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Pilot Design Using Bisection Searching Algorithm for OFDM Based Cognitive Radio System

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Abstract : Wireless communications play an important part in energy intake due to the fastest advancements in the wireless services. Design of Pilot pattern for the OFDM based cognitive radio system is considered. In existing system, pilot design is studied based on spectrum sensing. In this paper, Bisection searching algorithm is discussed for optimum pilot design. Simulation results show that the Bisection searching scheme not only reduces the complexity of searching while designing the optimum pilot pattern also improves the capacity of the system with less power allocation to the transmitted data.

Keywords : OFDM, Cognitive Radio, Pilot pattern, Bisection searching

1. INTRODUCTION

With developing technologies and with cumulative wireless communication devices, the congestion in radio spectrum is increasing day by day. But recent studies indicate that the licensed spectrum is underutilized. The spectrum utilization is based on the location and time of the day. It is seen that few bands are heavily used and other bands are underutilized [2]. This gives the motivation for development of an intelligent radio system that can adapt the spectrum changes dynamically based on the needs of the user. This is achieved via the development of Cognitive Radio (CR). It is a system with gained knowledge about the environment to plan for the future actions. Orthogonal Frequency Division Multiplexing (OFDM) is the good choice for physical layer of CR due to the attractive features of OFDM.

Therefore OFDM subcarriers are expected to be non-contiguous and designing of pilot pattern is critical in pilot assisted channel estimation method for OFDM based CR systems. The main feature of CR is to independently exploit vacant spectrum to increase available spectrum utilization. Additional features of CR comprise of interoperability between the many networks, roaming across boundaries while being able to compliance with regulations, adapting and adjusting the transmission and reception parameters without user interference. Some of the challenges in OFDM systems are high Peak to Average Power Ratio, larger out of band radiation, channel prediction and channel estimation. In OFDM based CR system, Primary users are protected from the interference from secondary user by nulling the corresponding subcarriers of the secondary user. In [1], constrained cross entropy optimization is proposed and it is modelled as Bernoulli random process. In [3], pilot pattern is framed as optimization problem by achieving the Minimum Mean Square Error (MMSE) and pilot pattern is obtained. In [4], pilot design method is discussed based on convex optimization and cross entropy to minimize MSE. In [5], parameter adaptation technique is presented for multicarrier based Cognitive Radio system. But all methods are based on the Least Square (LS) Channel Estimation.

The rest of the paper is organized as follows. Section II clarifies the system model. Section III deals with the pilot design scheme. Section IV represents the Bisection Searching algorithm. Simulation results and Conclusion are presented in Section V and VI respectively.

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2. SYSTEM MODEL

The OFDM based cognitive Radio system is considered in which sparse channel estimation is done [1] instead of the traditional channel estimation methods. The pilot design is based on spectrum sensing. Next to spectrum sensing, the subcarriers which are occupied by primary users are deactivated. From the remaining active subcarriers, a pilot pattern is framed [1]. To obtain time domain sequence, Inverse Fast Fourier Transform (IFFT) is applied to the frequency domain values. The reason for adding cyclic prefix(CP) is to avoid Inter Symbol Interference (ISI). The channel is selected as Finite Impulse Response of length L. To avoid ISI, Cyclic Prefix (CP) length L is selected which is equal to the length of the channel coefficients. Pilot subcarriers are $cp_1, cp_2, cp_3, \ldots cp\mathrm{K}$ and the corresponding transmit pilot symbols are denoted as $x(cp_1), x(cp_2), x(cp_3), \ldots x(cp\mathrm{K})$ and receive pilot symbols are represented as $y(cp_1), y(cp_2), y(cp_3), \ldots y(cp\mathrm{K})$.

At the receiver, cyclic prefix is removed first and Fast Fourier Transform (FFT) is applied. As the OFDM scheme has the ability to convert frequency selective multipath fading channels into parallel flat fading channels, it is possible to use Zero Forcing (ZF) equalizer to detect data.

