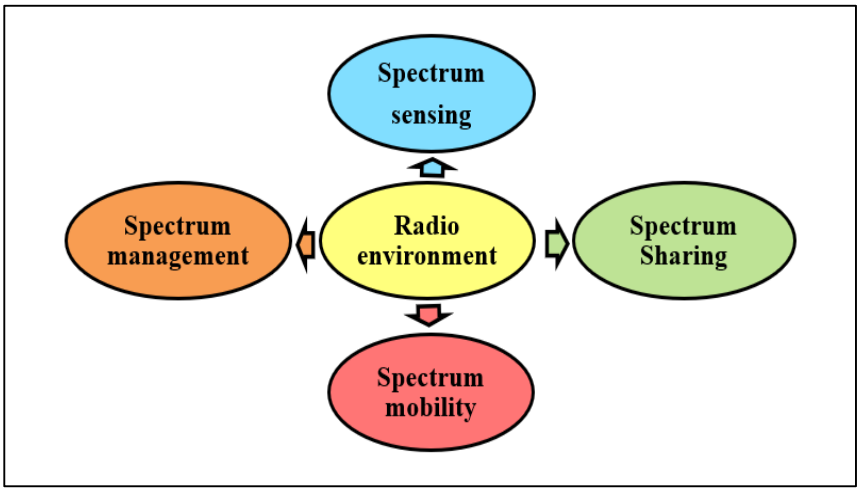


**Figure 2.** Functions of cognitive radio

Spectrum sharing is the process whereby the holes in the spectrum are reasonably distributed to the unlicensed user. If many unlicensed users try to access the spectrum, then access to the CR network should be coordinated to prevent multiple users from colliding in overlapping portions of the spectrum. not similar to spectrum sensing, which is used in the physical layer, and spectrum management, which is closely associated with upper-layer services. Spectrum sharing is identical to multi-user multi-access and resource allocation techniques in the MAC layer of current communication systems [4,5].

Spectrum mobility is responsible for maintaining continuous communication during SU movement from one channel to another. When a spectrum hole is detected and then allocated to SU, it can keep using this idle channel till PU starts transmitting again. At this point, SU must vacate the channel and move to another vacant channel.

Spectrum management is a procedure for spectrum analysis and judgment based on the spectrum sensor results, i.e., it is responsible for selecting the optimum channel from all spectrum sensing holes detected according to the Quality of Service (QoS) for communication that best meets the user's requirements [6]. In the CR system, the spectrum holes detected may disseminate in a wide band that may include both licensed bands and unlicensed bands [7].

The remainder of the paper is arranged as follows: The related works are described in Section II. The matched filter detector (MFD) approach is explained in Section III. Section IV presents the proposed methods. Section V goes into the discussion of the results. Section VI is where the paper finally ends.

## 2. Related Works

The matched filter detector was demonstrated in numerous studies from diverse angles. In [8], the authors proposed an Adaptive Threshold scheme for Matched Filter-based Detection over an Additive White Gaussian Noise channel to maximize the Probability of Detection for a given Probability of False Alarm in varying environmental conditions by implementing Artificial Neural Networks. observe that as the SNR increases, the probability of detection also increases for a fixed SNR equal to 30 dB.

In [9], the authors proposed spectrum sensing based on matched filter detection in CR networks. which demonstrates good performance simulations are carried out to measure the performance of the matched filter to detect primary users over the AWGN channel. A higher probability of detection is obtained with a SNR of 25 dB. As the probability of false alarm increases, threshold values are decreased. For a 0 dB SNR, the lower threshold is achieved for the probability of false alarm of 0.1. If the signal characteristics are known, the matched filter gives a better probability of detection.

In [10], the authors used a dynamic selection of the sensing threshold by measuring the power of noise present in the received signal using a blind technique in order to improve the detection performance. The proposed model was implemented and tested using GNU Radio software and USRP units. The signal was detected at an SNR of -10 dB when the probability of false alarm is 0.01 and at an SNR of -14 dB when the probability of false alarm is 0.02. The probability of detection corresponding to the sensing technique with a dynamic threshold reaches 100% for a value of SNR = −2 dB.

In [11], the authors used new multiple antenna elements (MAE) and matched filtering (MF) based spectrum sensing technique named MAE/MF, which is proposed for detection capability enhancement. Multiple antenna elements' utilization improves the received signal-to-noise ratio, which is proportional to the achieved antenna array gain. The likelihood ratio test is used to decide the presence or absence of the PU signal. Simulation results showed that the proposed MAE/MF technique outperforms the single antenna element based matched filter (SAE/MF) and other existing techniques in the state-of-the-art, especially at extremely low signal to noise ratios and with a limited number of received signal samples. At SNR = 6 dB, it becomes a probability of detection.

To handle the challenges of secondary users in detecting the spectrum issues, this paper employs an adaptive threshold matched filter detector and a cooperative matched filter detector to detect the spectrum.

## 3. Matched Filter Detector (MFD) Method

It is the most complex type of spectrum sensing technique and the most accurate. The sensing can give good results with high noise (low SNR) and PUs can be detected easily because the sensing time is short. It maximizes the signal-to-noise ratio at the output of the detector. However, it needs advanced knowledge of the primary user signal

[12]. The MFD strategy can only be used when the prerequisite knowledge, such as: pilot carrier, modulation type, spreading codes, and pulse shape, is known. It can tell the difference between other SU uses of the channel and the primary user [13]. The MFD statistical test is given [14]:

$$A_{matched}[k] = h[k-n] * x[n], \quad (1)$$

Where x is the received signal, * is the convolution, h is the impulse response.

The mathematical equation that is used for calculating the adaptive threshold (AT) level for the MFD is given in Equation (2) [15]:

$$AT_{matched} = Q^{-1}(P_f)\sqrt{E\sigma^2}, \quad (2)$$

Where $E$ is the PU signal energy and $\sigma^2$ is the variance [15].

The mathematical equation that is used for calculating $P_d$ of the matched filter detector is given in Equation (3) [15]:

$$P_{d,theoretical} = Q\left(\frac{(T-E)}{\sqrt{E\sigma^2}}\right), \quad (3)$$

Where $Q$ is the function, $T$ is the sensing threshold level.

