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Influence Number of Antennas on the Total Sensing Time in Cognitive Radio Systems

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ABSTRACT

In the cognitive radio (CR) systems the total scanning time that is the time taken by the receiver to sense the spectrum is one of the issues in perspective of the overall system performance. This paper proposes architecture for a dedicated receiver capable to reduce sensing time with using dual part: the main receiver and a dedicated one, each with multiple antennas (M). The achieved results show that the total sensing time is reduced by approximately 1/M with using the proposed structure.

Keywords: *Cognitive radio, antennas, sensing time, Radio systems.*

1. INTRODUCTION

Cognitive radio (CR) is a developed area to intelligently identify unused licensed spectrum bands (white space) and adaptively use them. CR users are allowed to use the licensed spectrum only if they guarantee ones are not harmfully interference with licensed (primary) users [1]. CR system requires an accurate assessment of the activities in a desired frequency spectrum in order to determine the availability of idle channels suitable for opportunistic cognitive use. The spectrum sensing is a critical functionality of CR networks; it allows cognitive users to detect spectral "holes" and to opportunistically use them under-utilized frequency bands without causing harmful interference to legacy systems.

There are several ways for fulfilling the spectrum sensing [2-7]. In [2] the authors used cooperative sensing scheme to reduce the total sensing time, the based idea of this sensing is two or more secondary users cooperate to find the presence of the primary user. Cyclostationary sensing technique is used in [3] for dealing with spectrum sensing. Blind Sensing Algorithms are investigated in [4, 5]. This sensing is called blind because it does not require knowledge about status of the channel or the noise power. Another technique is used for spectrum sensing is the dedicated sensing receiver (DSC) [6, 7]. This technique is a suitable solution for challenging in the prior ways of sensing spectrum.

H. Zammat and B. Natarajan [6] focused on using the bandwidth (B_{sys}) as a one stage only coarse mode but with multiple antenna while the researchers in [7] presented a necessary way to dividing the system bandwidth (B_{sys}) into coarse bins and each coarse bins into fine bins but with a single number of antennas. In this paper, we design a system with two receivers (the main receiver with a DSR) but each receiver with multiple numbers of antennas. The achieved results indicate that the total time for sensing is dramatically suppressed with increasing number of antennas used in any of the two parts of the proposed system.

The remainder of the paper is organized as follows. In Section 2, structure of the designed system is presented. Section 3 analyzes the system model and the analytical results given in section 4 and finally the conclusions are drawn to Section 5.

2. STRUCTURE OF THE SYSTEM

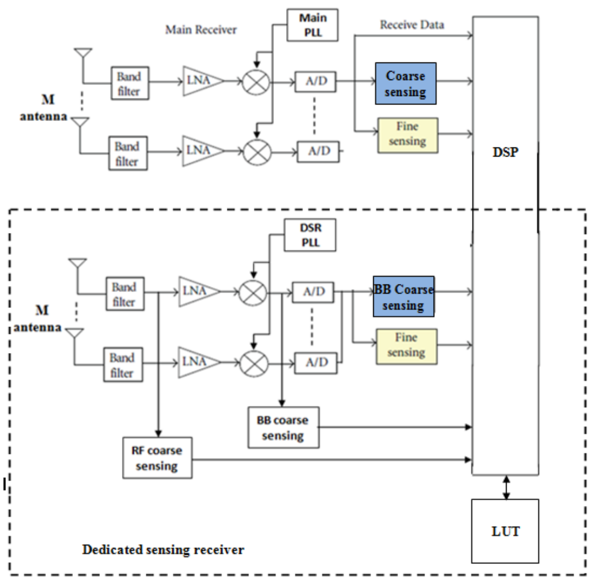

Figure 1: Proposed block diagram

Figure 1 illustrates the block diagram for the proposed system. A multi resolution sensing technique is used, where the parallel sensing employed to reduce the total sensing time. This system requires multiple data-chains at the receiver and, hence, is amenable to multiple-antenna receivers. In the case of an M antenna receiver is used, the total sensing time is reduced by an approximate factor of M.