Once the subcarriers that are engaged by primary users are deactivated, the remaining subcarriers are length M. Hence there are M active noncontigous subcarriers.

The transmit and receive pilot pattern are related as

$$y = x\mathrm{F}h + n \tag{1}$$

where F is Discrete Fourier Transform submatrix and n is the Additive White Gaussian Noise(AWGN) with zero mean.

Let $\mathrm{A} = x\mathrm{F}$, then

$$y = \mathrm{A}h + n \tag{2}$$

Pilot pattern is

$$p = \{c_{p1}, c_{p2}, c_{p3}, \ldots c_{p\mathrm{K}}\} \tag{3}$$

The coherence of A is defined as

$$g(p) = \max_{0 \le m < n \le \mathrm{L}} |\mathrm{A}(m), \mathrm{A}(n)| \tag{4}$$

Optimal Pilot pattern can be written as

$$p_{opt} = \arg\min_{p} g(p) \tag{5}$$

3. PILOT DESIGN

To obtain the best pilot pattern, it is possible to search among the all pilot patterns. This may be computationally inefficient scheme. Hence a Pilot design scheme discussed in [1] uses constrained cross entropy optimization method to obtain optimized pilot pattern. The model is chosen as Independent Beroulli random process. In linear search algorithm, number of iterations are high. So there is a need of new search algorithm. Section IV presents Bisection Searching Algorithm to reduce the number of iterations.

4. BISECTION SEARCHING ALGORITHM

This algorithm begins with an interval $[\eta_1, \eta_u]$, which processes the optimal value of η^*. Then problem is solved at its centre, $t = (\eta l + \eta u)/2$. If the solution is possible, the optimum value η^* lies in the upper half of the interval. Otherwise, the optimum value η^* lies in the lower half of the interval. The interval is updated according to optimum solution and this procedure is repeated until the length of the interval is small enough. The initial interval can be chosen as the lower and upper bound of the optimum value.

The algorithm is described below.

Input : Initial interval ηl and ηu, and EE accuracy • > 0.

Output : optimal solution

$$\alpha^*, \{\beta^* m\}\mathrm{M}\ m = 1, \text{and } \eta^*.$$

1. Initialize $tl \leftarrow \eta l$ and $tr \leftarrow \eta u$.
2. **while** $(tr - tl) > \bullet$
3. $t = (tr + tl)/2$.
4. Solve for the feasibility
5. **if** it is feasible,
6. $tr = t$
7. **else**
8. $tl = t$;
9. **end**
10. **end**

This algorithm is used to reduce the number of iterations in the searching process.

5. SIMULATION RESULTS

In this section, performance estimation of the Linear Search algorithm and Bisection Searching Algorithm is done in terms of overall transmit power, and capacity.

