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Research Article

A New Adaptive Two Stage Spectrum Sensing Technique in Cognitive Radio System for Different Modulation Schemes

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Abstract: The aim of this study is to suggests a new two stage spectrum sensing approach. More specifically, a fast spectrum sensing algorithm based on the energy detection is introduced. The proposed system deals with soft decision with multilevel threshold values. Also, constant value of false alarm probability is used to obtain the constant false alarm rate principles. Matlab simulation program is used to obtain the results. In order to evaluate the performance of the proposed adaptive cognitive radio detection system, different modulated digital signals are generated at low SNR values. These different levels of 2FSK, 4FSK, BPSK, QPSK, 8PSK, 4QAM, 16QAM, 64QAM and 256QAM are used together for the first time in this study. The obtained results show excellent performance for the proposed system due to their detection probability of 100% at -15dB for probability of false alarm is 0.1. Different message lengths with different noisy channels such as AWGN and fading are also examined. Numerical results indicate that better performance is achieved by proposed two stage sensing detection compared to the conventional energy detector of the published papers.

Keywords: Cfar, cognitive radio, PU, SDR, spectrum sensing, SU

INTRODUCTION

With the rapid growth of wireless communication, it becomes more and more congested for the limited frequency spectrum. In connection with an evaluation of future communications-related demands, the spectrum is expected to become even more tremendously in the coming years. However, the current spectrum scarcity is largely due to the inefficient static spectrum allocations than the physical shortage of the spectrum. This point of view is supported by recent studies of the FCC (Li, 2009). To deal with the conflicts between spectrum congestion and spectrum under-utilization, cognitive radio has been recently considered as an efficient approach to improve the spectrum utilization via opportunistic spectrum sharing. However, Cognitive Radio (CR) is considered lower priority to a PU. This Fundamental requirement is to avoid interference to Potential primary users (Pus) in their vicinity. To implement without interference to the primary signal, the CR needs to sense the availability of the spectrum before accessing the channel (Yue and Zheng, 2009). Currently, the spectrum sensing techniques can be classified as matched filter, cyclostationary feature detection and energy detection. The matched filter is viewed as optimal since it maximizes received Signal-to-Noise Ratio (SNR) in communication systems. However, a significant drawback of a matched filter is that it needs the prior knowledge of the primary user's signal such as the modulation type and order, pulse shaping and packet format. Cyclostationary feature detection (Singh and Rai, 2014) can detect the signals with very low SNR but still requires some prior knowledge of the PU. CRs have been proposed as a possible solution to improve spectrum utilization by enabling opportunistic spectrum sharing. Their technological capabilities allow CRs to dynamically seek and access to unused portions of the radio spectrum and thus improving spectral resources utilization (Chakraborty *et al*., 2010). The main requirement for the CR to make use of spectral opportunities is to protect licensed users from interference caused by secondary transmissions.

Figure 1 represents the frequency spectrum and shows the basic goal of the CR to detect the signal and sense the spectrum either used or not used.

There are three regions are shown in this figure; heavy use, medium use and sparse used regions. Sparse used regions can be used as a good environment for applying CR concept.

The radio spectrum is limited resource and is regulated by government agencies such as Federal Communications Commission (FCC) (2002) and

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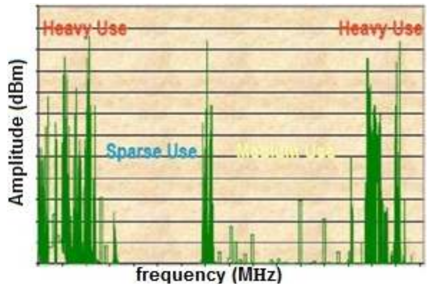

Fig. 1: Frequency spectrum that shows different regions

(Zahir, 2014). In this study, a new adaptive two stage CR detection system is proposed. The principles of energy detection are used with soft decision to detect the signal from noise. More than one threshold is used to increase the detection probability.

Cognitive radio concept: CR including Software-Defined Radio (SDR) as enabling technology, was proposed in Venkata (2011) to realize adaptable and effective usage of spectrum. The term cognitive radio is gotten from “cognition”. Cognition is a term referring to the mental processes involved in picking up information and comprehension, including thinking, knowing, recollecting, judging and problem-solving. These higher-level functions of the brain include language, imagination, perception and planning (Haykin, 2005).

CR may have significant impacts on both technology and regulation of use of spectrum leading to a revolution in wireless communication overcoming existing regulatory barriers (Puttupu, 2013).