To calculate $P_d$ in Simulink, the Equation (4) is used:

$$P_{d,Simulation} = {N_d}/{N}, \quad (4)$$

Where $N_d$ represents the number of detections, $N$ represents the number of samples. The theoretical and simulation equations for the $P_m$ of matched filter detector are as follows [16]:

$$P_{m,theoretical} = 1 - P_{d,theoretical}, \quad (5)$$

$$P_{m,Simulation} = {N_m}/{N}, \quad (6)$$

Where $N_m$ represents the number of miss detection, $N$ represents the number of samples. The mathematics equation that is used for calculating $P_f$ of the MFD is given in Equation (7) [15]:

$$P_{f,theoretical} = Q\left(\frac{T}{\sqrt{E\sigma^2}}\right), \quad (7)$$

To calculate $Pf$ in Simulink, the Equation (8) is used:

$$P_{f,Simulation} = {N_f}/{N} \quad (8)$$

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Where $N_f$ represents the number of miss detections, $N$ represents the number of samples.

## 4. Proposed Methods

Two solutions are presented to handle the problem of not understanding the value of the noise and the PU being unseen to all SUs: the matched filter detector algorithm using adaptive threshold and the cooperative matched filter detector algorithm using an adaptive threshold.

### *4.1. Matched Filter Detector Algorithm Using an Adaptive Threshold*

A matched filter detector (MFD) algorithm is proposed using the adaptive threshold (AT) level to solve the problem of lack of noise value. As shown in Figure (3) demonstrates the overall work and the preliminary parameters of some variables, such as the number of samples, SNR, probability of false alarm ($P_f$), and the input signal simulated as Binary Phase-shift keying (BPSK). The MFD level is calculated using Equation (1) after adding AWGN, and the AT level for MFD is calculated depending on Equation (2). After that, the value of AT is compared with the value of MFD so that the probability of detection ($P_d$)and probability of miss detection (Pm) can be calculated. This process is continued and repeated until the last number of samples with different SNR range values is completed.

### *4.2. Cooperative Matched Filter Detector Algorithm Using an Adaptive Threshold*

This method employs the following procedures:

- Using many SUs to sense the same spectrum;
- Each SU has different circumstances (noise and gain);
- Every SU follows the MFD algorithm mentioned in Figure (3);
- The result of the comparison between MFD and AT should be transferred to the FC;
- The results come from the comparison. Apply either the OR fusion rule or the AND fusion rule;
- The steps are repeated until the number of samples and SNR values are completed;

A flowchart for a cooperative matched filter detection algorithm using an adaptive threshold is given in Figure (4).

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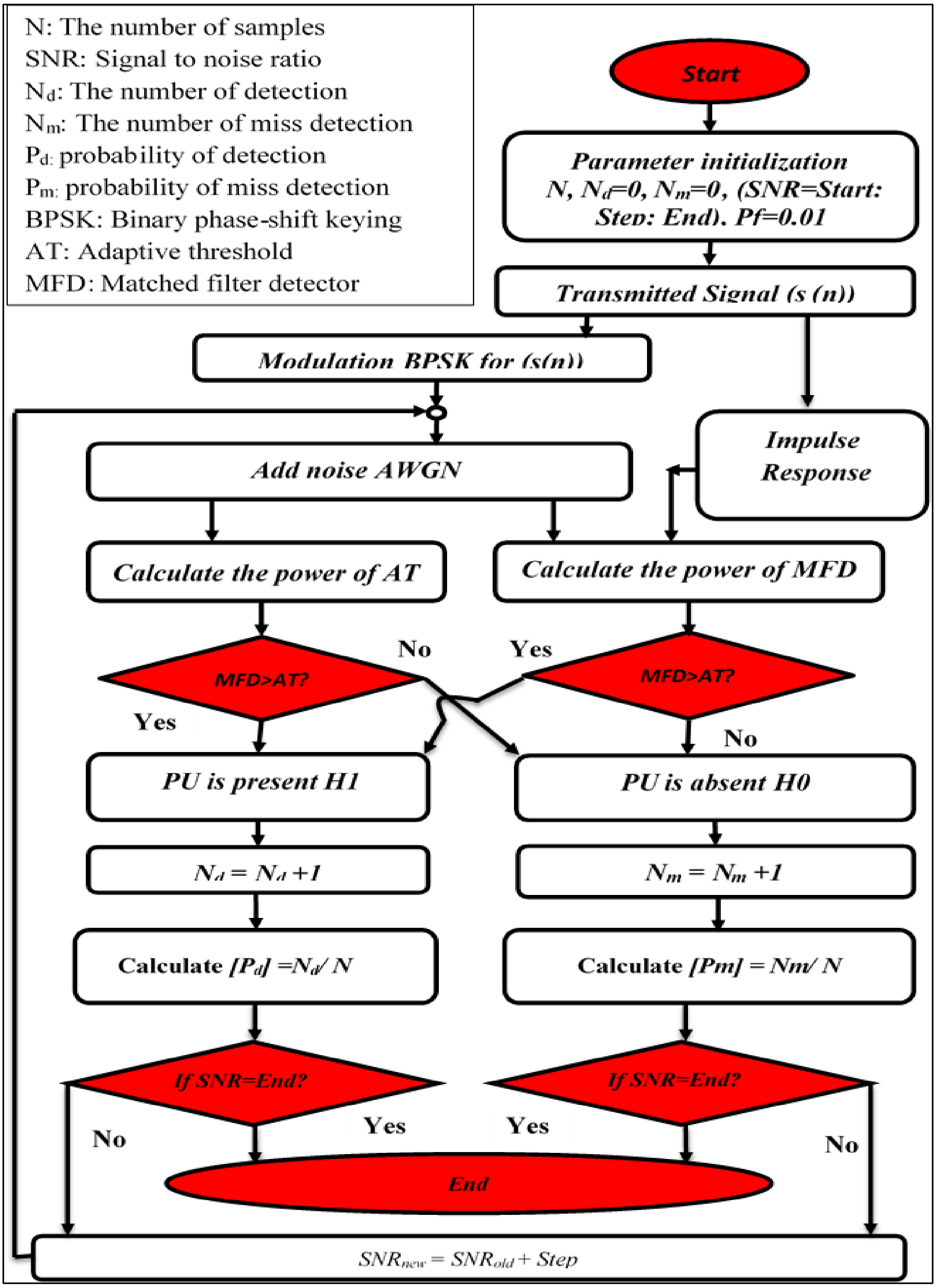