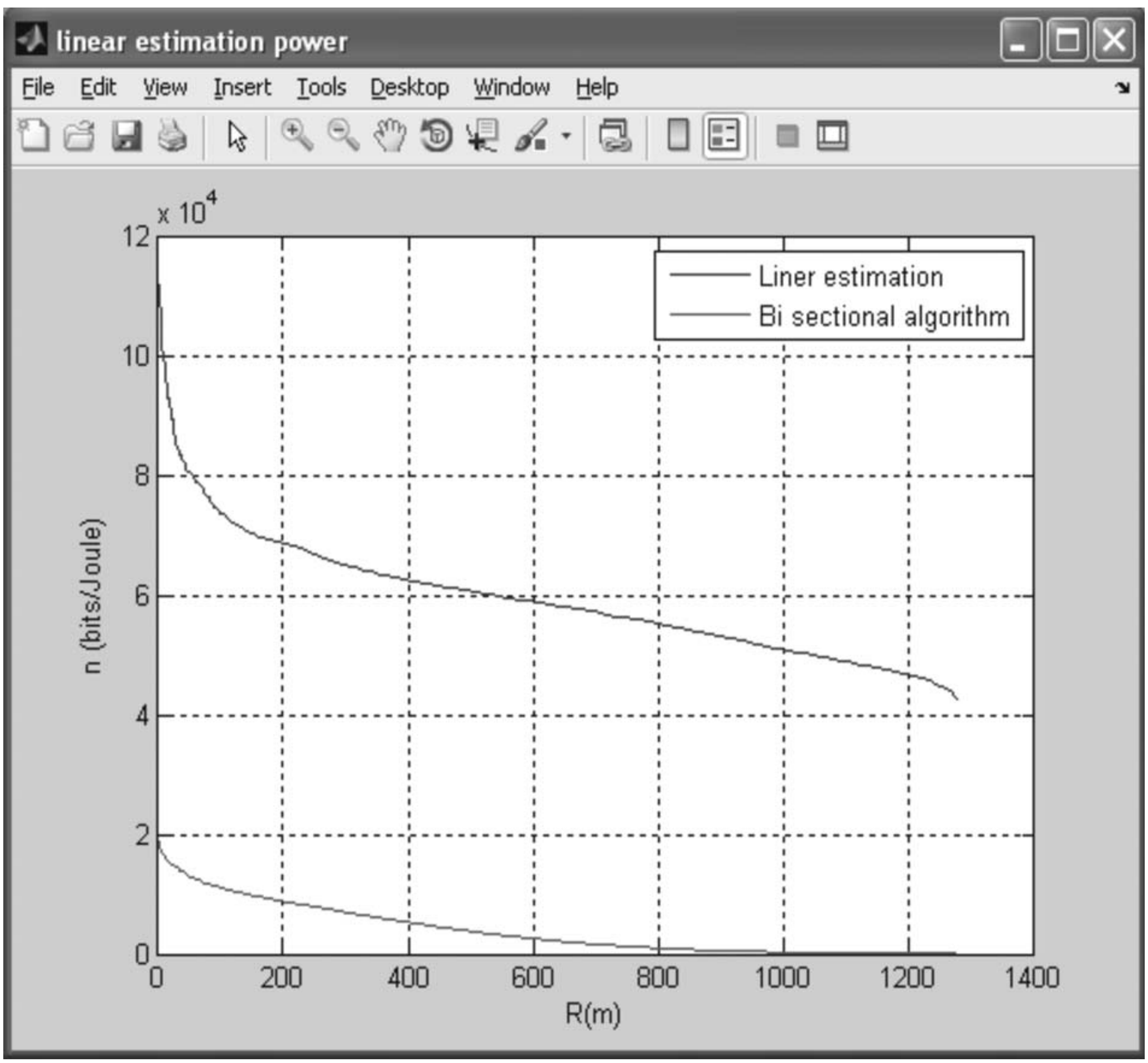

Fig. 1. Performance comparisons of Power allocation in OFDM Systems

The Fig 1 illustrates the comparison of power allocation between the linear searching algorithm and bisection algorithm. Linear search algorithm requires more power than Bisection searching algorithm. It is noted that Bisection algorithm requires the power of less than 2 in the order of 104.