CR came from number of technologies such as the improvement of Digital Signal Processing (DSP), math tools and source coding of data, voice and image etc. CR has turned into promising strategy to solve the spectrum scarcity problem for supporting evolving wireless services and applications. In cognitive radio systems, the unlicensed users can use the licensed frequencies while PU is not dynamic. For accomplishing good spectrum sensing performance (Bagwari *et al*., 2014; Cabric *et al*., 2006).

CR was introduced at 1999 by Joseph (2000). It is supposed to change their operating band, if the currently used band becomes too occupied or the primary user takes the band into use. The most important feature of the cognitive radios is the capacity to sense the spectrum, whether to take a certain band into use or not.

CR can adapt to their environment via varying their transmitter factors to different signaling systems. Depending upon the network and cooperation with other cognitive devices, they can trade information about their location and environment. CR can cooperate with other cognitive radios and offer information between each other. Reconfigurability was used in radio development. A common radio communication system is implemented in hardware. In a software defined radio most of the required hardware and required transmitter and receiver algorithms are implemented in software, thus high reconfigurability is achieved (Plata and Reátiga, 2012; Bansal and Mahajan, 2009).

As a general definition for CR is: “Cognitive radio is a radio of an intelligent wireless communication system that senses and is aware of its surrounding environment and capable to use or share the spectrum in an opportunistic manner without interfering the licensed users” (Chakraborty *et al*., 2010).

It uses different techniques to become aware of the surroundings, have the capacities to learn from the outer environment and can change the parameters of the transmitted and received data to achieve the goal of effective communication without interference (Haykin, 2005). Figure 2 represents the detection cycle of CR that shows the steps of detection process.

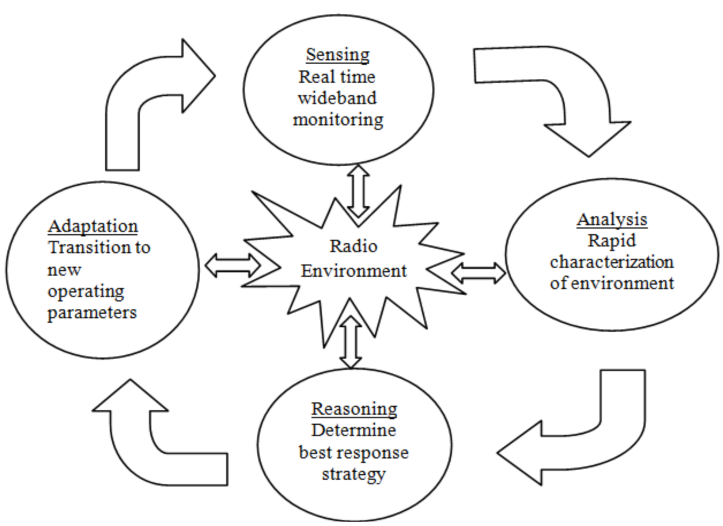

Fig. 2: Detection cycle of CR

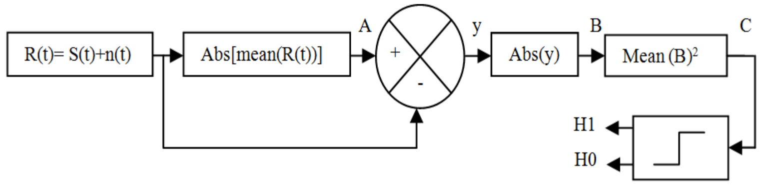

Fig. 3: Block diagram of the proposed CR system

It's clearly seen from the figure that the sensing stage is the first and the most important stage. There are different sensing techniques can be seen in Thabit and Ziboon (2015).

Concept of two hypotheses: Spectrum sensing can be simply decreased to an identification problem, this is can be modeled as a hypothesis test (Bansal and Mahajan, 2009; Ivan, 2016). The sensing equipment has to just decide between two hypotheses:

$$H_o : y[n] = w[n] \quad (1)$$

$$H_1 : y[n] = s[n] + w[n] \quad (2)$$
$n = 1\ldots N$,

where,
s(n) = The signal transmitted via the primary users
y(n) = The signal received via the secondary users
w(n) = The additive white Gaussian noise with variances
N = The length of message

Hypothesis 'H_0' indicates absence of primary user and that the frequency band of interest only has noise whereas 'H_1' points towards presence of primary user.