**Figure 3.** A flowchart for a matched filter detector algorithm using an adaptive threshold

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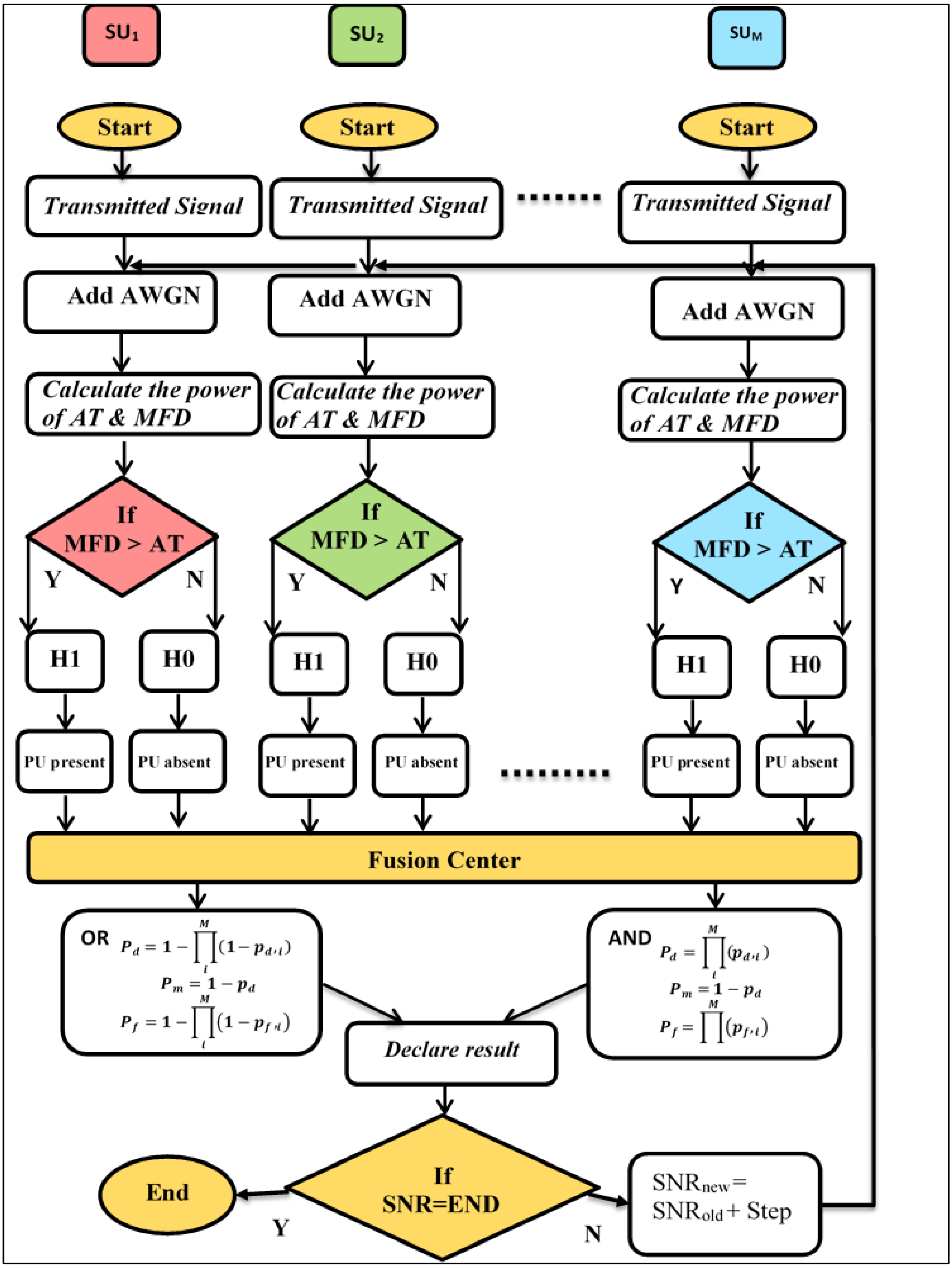


**Figure 4.** A flowchart for a cooperative matched filter detection algorithm using an adaptive threshold

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## 4. Results and Discussion

Matlab programs are used to simulate and assess the effects of a suggested system design. The initial settings used in the simulation are as follows: $N$ =100 samples, $P_f$= 0.01, and *SNR* is changed between -20 and 20 dB.

Figure (5) shows the probability of detection for a matched filter detector ($P_d$) and the *SNR* for the two cases, theoretical and simulation. The *SNR* value is varied in steps from -20 dB to 20 dB. In the simulation case, it is seen that the $P_d$ value is small (about 0.044) at a small value of *SNR* till -20dB, and it rises to be 1 at SNR equals 0 dB up to 20 dB. In the theoretical case, the figure seems to be very close to the simulation case.

Figure (6) shows the relation between the probability of miss detection for matched filter detectors (Pm) and SNR for both theoretical and simulation cases. In the simulation case, Pm value (about 0.956) at SNR equals-20dB, and they decrease to 0 at SNR equals 0 dB, up to 20 dB. In the theoretical case, Pm value (about 0.95) at SNR equals -20 dB, and they decrease to 1 dB at SNR equals-1 dB, up to 20 dB.

