Energy Detection in MIMO Cognitive Radio Networks

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***Abstract*— Cognitive radio as a concept is based on the ability to detect and share the underutilized spectrum. For the realization of the cognitive radio concept, energy detection as one of the spectrum sensing methods is broadly considered, because of its low computational complexity and implementation costs. The energy detection accuracy of the primary user signal is susceptible to noise uncertainty variations and the accuracy of the dynamic threshold adaptation. One of the prominent techniques for improving the spectrum utilization in wireless networks is the Multiple-Input Multiple-Output technique. In this paper, the influence of Multiple-Input Multiple-Output technique on the energy detection of signals transmitted using orthogonal frequency division multiplexing is investigated for different signal to noise ratios. Obtained results show a significant impact of noise uncertainty variations, dynamic threshold adaptations, MIMO configurations and sampling densities during the sensing, on the probability of signal detection.**

Keywords—MIMO, energy detection, cognitive networks, OFDM, wireless, SNR, probability, signal, power, sensing

I. INTRODUCTION

Cognitive radio networks (CRN) based on spectrum sensing represent intelligent wireless communication technology dedicated to more efficient exploitation of the available frequency spectrum. Various methods have been proposed in the literature for spectrum sensing. Energy detection (ED) as one of the non-cooperative methods of spectrum sensing is broadly considered due to its low computational complexity and simple implementation [1-3].

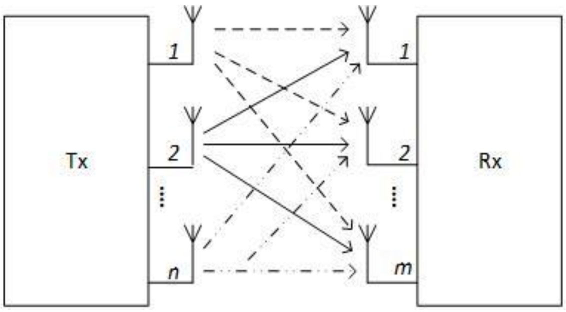

Fig. 1. The basic structure of the MIMO system

Multiple-Input Multiple-Output (MIMO) orthogonal frequency division modulation (OFDM) is the dominant access technology for the 4th and 5th generation (4G and 5G) broadband wireless communication systems. OFDM combined with MIMO may improve the performance of the wireless communication system in terms of spectral efficiency, capacity, reliability and quality of service (QoS).

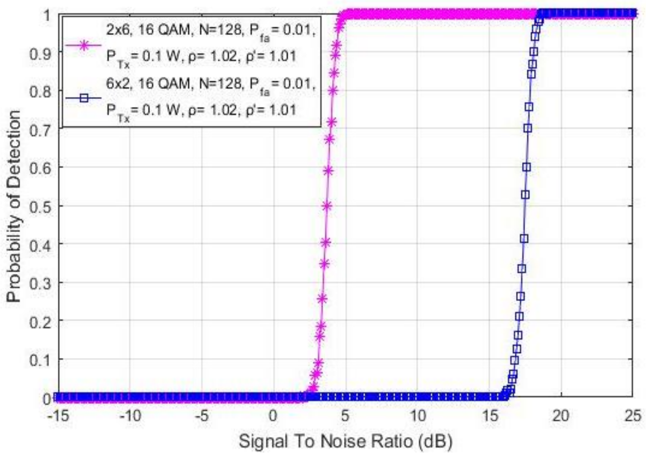

Fig. 2. SNR vs. probability of detection for an asymmetric MIMO system with OFDM as the modulation scheme

An example of the MIMO system is presented in Fig. 1. [4]. In this paper, the performance of the MIMO spectrum sensing for the ED method is evaluated by the Space-Time Block Codes (STBCs) using the Matlab simulation toolbox (version R2016a). STBC is a complex orthogonal space-time code where multiple transmit and single or multiple receive antennas are used for sending multiple copies of the same data or messages over independent and faded transmission paths [5, 6]. The goal of performed simulation analysis is to show how MIMO transmission impacts the ED probability of signals received in environments with different signal to noise ratio (SNR) levels.

II. SIMULATION RESULTS AND DISCUSSION

A. *Influence of MIMO techniques on the energy detection process*

The analysis is performed for *nxm* MIMO system, where *n* defines the number of transmitting (Tx) chains with corresponding antennas of primary user (PU) and *m* defines the number of reception (Rx) chains with corresponding antennas of the secondary user (SU). In Fig. 2, the relationship between SNR and the probability of detection (P_{di}) for the OFDM system concerning the different number of antennas on Tx and Rx side (MIMO *2x6* and *6x2*) has been presented. The results are obtained for equal: the number of samples (N=128), transmit power ($P_{Tx} = 0.1$ W), probability of false alarm ($P_{fa} = 0.01$), noise uncertainty NU (ρ=1.02) and dynamic threshold DT factor ($\rho' = 1.01$). Results presented in Fig.2 show that the probability of detection will be higher for a higher number of antennas on the receiver side.