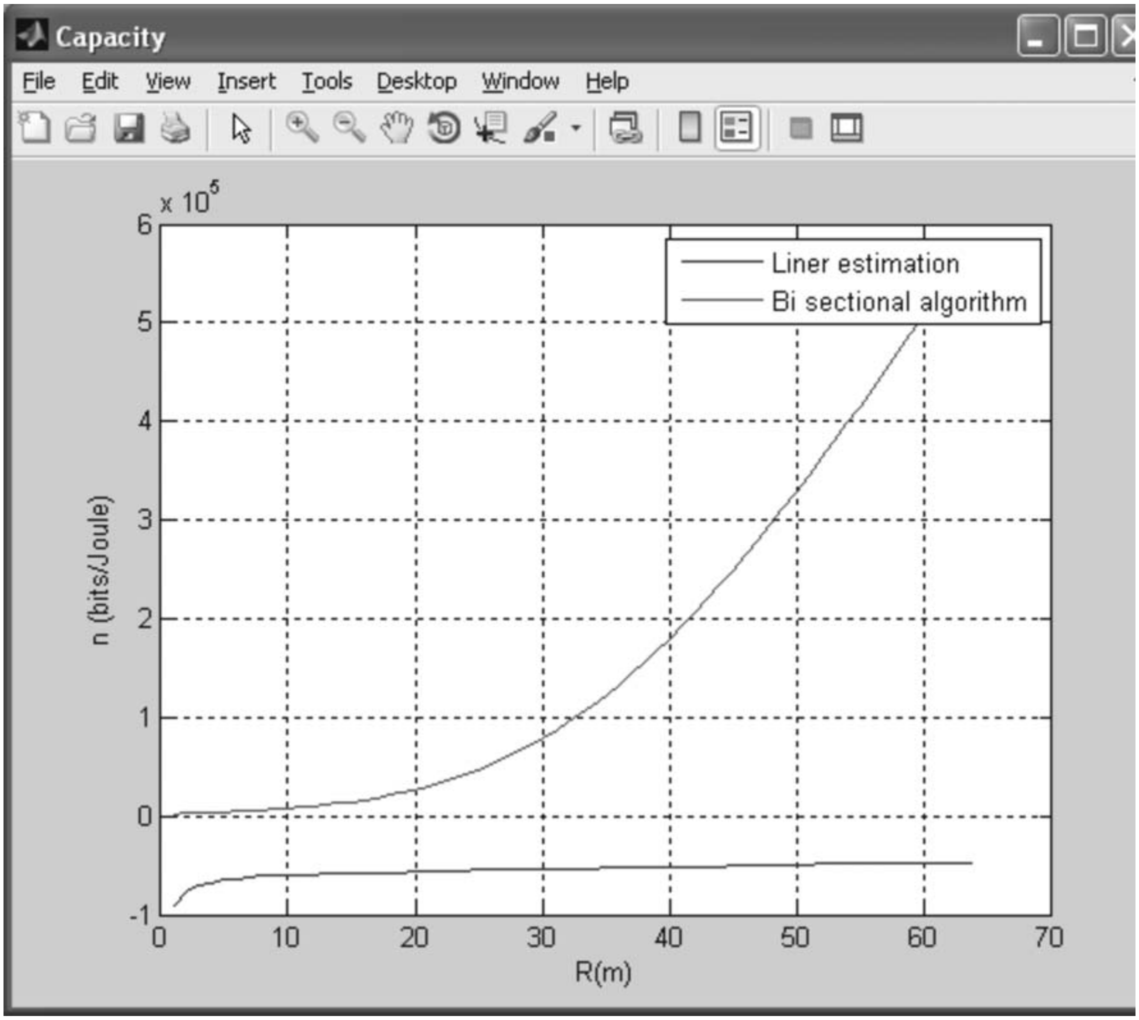

Fig. 2. Capacity of the Bisection search algorithm and Linear search algorithm

The Fig 2 shows the total capacity comparision of the Bisection searching and Linear search algorithm. The Linear search algorithm the response curve for measuring the capacity decreses. The capacity required for all values of 70 are equal. But, in the binary search method, the capacity increases exponentially. It is clear that Binary search algorithm shows better performance than the Linear search algorithm for calculating the capacity of the OFDM-CR system.

6. CONCLUSION

In pilot design scheme, the linear search algorithm to find the optimal pilot pattern results with higher number of iterations in the searching process. As a result bisection searching algorithm was established to find optimal solution. The main idea behind Bisection searching algorithm is continually bisects an interval and then picks a subinterval in which a target value must lie for further processing. Simulation results show that the Bisection algorithm is better than Linear search algorithm to obtain optimal solution. Performance estimation of the proposed scheme in Multi Input Multi output (MIMO) system shall be the future scope.

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