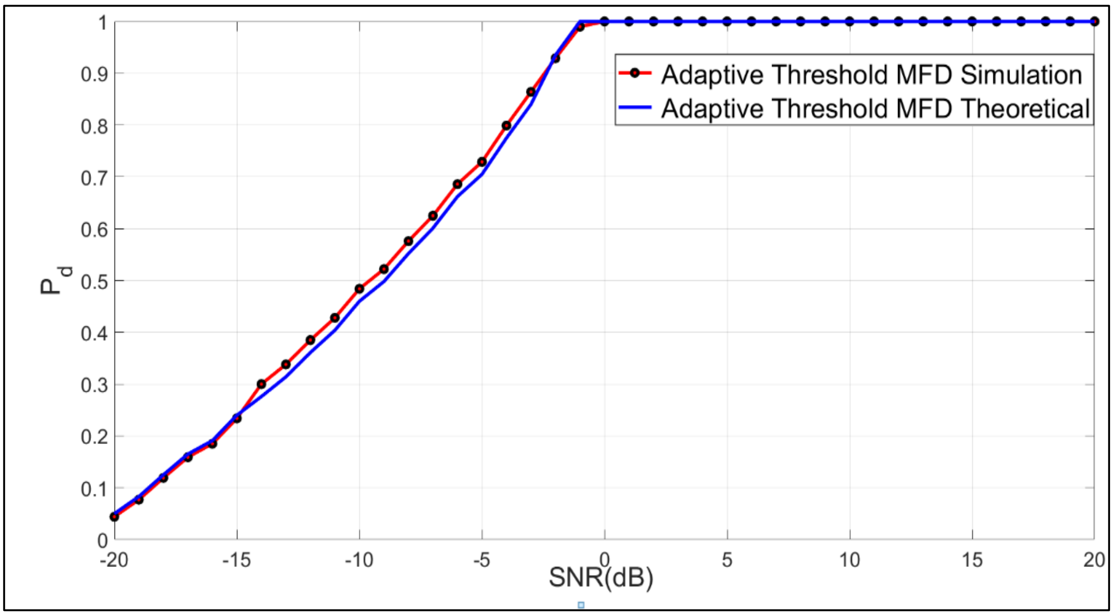


**Figure 5.** Theoretical and simulation $P_d$ for the MFD case vs. *SNR*

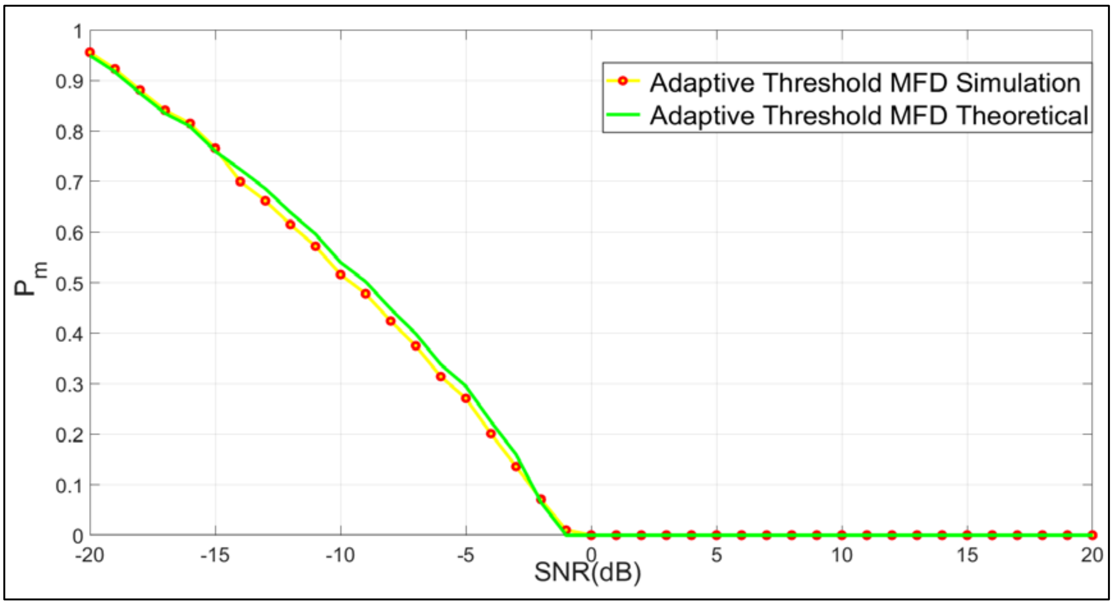

**Figure 6.** Theoretical and simulation *Pm* for the MFD case vs. *SNR*

Figure (7) shows the relationship between the probability of false alarm for a matched filter detector (Pf) and SNR. In both theoretical and simulation cases, Pf values in simulation are high (about 0.94) at a very small value of SNR till -20dB, and then they decrease to 0 at SNR equal to -1dB up to 20 dB. In the theoretical case, the figure seems to be very close to the simulation case. All the theoretical and simulation values for Pd, Pm, and Pf are summarized in Table (1) for various SNR values.