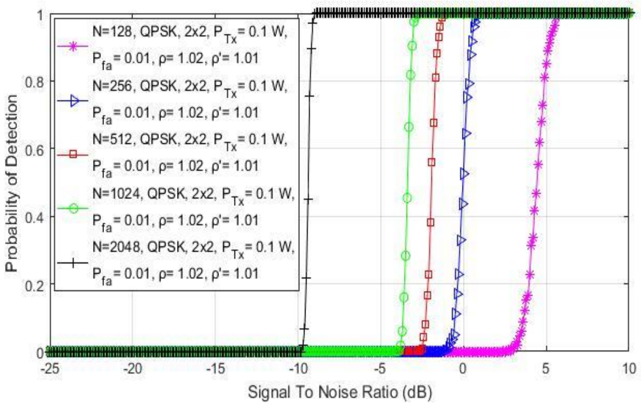

Fig. 3. Impact of SNR and number of samples on the probability of detection in MIMO *2x2* OFDM system

For low values of SNR, the probability of detection is zero and for high values of SNR, it approaches one. The two ranges are connected by a narrow transitional range of SNR values. The location and the width of the transitional range of SNR values depend on the MIMO system parameters. This means that the *2x6* system has better ED performance when compared to *6x2* systems. The consequence of this can be found in the better detection accuracy for systems having a higher number of Rx chains and corresponding antennas.

B. *Influence of the number of samples on the MIMO energy detection process*

The influence of the number of samples (N) on the probability of detection(P_{di}) for the MIMO *2x2* OFDM system has been presented in Fig. 3. The results for the fixed probability of false alarm equal to P_{fa} =0.1, DT factor ρ′= 1.01, and transmission at Tx power level of 0.1 W in channels with fixed NU variation ρ= 1.02 are obtained and presented in Fig. 3. The obtained results show that the lower probability of detection will be achieved for a lower number of samples and lower SNR and vice versa. This means that the number of samples impacts on the probability of detection, since a higher number of samples means more dense sensing periods during which detection has been performed.

C. *Impact of different Tx powers on MIMO energy detection process*

Further analysis was dedicated to the presentation of the impact of the different values of transmitting (Tx) power on ED capabilities. In Fig. 4., the influence of SNR on the probability of OFDM signal detection, for three different Tx power levels (0.1 W, 5 W and 10 W) over a channel with equal channel conditions are presented. The results confirm that the level of PU Tx power at the location of the SU has an impact on the probability of detection in OFDM systems. As expected, for higher levels of Tx power, the probability of detection will be higher and vice versa. Higher probabilities of detection are the consequence of the higher Tx power levels which generate higher energy on the Rx antennas of SUs. The SU with a higher number of Rx antennas obtains better results in terms of probability of detection since a higher number of Rx chains and corresponding antennas can detect higher levels of signal energy at the location of SU.

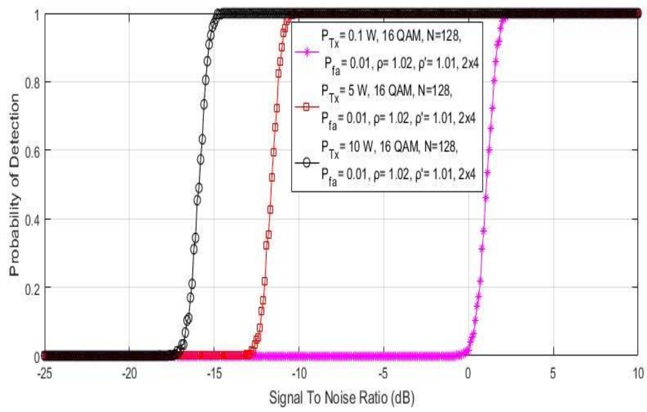

Fig. 4. SNR vs. probability of detection for OFDM signals transmitted in *2xm* MIMO system with *m= 2, 3* and *4*

III. CONCLUSION

In this work, the impact of MIMO transmission on the performance of ED of OFDM signals in CR networks was analyzed. Obtained results indicate that MIMO as a prominent wireless transmission technique in modern communication systems has an impact on the ED of OFDM signals. Results also show that the implementation of MIMO transmission can improve the ED process. It can be concluded that the probability of signal detection increases when a higher number of Rx antennas are used by SUs in the ED process. Also, it is shown that the probability of PU signal detection increases if a higher number of samples is used in the process of OFDM signal detection. Furthermore, results indicate that for higher levels of Tx power, the probability of detection will be higher due to a higher level of received energy at Rx antennas of SU. The overall results of analyses show that the MIMO technique can be a promising candidate for the improvement of ED performance in modern communication systems. Further research will be dedicated to the analyses of the interdependence among the probability of signal detection and the probability of false alarm in MIMO OFDM systems.

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