Thus for the two state hypotheses numbers of important cases are: The Probability of Detection (Pd) is of main concern as it gives the probability of correctly sensing for the presence of primary users in the frequency band. Probability of miss-detection (Pm) is just the complement of detection probability. The goal of the sensing schemes is to maximize the detection probability for a low probability of false alarm. But there is always a trade-off between these two probabilities. Receiver Operating Characteristics (ROC) presents very valuable information as regards the behavior of detection probability with changing false alarm probability (Pd v/s Pf) or miss-detection probability (Pd v/s Pm) (Puttupu, 2013; Bagwari *et al*., 2014; Cabric *et al*., 2006; Joseph, 2000; Plata and Reátiga, 2012; Bansal and Mahajan, 2009).

Proposed system: In order to enhance the probability of detection at low SNR, a two stage CR system with multilevel threshold is proposed. This system consists of two stages based on energy detector principles. At the first stage of the detection, the received noisy signal is squared, averaged then absolute to extract the power of the signal which represents conventional energy detection as shown in Fig. 3. The second stage consists of subtraction between the received noisy signal and the output of the first stage. The result is absolute then squaring the result and taking the mean of the signal to compare it with two threshold levels (0.95 and 1.05) to decide whether the channel is free or not. These thresholds selected according to the requirements for good detection such as high Probability of Detection (Pd) at low SNR. Figure 3 represents the block diagram of the proposed two stages detection system.

Where R(t) is the received noisy signal that consist of different modulation signals S(t) with noise (n(t)) either AWGN or fading. Different modulation types such as 2FSK, 4FSK, BPSK, QPSK, 8PSK, 4QAM, 16QAM, 64QAM and 256QAM are generated at baseband stage depend on the value of received SNR. These multimodulations signals that consist of 9 different types of generated modulated signals are used together for the first time in this study and hence this collection gives the system more close to real case when different types of random signals reach to the receiver. The flowchart of proposed two stage detection system as shown in Fig. 4 that shows the steps to obtain the decision:

This flowchart shows the details of the two stage of the proposed system.

SIMULATION RESULTS AND DISCUSSION

Matlab simulation program is used to obtain the results. In order to evaluate the performance of the proposed CR detection systems, digital signals are generated in matlab at different low SNR. The different levels of FSK, PSK and QAM signals are generated are 2FSK, 4FSK, 2BPSK, QPSK, 8PSK, 16PSK, 4QAM, 16QAM, 64QAM, 128QAM and 256QAM. The simulation is made for different trails in order to guarantee that the results are accurately representing the performance of the proposed detection systems. Each trail consists of one thousand of generated signal for each type of digital modulations. Each signal consists of different number of samples. The trails are simulated for each testing SNR. For each type of signals, the probability of detection is evaluated for different SNR.

The table of the designed parameters is shown in Table 1. The selected parameters were selected according to the design requirements.

Figure 5 stand for SNR versus P_d at $P_f = 0.1$ with number of iteration is 10 with message length = 500, it's noted from the figure that P_d is 100% at SNR = -8 dB.