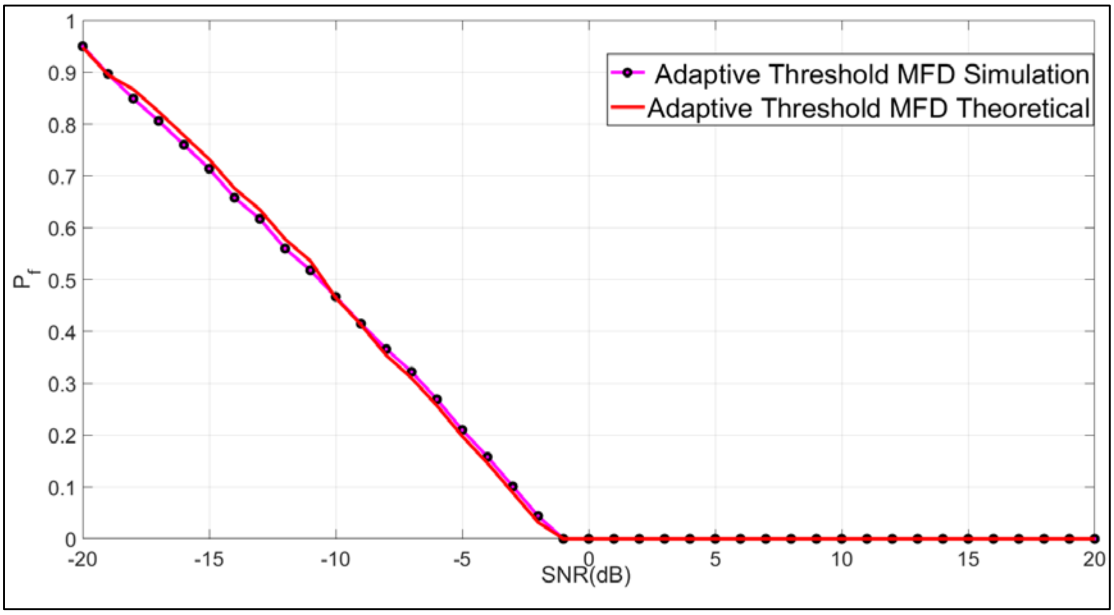


**Figure 7.** Theoretical and simulation Pf for the MFD case vs. SNR

**Table 1** Summery results of matched filter detector using an adaptive threshold

| SNR | Pd Simulation | Pd Theoretical | Pm Simulation | Pm Theoretical | Pf Simulation | Pf Theoretical |
|---|---|---|---|---|---|---|
| -20 | 0.044 | 0.05 | 0.956 | 0.95 | 0.95 | 0.948 |
| -19 | 0.077 | 0.083 | 0.923 | 0.917 | 0.897 | 0.895 |
| -18 | 0.119 | 0.125 | 0.881 | 0.875 | 0.849 | 0.867 |
| -17 | 0.159 | 0.165 | 0.841 | 0.835 | 0.806 | 0.824 |
| -16 | 0.185 | 0.191 | 0.815 | 0.809 | 0.76 | 0.778 |
| -15 | 0.234 | 0.24 | 0.766 | 0.76 | 0.714 | 0.732 |
| -14 | 0.3 | 0.276 | 0.7 | 0.724 | 0.658 | 0.676 |
| -13 | 0.338 | 0.314 | 0.662 | 0.686 | 0.617 | 0.635 |
| -12 | 0.385 | 0.361 | 0.615 | 0.639 | 0.56 | 0.578 |
| -11 | 0.428 | 0.404 | 0.572 | 0.596 | 0.518 | 0.536 |
| -10 | 0.484 | 0.46 | 0.516 | 0.54 | 0.467 | 0.465 |
| -9 | 0.522 | 0.498 | 0.478 | 0.502 | 0.415 | 0.413 |
| -8 | 0.576 | 0.552 | 0.424 | 0.448 | 0.366 | 0.354 |
| -7 | 0.625 | 0.601 | 0.375 | 0.399 | 0.322 | 0.31 |

The following figures give the results of the analysis of the cooperative matched

| | | | | | | |
|---|---|---|---|---|---|---|
| -6 | 0.686 | 0.662 | 0.314 | 0.338 | 0.269 | 0.257 |
| -5 | 0.729 | 0.705 | 0.271 | 0.295 | 0.21 | 0.198 |
| -4 | 0.799 | 0.775 | 0.201 | 0.225 | 0.158 | 0.146 |
| -3 | 0.864 | 0.84 | 0.136 | 0.16 | 0.101 | 0.089 |
| -2 | 0.929 | 0.935 | 0.071 | 0.065 | 0.044 | 0.032 |
| -1 | 0.99 | 1 | 0.01 | 0 | 0 | 0 |
| 0-20 | 1 | 1 | 0 | 0 | 0 | 0 |

filter detector algorithm in Figure (4) using AT level. It is seen that the result of cooperative MFD is better than a single MFD because there is more than one detector doing the check on the channel. Figure (8) illustrates the relationship between Pd and SNR using six SUs with various environmental conditions (gain, noise). As shown in Table (2).

**Table 2** The environmental conditions for six SUs using step noise (-20 – 20)

| Secondary user | Normalcy again |
|---|---|
| Su1 | 0.4 |
| Su2 | 0.3 |
| Su3 | 0.8 |
| Su4 | 0.5 |
| Su5 | 0.9 |
| Su6 | 1 |

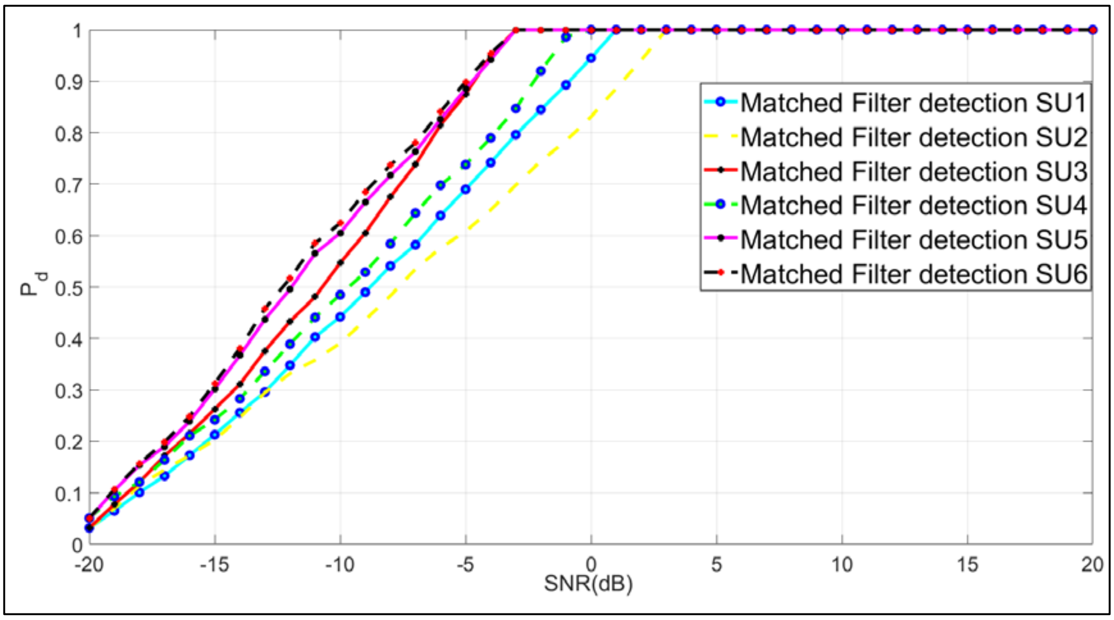


**Figure 8.** Pd for six individual SUs vs. SNR for MFD

Figure (9) shows the relationship between Pd and SNR when using the two fusion rules (OR-Cooperative, AND-Cooperative). Also, the MFD case is plotted. It is noticed that OR-Cooperative is the better, where Pd value is (0.19) at -20 dB and it rises to be 1 at SNR equal to -5 dB to 20 dB. While in the AND-Cooperative, it is seen that the Pd value is very small (0.005) at a small value of SNR till -20 dB, and it rises to be 1 at SNR equals 0 dB to 20 dB. In the results of the non-cooperative case, it is seen that the Pd value is small (0.045) at a small value of SNR till -20 dB, and it rises to be 1 at SNR equal to -2 dB to 20 dB.The values of OR-Cooperative, AND-Cooperative, and non-cooperative cases are summarized in Table (3).

