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Research Article

Spectrum Sharing in Cognitive Radio Prop up the Minimum Transmission Power and Maxi-Min SINR Stratagem

[1]S. Azmat. Hussain, [2]A. Naveed. Malik, [3]I.M. Qureshi and [4]F. Zaman
[1, 2]School of Engineering and Applied Sciences (SEAS) Isra University, Islamabad Campus, Pakistan
[3, 4]Department of Electronic Engineering, IIU, H-10, Islamabad, Pakistan

Abstract: With the rapid growth of vigilance that cognitive radio participate an essential task in wireless communication to resolve the spectrum scarcity vs. under-utilization dilemma owing to the dormant spectrum supervision policies. In this study, we explore the innovative scenario that the secondary user frequently has to trade off between two goals at the same time: one is to maximize its own throughput; and the other is to minimize interference at primary receiver. In conclusion, the author give a novel idea about the seminal work of spectrum sharing by minimizing transmit power strategy and maximizing Signal to Interference plus Noise Ratio (SINR) strategy which are inversely and directly proportional according to the condition of separation angles.

Keywords: Convex optimization, interference margin, OTBF, primary users, secondary users, spectrum sharing, SINR

INTRODUCTION

Key spectrum allocation tilt for conservative wireless communication services is due to rigid spectrum allocation policy. Particularly, consecutively to evade intrusion, diverse wireless services be allocated by dissimilar accredited bands. By the acknowledgment of diverse wireless technologies, permanent spectrum allocation tactics have resulted in shortage in the radio spectrum, owing to the truth that generally the accessible spectrum has been allocated. According to Mitola and Maguire (1999) and Haykin (2005) it has been proved by the FCC that more than 70% of the allocated spectrum in the United States is not utilized. This motivates the innovation of Cognitive Radio (CR) network. Spectrum sharing is probable when accurate spectrum sensing is achieved by using different detection (Akyildiz *et al*., 2006) techniques such as energy detection, matched filter detection, cyclostationary detection, wavelet detection, compressed detection etc. As the primary user and the secondary user transmit in all directions so with the recent advances in multi-antenna technologies, multiple users can be multiplexed into the same channel at the same time in the same geographical region. The angular dimension has not been exploited well enough for spectrum opportunity. In other words, a directional dimension of spectral space can be created as a new opportunity (Tundra and Sahai, 2008). The Direction of Arrival (DOA) estimation is very important for judgment of the primary user location by using the single snapshot and without the computational complexity (Zaman *et al*., 2012a, b). Moreover, the spectrum utilization swerve in space, time and frequency. Due to increase in the fast data communication the antenna diversity schemes are used which enables the reliable links between the source and the destination (Alamouti, 1998; Tarokh *et al*., 2002; Jafarkhani, 2001. The overlay and underlay support opportunistic spectrum sharing by allowing the secondary (lower priority) users to share the radio spectrum formerly allocated to the primary (higher priority) users. By doing so, the utilization efficiency of the radio spectrum can be drastically improved (Chakravarthy *et al*., 2009; Pedersen and Mogensen, 2003; Zhang and Liang, 2008). Cognitive Radio (CR) is a talented skill that has a huge prospective to mitigate the spectrum shortage dilemma and to develop the utilization of the inadequate wireless resources. The Channel State Information (CSI) conditions with multiple antennas at the secondary transmitter exploit the spatial opportunity (Bixio *et al*., 2010).

In this study, simultaneous transmission of primary and secondary users particularly investigate the paradigms in favor of spectrum sharing in cognitive radio. Although the secondary user have been coexisting with the authorizes user bands in conjunction with coping the minimum power strategy and max-min SINR strategy. For progression of the minimum power strategy, at the start, we lay down the minimum required SINR per secondary user. Secondly we set the Interference Margin (IM) limits, to control the

Corresponding Author: S. Azmat. Hussain, School of Engineering and Applied Sciences (SEAS) Isra University, Islamabad Campus, Pakistan