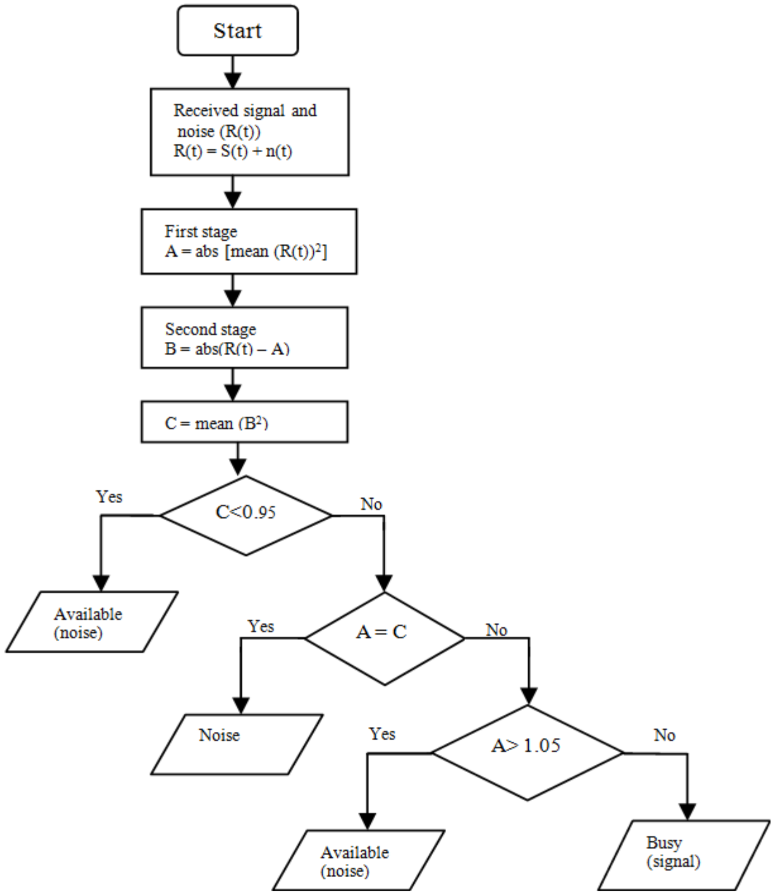

Fig. 4: Flowchart of the proposed two stages CR

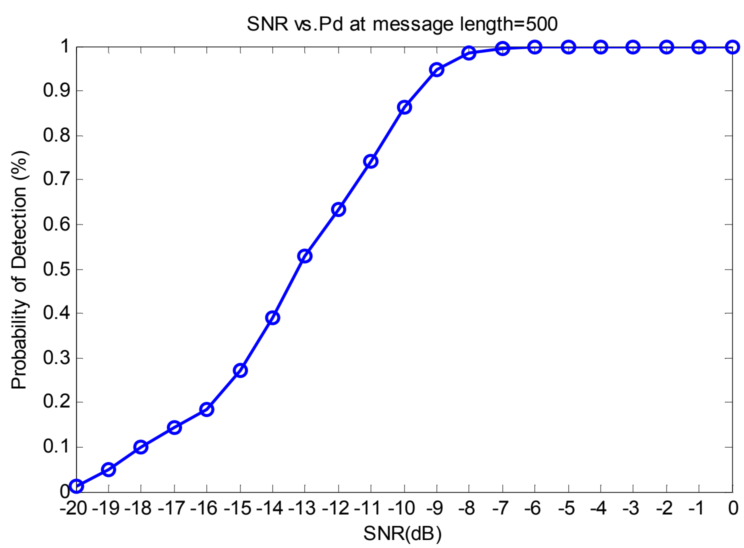

Fig. 5: SNR versus P_d at P_f = 0.1, iterations is 10 with message length = 500

Table 1: Design parameters of two stage energy detection

Parameters	Values
P_f	0.1
Number of iterations	10, 100, 1000, 10000
Message length	500,1000,…8000
SNR ranges	-20dB → 0dB
Modulation type	MFSK,MPSK and MQAM

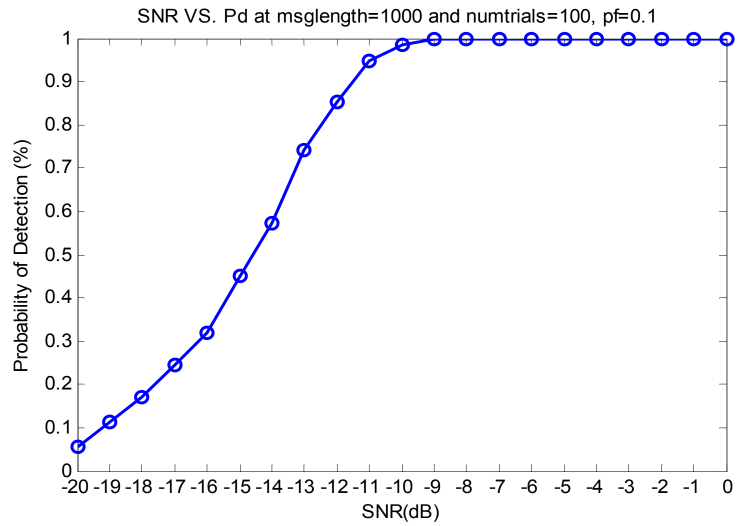

Fig. 6: SNR versus P_d at P_f = 0.1, iterations is 100 with message length = 1000