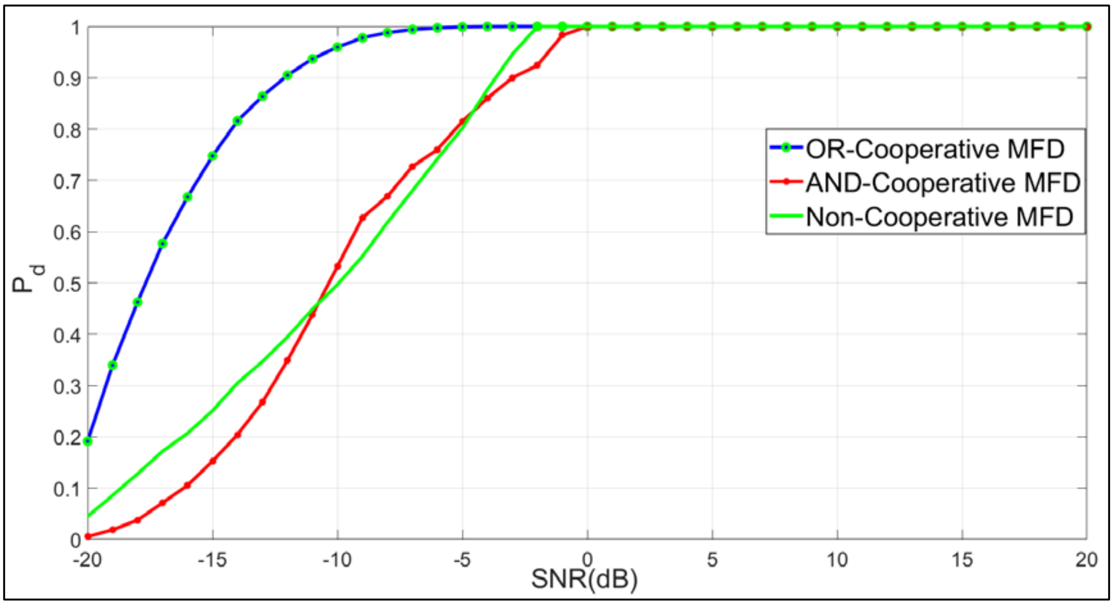


**Figure 9.** Pd (OR-Cooperative, AND-Cooperative, Non-Cooperative) vs. SNR for MFD

**Table 3** $P_d$ (OR-Cooperative, AND-Cooperative, Non-Cooperative) and *SNR* for MFD

| SNR | OR-Cooperative | AND-Cooperative | Non-Cooperative |
|---|---|---|---|
| -20 | 0.191517 | 0.005376 | 0.045 |
| -19 | 0.339672 | 0.018887 | 0.086 |
| -18 | 0.462811 | 0.037752 | 0.128 |
| -17 | 0.576826 | 0.0714 | 0.172 |
| -16 | 0.667771 | 0.105462 | 0.207 |
| -15 | 0.747588 | 0.15264 | 0.251 |
| -14 | 0.816109 | 0.204288 | 0.305 |
| -13 | 0.863957 | 0.267804 | 0.347 |
| -12 | 0.904998 | 0.349325 | 0.395 |
| -11 | 0.936993 | 0.438 | 0.449 |
| -10 | 0.959762 | 0.532539 | 0.497 |
| -9 | 0.978095 | 0.627 | 0.552 |
| -8 | 0.988115 | 0.669 | 0.618 |
| -7 | 0.994216 | 0.727 | 0.68 |
| -6 | 0.997313 | 0.76 | 0.742 |
| -5 | 1 | 0.815 | 0.802 |
| -4 | 1 | 0.86 | 0.877 |
| -3 | 1 | 0.9 | 0.946 |
| -2 | 1 | 0.924 | 1 |
| -1 | 1 | 0.983 | 1 |
| 0-20 | 1 | 1 | 1 |

Figure (11) describes the relationship between Pm and SNR, for OR-Cooperative, AND-Cooperative, and Non-Cooperative. It is clear that the OR-Cooperative case is the better of the three, while the two other cases are nearly identical. The values (OR-Cooperative, AND-Cooperative, and Non-Cooperative) for MFD are summarized in Table (4).