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Both the main receiver and the DSR in Fig.1 perform the coarse sensing in essence sharing the work between the two receivers. Once the initial results in the look up table (LUT), the DSR performs the fine sensing on the candidate channels. In order to avoid conflict with a primary user (PU) or another secondary user (SU), continuous channel monitoring is done via detectors in the analog domain because of their fast response time. Also, to take full advantages of the DSR, a radio architecture and especially the phase locked loop (PLL) must be able to quickly hop and settle onto the desired frequency. Without an agile PLL, the system scan time would be gated by the radio hardware. The overall PLL design is critical to the performance, cost and complexity of the CR specifically across wideband operation. One important aspect of the cognitive radio network is to insure that the CR does not interfere with a PU or another SU in the band. There are many challenges in radio such as receiver sensitivity, dynamic range, frequency generation (synthesizers) and other RF impairments [8]. These challenges can be solved by using "RF Coarse Sensing" as shown in Figure 1 and the analyses in the next sections.

3. SCAN TIME ANALYSIS

Assume that overall system band width (B_{sys}) is divided into coarse bins (B_{sys}). Each coarse bin is further divided into α fine bins (B_{fin}) as shown in Fig. 2.

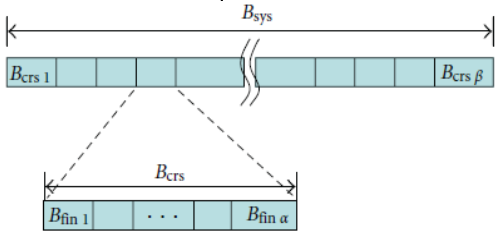

Figure 2 channel model

Figure 2 shows that the system bandwidth and coarse resolution sensing bandwidth should be an integer multiple of B_{crs} *and* B_{fin} respectively as given by equations 1and 2

$$B_{sys} = \beta B_{crs} \quad \text{where} \quad \beta = 1, 2, 3, 4, \ldots.. \quad (1)$$

$$B_{crs} = \alpha B_{fin} \quad \text{where} \quad \alpha = 1, 2, 3, 4, \ldots.. \quad (2)$$

In order to compare the sensing time for the new parallel, multi-resolution sensing approach to the serial, fixed resolution approach, we first define the bandwidths of the coarse and fine resolution sensing modes, B_{crs} and B_{fin}, respectively. B_{fin} is set by the number of points in the FFT, N, as well as the minimum sensing frequency resolution, F_{res}, and is given by:

$$B_{fin} = NF_{res} \quad (3)$$

where F_{res} is the resolution of the sensing. The total time to perform a discrete Fourier Transform (DFT) is given as:

$$T_{DFT} = \frac{1}{F_{DSP}} (4Nlog_2 N - 6N + 8) \quad (4)$$

where F_{DSP} is the DSP operating frequency. For simplicity, assume that the DSP is capable of performing one addition and one multiplication per clock cycle, the total sensing time for coarse and fine sensing of the total bandwidth are given by:

$$T_{crs} = \frac{B_{sys}}{\alpha NM\, F_{res}\, F_{DSP}} [4\frac{N}{M} log_2 \left(\frac{N}{M}\right) - 6\frac{N}{M} + 8] \quad (5)$$

$$T_{fin} = \frac{\alpha}{F_{DSP}} [4Nlog_2(N) - 6N + 8] \quad (6)$$

The overall system sensing time requires including the radio tuning time which is mostly dominated by the PLL lock times. Let us define three different PLL locks times: T_{init} the initial lock time, $T_{PLL_{crs}}$ the PLL lock time for a coarse step, and $T_{PLL_{fin}}$ to indicate to the PLL lock time for a fine step. So, the total PLL sweep time $T_{PLL_{crs}}$ during the sensing operation is give by:

$$T_{PLL_{sys}} = T_{init} + \alpha\beta T_{PLL_{fin}} + \beta T_{PLL_{crs}} \quad (7)$$

And, the overall system scan time is descriptive as:

$$T_{sys} = \frac{B_{sys}}{\alpha M N_{crs} F_{rcs} F_{DSP}} [4N_{crs} log_2(N_{crs}) - 6N_{crs} + 8] + \frac{\alpha\beta\rho}{F_{DSP}\, M} [4N_{fin} log_2(N_{fin}) - 6N_{fin} + 8] + T_{init} + \frac{\alpha\beta\rho}{M} T_{PLL_{fin}} + \frac{\beta}{M} T_{PLL_{crs}}$$

where N_{crs} and N_{fin} are the number of FFT points used in coarse and fine mode, respectively.