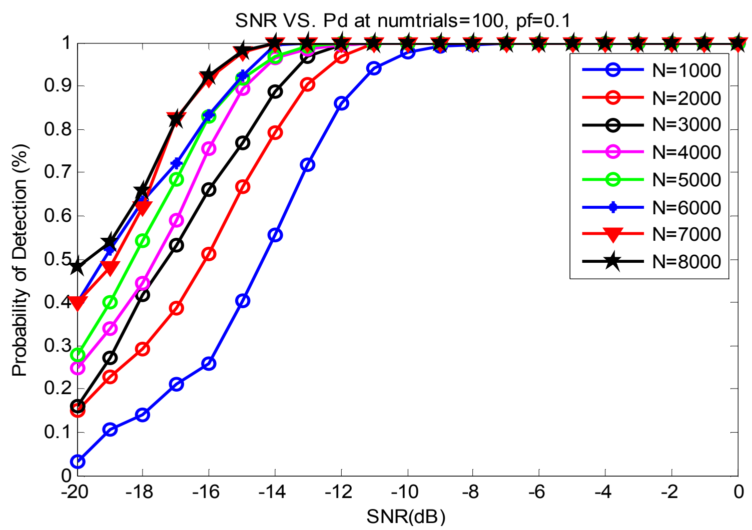

Fig. 7: SNR versus P_d at P_f = 0.1 with number of iteration is 100 with different message lengths

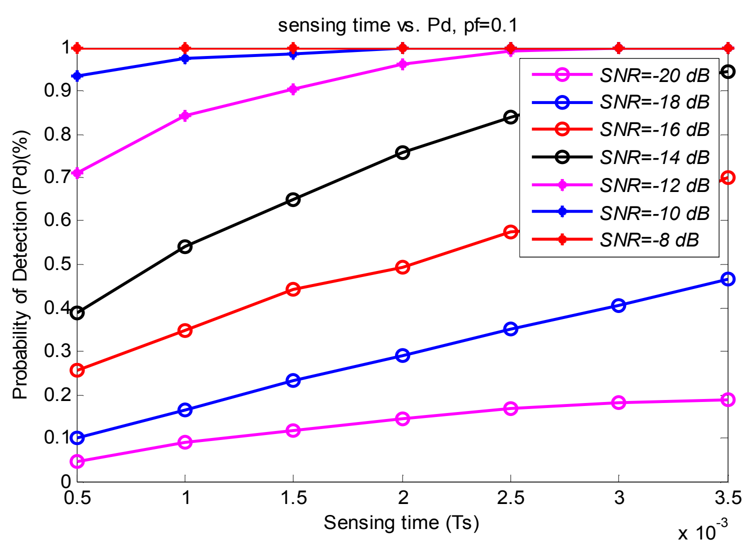

Fig. 8: Sensing time and Pd at different SNR values

When the message length is increased, this lead to increases P_d at lower SNR as shown in Fig. 6 that deals with message length = 1000. It seen that Pd is 100% at SNR = - 10 Db

The rest cases are shown in Fig. 7 that represents the different cases when different message length are used with $P_f = 0.1$.

It is better to examine the sensing time of the system to evaluate the performance of CR detection time.

Figure 8 shows the sensing time of the proposed two stages CR detection system. This figure consists of different cases of SNR at time of millisecond.

To show the performance of the system at different noisy channel such as multipath fading channels. Figure 9 and 10 show different cases of noisy channels at different values of Doppler shift frequency.

The double stage has a good response and better than the system of the single stage. This is can be seen in Fig. 11 and 12 as an example for comparison at message lengths 1000 and 3000 respectively with (Venkata, 2011).

CONCLUSION

It's seen clearly from the simulation results of the figures, that the proposed system is more powerful than traditional detection systems. This is due to the double stage that used in this design. Numerical results shows that the proposed approach can guarantee a reliable sensing while enhancing the spectrum utilization greatly such as $P_d = 100\%$ for $P_f = 0.1$ at SNR = -15dB. This figure is for message length = 8000 samples. These results are higher than the other results that obtained in the other papers.

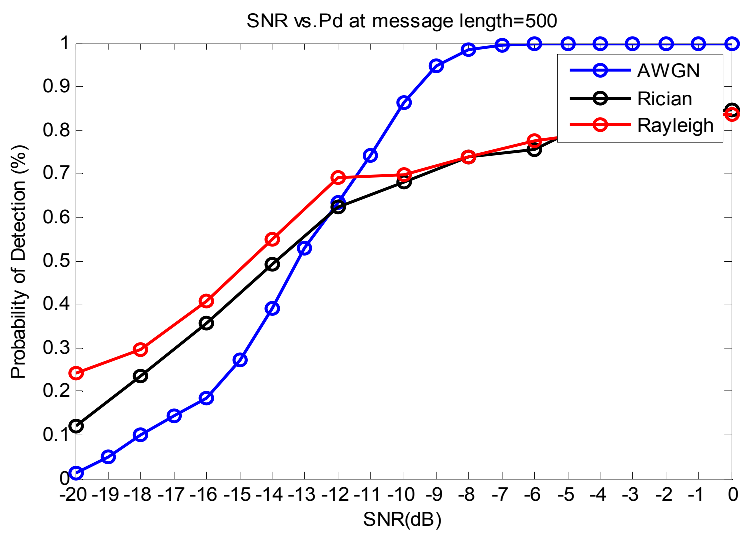

Fig. 9: SNR versus P_d at $P_f = 0.1$, message length is 500 for different noisy channels