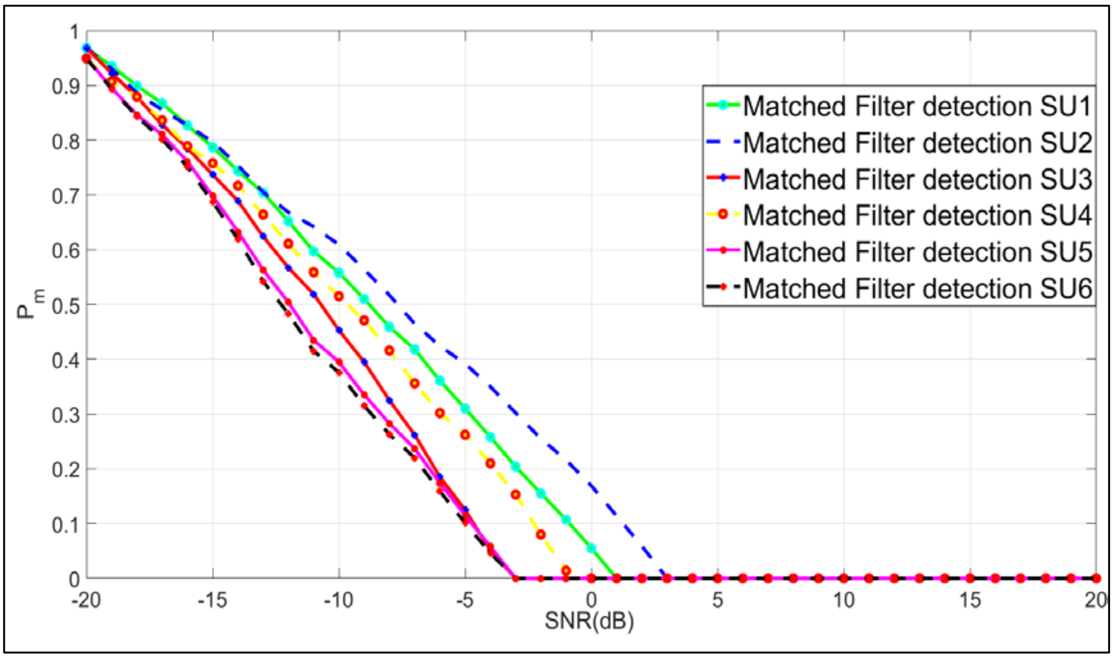


**Figure 10.** $P_m$ for six individual SUs vs. SNR for MFD

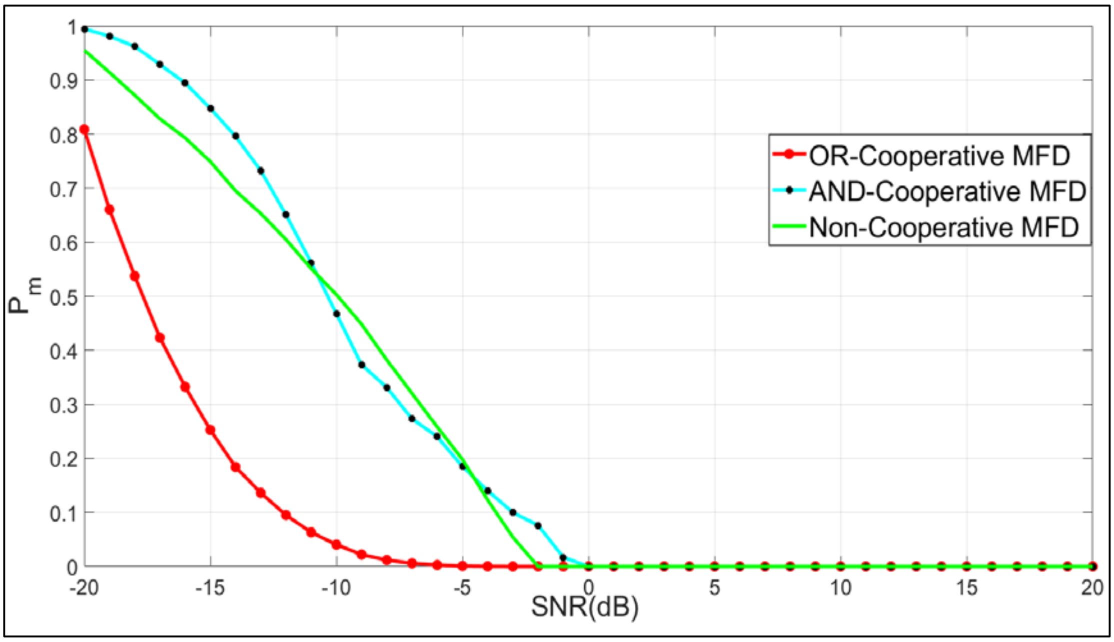


**Figure 11.** P_m (OR-Cooperative, AND-Cooperative, Non-Cooperative) vs. SNR for MFD

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**Table 4** $P_m$ (OR-Cooperative, AND-Cooperative, Non-Cooperative) and *SNR* for MFD

| SNR | OR-Cooperative | AND-Cooperative | Non-Cooperative |
|---|---|---|---|
| -20 | 0.808483 | 0.994624 | 0.956 |
| -19 | 0.660328 | 0.981113 | 0.923 |
| -18 | 0.537189 | 0.962248 | 0.881 |
| -17 | 0.423174 | 0.9286 | 0.841 |
| -16 | 0.332229 | 0.894538 | 0.815 |
| -15 | 0.252412 | 0.84736 | 0.766 |
| -14 | 0.183891 | 0.795712 | 0.7 |
| -13 | 0.136043 | 0.732196 | 0.662 |
| -12 | 0.095002 | 0.650675 | 0.615 |
| -11 | 0.063007 | 0.562 | 0.572 |
| -10 | 0.040238 | 0.467461 | 0.516 |
| -9 | 0.021905 | 0.373 | 0.478 |
| -8 | 0.011885 | 0.331 | 0.424 |
| -7 | 0.005784 | 0.273 | 0.375 |
| -6 | 0.002687 | 0.24 | 0.3140 |
| -5 | 0 | 0.185 | 0.271 |
| -4 | 0 | 0.14 | 0.201 |
| -3 | 0 | 0.1 | 0.136 |
| -2 | 0 | 0.076 | 0 |
| -1 | 0 | 0.017 | 0 |
| 0-20 | 0 | 0 | 0 |

Figure (12) illustrates the relationship between Pf and SNR using six SUs individually with different environmental conditions (gain, noise). Figure (13) indicates the relationship between Pf and SNR, for (OR, AND, and Non-Cooperative MFD). Here also, the better case is the OR case, and the other two cases are nearly the same. The values (OR-Cooperative, AND-Cooperative, Non-Cooperative) are summarized in Table (5).