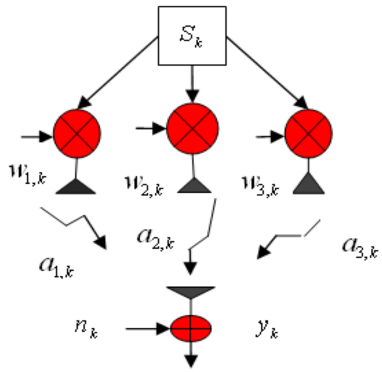

Fig.1: Multiuser MISO model

interference in favor of the primary user. By using the minimum power strategy we show the minimum total transmit power without considering the constraint of maximum allowable interference to the primary user. Subsequently we consider the constraint of interference to the primary users. As we lower the maximum allowed interference to primary users, the minimum required total transmission power increases. The reason for this is that the weights are assigned in such a way that interference to primary remains below the constraint. This is achieved by directing the beam slightly away from the primary user, thus opposing from ideal beam direction for the secondary user. So, in order to maintain the SINR above the constraint of 10dB, power has to be increased. The minimum transmission powers become equal when interference to the primary without constraint falls below the respective thresholds. This shows that our minimum power strategy in cognitive scenario only affects the performance of the secondary user's as long as the interference to the primary without constraint is above the threshold.

Secondly we investigate the Max-SINR strategy so we set the maximum allowable total transmission power. Again, we will analyze the performance of this strategy at the same values of primary interference margin constraints. In other words, using the maximum SINR strategy, the interference to the primary user without the constraint of maximum allowable interference is always greater than the interference to the primary under the constraint. In this we particularly use the MISO model for multiuser along with a uniform linear array. Moreover, study the effect of the angular separation on the Min power transmission and Max SINR strategy by utilization of convex optimization technique together with various constraints. Simulation results with different constraints confirmed that primary and secondary share the spectrum with controlled interference at the primary receiver.

Multiuser MISO model: The model consists of the multiple primary and secondary source signals S_k which impinge on the uniform linear array with multiple antenna elements at the base station. Source signal is multiplied with the weights and the respective channel gain (Fig.1).

Mathematically, the generalized output of the multiuser having multiple input and single output is given as:

$$y_k = \sum_{i=1}^{K} \mathbf{a}_i \mathbf{w}_i s_k + n_k \quad 1 < k < K$$

where,

s_k = *kth* users

w_k = Weight vector $(1\times N)^T$ of a kth user

α_k = Channel response vector (1×N) of the *kth* user

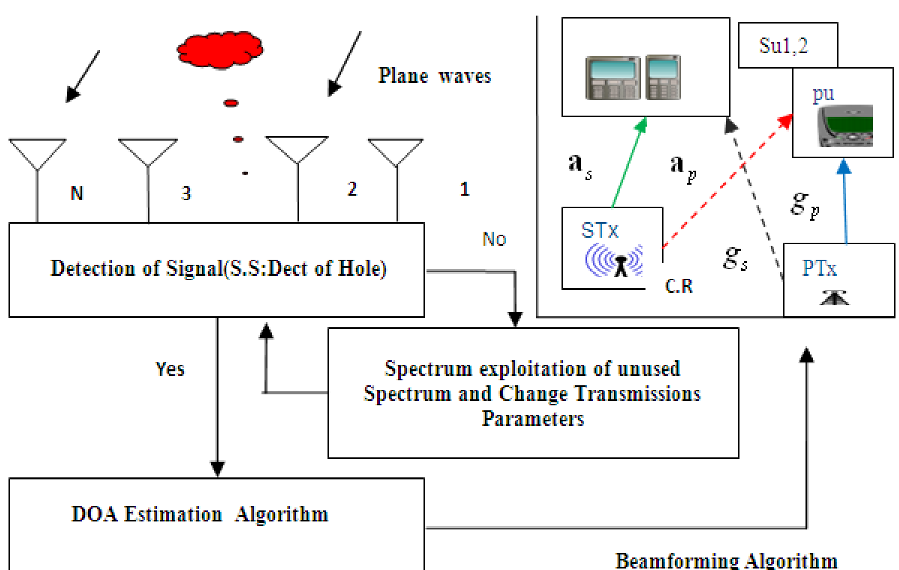

Fig. 2: Cognitive radio model exploiting spectrum

n_k = Additive white Gaussian noise with mean zero
σ^2_k = Variance of *kth* users.
y_k = The output of the MISO for *kth* users

Formulation and proposed algorithm: The proposed model is shown in Fig. 2, where initially adapts the spectrum sensing (S.S) strategy. As soon as the availability of the secondary user subsequent to sensing the spectrum is available in the authoritative spectrum at that moment we estimate the angle by applying the DOA algorithm. On the other hand if the spectrum hole is not available then the system exploits the transmission parameter repeatedly. When the sensing task such as the detection of the hole and DOA estimation is ended subsequently we apply the adaptive beamforming algorithm to maximize the power in the direction of the secondary users and minimized the power in the direction of the primary users.