4. RESULTS

Figure 3 illustrates variation of T_{sys} with the number of coarse bins (β) for different values of number of antennas (M). The main parameters values used in the model are that in [8, 9] and arranged in Table 1. The results show that for small number of coarse bins a large value of M is the best and vice-versa. This is attributed to that increasing β leads to increase number of ideal channels. Hence, increasing the time to select the non-occupied channel by the cognitive users. On the other side, Fig. 3 shows that T_{sys} decreases as M increases. This is due to that increasing number of antennas at cognitive user side means that the scanning time sharing is shared between more elements, where each receiver is tasked to scan a 1/M of the desired frequency band.

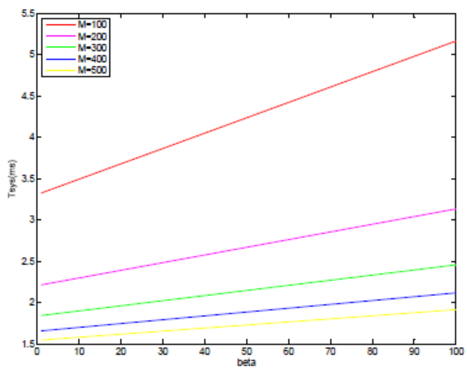

Figure 3: Total sensing time versus β for different number of antennas.

Table 1: Values of the used parameters

Number of antennas (M)	500
FFT points for coarse mode (N_{crs})	128
FFT points for fine mode (N_{fin})	1024
DSP frequency (F_{DSP})	100MHz
Sensing resolution (F_{res})	10kHz
System frequency of operation (B_{sys})	100GHz
B_{fin}	10MHz
B_{crs}	100MHz
B	100
A	10
P	0.4
T_{init}	1.1ms

Variation of T_{sys} to the number of fine bins α for different values of M (100, 200, 300, 400 and 500) is shown in Fig. 4. T_{sys} decreases as α decreases for different values of M. As α decrease the channels become crowded, then the probability of finding an idle channel decreases, hence additional sensing time is required.

Results in Fig. 5 are presented to test influence of the fine and coarse bins together in the scanning time. The sensing time is typically lower at lower β and increases as α decrease. This result is presented for M=500.

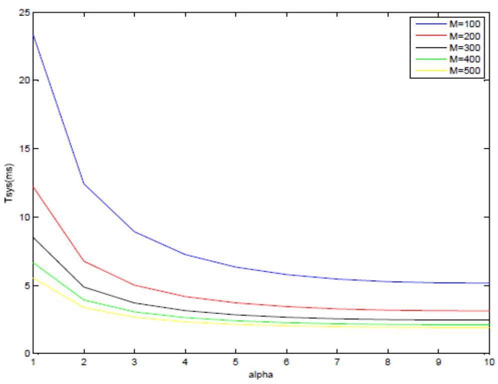

Figure 4: Total sensing time versus α for different number of antenna.

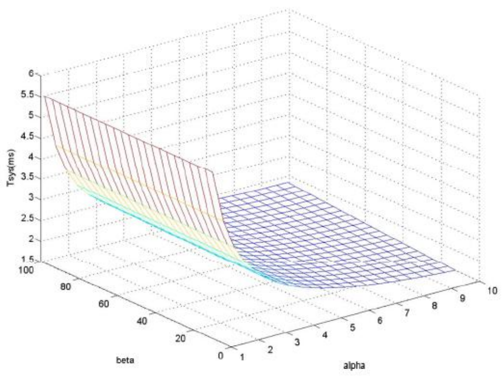

Figure 5: Total sensing time versus β and α.

5. CONCLUSION

This paper proposes using a dedicated sensing receiver architecture with a 2-stage and each stage has a multiple number of antennas. Effects of channel variables (α, number of antennas, and β) on the total sensing time are presented. The best value of sensing time is achieved when using a small number of coarse bins and a large value of number of antennas and vice-versa. Also, the optimum value of sensing time can be gotten if small values of number of fine bins are used. Using the 2-stages sensing scheme proposed in this paper is demonstrated with reducing the sensing time. In the case of an M antenna receiver is used, the total sensing time is reduced by approximate factor of M.

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