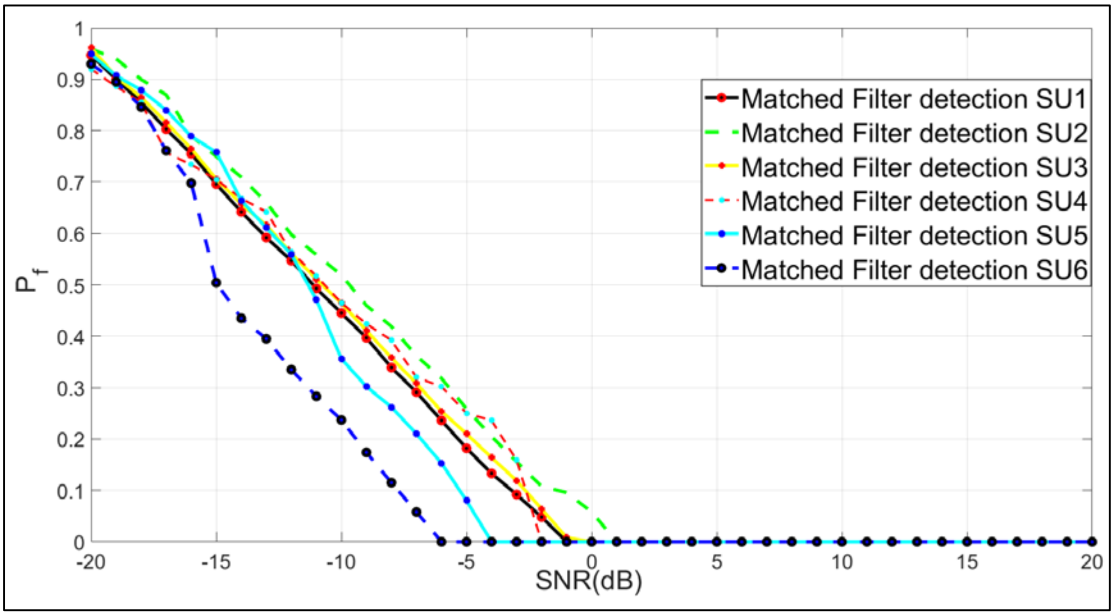


**Figure 12.** Pf for six individual SUs vs. SNR for MFD

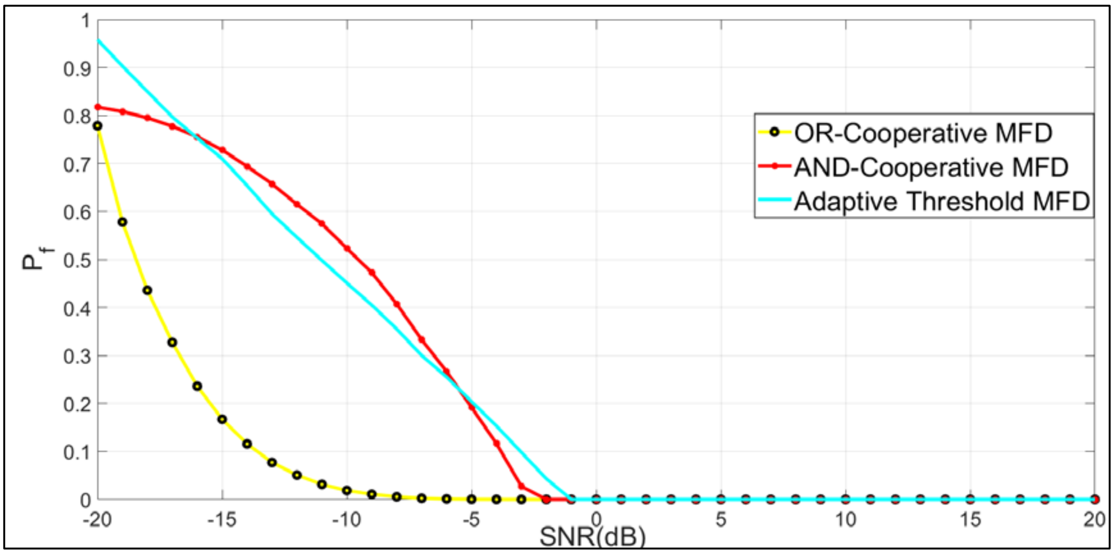


**Figure 13.** Pf (OR-Cooperative, AND-Cooperative, Non-Cooperative) vs. SNR for MFD

**Table 5** Pf (OR − Cooperative, AND − Cooperative, Non − Cooperative) and SNR for MFD

| SNR | OR-Cooperative | AND-Cooperative | Non-Cooperative |
|---|---|---|---|
| -20 | 0.778626 | 0.994624 | 0.94 |
| -19 | 0.578038 | 0.981113 | 0.887 |
| -18 | 0.435889 | 0.962248 | 0.839 |
| -17 | 0.327209 | 0.9286 | 0.796 |
| -16 | 0.235948 | 0.894538 | 0.75 |
| -15 | 0.166959 | 0.84736 | 0.704 |
| -14 | 0.115614 | 0.795712 | 0.648 |
| -13 | 0.076924 | 0.732196 | 0.607 |
| -12 | 0.05063 | 0.650675 | 0.55 |
| -11 | 0.031206 | 0.562 | 0.508 |
| -10 | 0.018598 | 0.467461 | 0.457 |
| -9 | 0.010696 | 0.373 | 0.405 |
| -8 | 0.003507 | 0.331 | 0.356 |
| -7 | 0.000139 | 0.273 | 0.312 |
| -6 | 0 | 0.24 | 0.259 |
| -5 | 0 | 0.185 | 0.2 |
| -4 | 0 | 0.14 | 0.148 |
| -3 | 0 | 0.1 | 0.091 |
| -2 | 0 | 0 | 0.034 |
| -1- 20 | 0 | 0 | 0 |

## 5. Conclusions

This paper proposes a matched filter detector with an adaptive threshold and a cooperative matched filter detector with an adaptive threshold to address two major issues arising in spectrum sensing. The first issue is that narrow-scope detection is difficult to detect due to the lack of noise level. The primary user is hidden from all secondary users, which is the second major issue. To determine the spectrum's sensing precision, the proposed methods are evaluated using the Pd, Pm, and Pf criteria.

The simulation results show that in the matched filter detector using an adaptive threshold case, the Pd value at -20 dB SNR is 0.045 and increases to 1 when SNR is -1dB. The Pm value was 0.956 at SNR equal to -20 dB and decreased to 0 at SNR of -1 dB. Pf is 0.94 when the SNR is -20 dB, but it is 0 when the SNR is 1 dB. While in the case of cooperative matched filter detector using an adaptive threshold for OR cases, the results were:

- At SNR -20 dB, the Pd value is 0.19 and goes up to 1 at SNR -6 dB. Pd is 0.005 for the AND case when SNR is -20 dB and increases to 1 when SNR is -1 dB;
- The Pm value at SNR -20 dB is 0.8 and goes down to 0 at -2 dB. For the AND case, when SNR is -20 dB, Pm is 0.99 and decreases to 0 at SNR of 0 dB;
- The Pf value at SNR at -20 dB is 0.77 and goes down to 0 at SNR -6 dB. For the AND case, when SNR -20 dB is 0.99 and decreases to 0 at SNR -3 dB;

It is noticed from the results that the cooperative matched filter detector is better than the single matched filter detector.

**Supplementary Materials:** The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

**Author Contributions:** Conceptualization, Zozan Ayoub and G.Khalil; methodology, Zozan Ayoub and G. Khalil; software, Zozan Ayoub and Ayoob Ayoob; validation, Zozan Ayoob and G. Khalil; formal analysis, Zozan Ayoob and Ayoob Ayoob; investigation, Zozan Ayoob and Ayoob Ayoob; resources, Zozan Ayoob; data curation, Zozan Ayoob; writing—original draft preparation, Zozan Ayoob.; writing—review and editing, Zozan Ayoob and Ayoob Ayoob; visualization, G. Khalil.; supervision, G. Khalil.; project administration, Ayoob Ayoob and G.Khalil.; funding acquisition, G. Khalil. All authors have read and agreed to the published version of the manuscript.”

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## References

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1. Author 1, A.B.; Author 2, C.D. Title of the article. *Abbreviated Journal Name* **Year**, *Volume*, page range.
2. Author 1, A.; Author 2, B. Title of the chapter. In *Book Title*, 2nd ed.; Editor 1, A., Editor 2, B., Eds.; Publisher: Publisher Location, Country, 2007; Volume 3, pp. 154–196.
3. Author 1, A.; Author 2, B. *Book Title*, 3rd ed.; Publisher: Publisher Location, Country, 2008; pp. 154–196.
4. Author 1, A.B.; Author 2, C. Title of Unpublished Work. *Abbreviated Journal Name* year, *phrase indicating stage of publication (submitted; accepted; in press)*.
5. Author 1, A.B. (University, City, State, Country); Author 2, C. (Institute, City, State, Country). Personal communication, 2012.
6. Author 1, A.B.; Author 2, C.D.; Author 3, E.F. Title of Presentation. In Proceedings of the Name of the Conference, Location of Conference, Country, Date of Conference (Day Month Year).
7. Author 1, A.B. Title of Thesis. Level of Thesis, Degree-Granting University, Location of University, Date of Completion.
8. Title of Site. Available online: URL (accessed on Day Month Year).