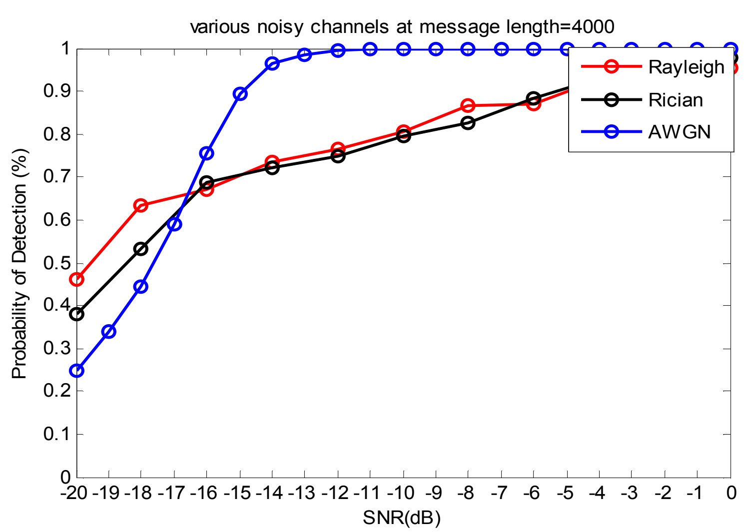

Fig. 10: SNR versus P_d at $P_f = 0.1$, message length is 4000 for different noisy channels

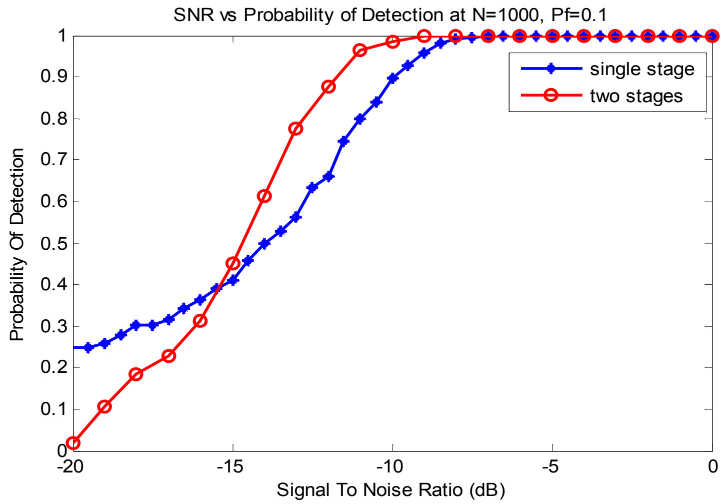

Fig. 11: Comparison between single stage and two stages at 1000 samples

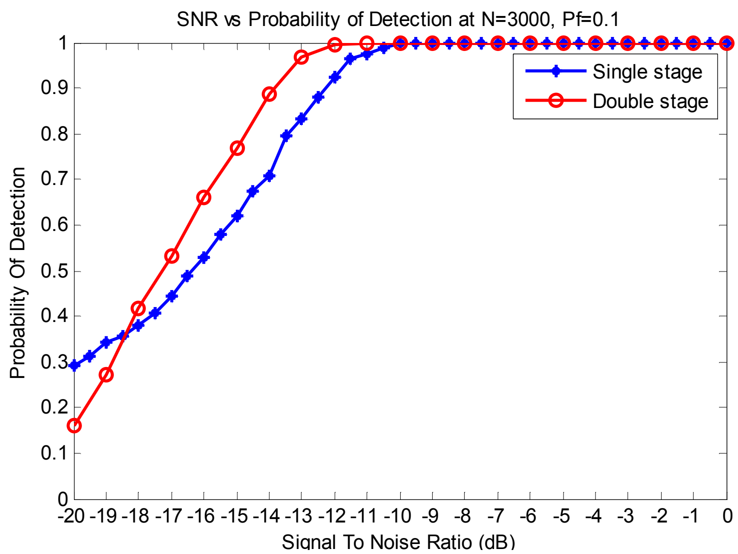

Fig. 12: Comparison between single stage and two stages at 3000 samples

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