In this proposed algorithm we exploit the optimization technique which maximized the secondary user power under some constraints in the direction of the secondary user with minimum transmission power. Through, the different interference margin constraint for primary user, we try to reduce the interference at the primary receiver. Finally try to make the relation among the minimum power transmission and maximum signal to interference plus noise ratio. We also observe, the effect on the transmission power when the separation angle between the primary user and the secondary user larger or smaller. Whenever antenna elements are increasing, transmission power decrease. According to Eq. (1) where a_k is the vector showing the response of the MISO channel. However, the MISO is working at the base station as a part of the cognitive system. We assume that the plane wave propagates in a homogeneous medium and that the array consists of identical distortion-free omnidirectional elements. The time taken by a plane wave arriving from the source to an element with delay such that:

Steering vector (Zaman *et al*., 2012a) for the antenna array is given as:

$$\mathbf{v}(\theta_k) = \left[1 \;\ldots\; e^{j2K\cos(\theta_k)} \;\; e^{j(L-1)K\cos(\theta_k)}\right]^T \tag{1}$$

where,

$$K = \frac{2\pi f_0}{\lambda}$$

$\lambda = \frac{c}{f_0}$ = wavelength

L = Antenna elements

So the channel response vector a_s from primary transmitter to secondary receiver using the MISO is written as:

$$\mathbf{a}_s = d^{\alpha}\mathbf{v}(\theta_k) \tag{2}$$

where, α is the path loss and the $v(\theta_k)$ is a steering vector. According to the model the output of the primary and secondary is written as:

$$y_s = \sum_{j=1}^{K}\sqrt{P_j}\,\mathbf{a}_s\mathbf{w}_j s_j + \sqrt{P_p}\,g_s s_p + \eta_s \tag{3}$$

where $w = [w_{k,1}\ w_{k,2}\ \ldots\ w_{k,M}]^T$ weight vector and channel response from primary transmitter with secondary user:

$$y_p = \sum_{j=1}^{K}\sqrt{P_j}\,\mathbf{a}_p\mathbf{w}_j s_j + \sqrt{P_p}\,g_p s_p + \eta_p \tag{4}$$

where a_p channel response from secondary to primary users and g_p channel response from primary transmitter to primary users.

The signal to interference plus noise ratio for the secondary user is written as:

$$SINR_s = \frac{P_s\left|\mathbf{a}_s\mathbf{w}_s\right|^2}{\sum_{j=s,j\neq s}^{K} P_s\left|\mathbf{a}_s\mathbf{w}_j\right|^2 + \left|g_s\right|^2 P_p + \sigma^2} \tag{5}$$

$$SINR_p = \frac{P_p\left|g_p\right|^2}{\sum_{j=1}^{K} P_j\left|\mathbf{a}_p\mathbf{w}_j\right|^2 + \sigma^2} \tag{6}$$

In this study, we consider the Orthogonal Transmit Beamforming (OTBF) for multiuser systems with the constraint of minimum transmit power and max SINR requirements for each user. So we consider that:

$$\mathbf{a}_s^H\mathbf{w}_s = 1,\ \mathbf{a}_s^H\mathbf{w}_j = 0,\ j \neq s \tag{7}$$

We design the system which based on:

- Minimize the transmission power subject to minimum required SINR at each receiver
- Maximize the minimum SINR at each receiver subject to limited transmission power.

Correlation matrix, for the secondary user is taken as:

$$\mathbf{R}_s = \mathbf{a}_s^H\mathbf{a}_k \tag{8}$$

To attain the foremost objective we consider the transmitted power for the *kth* user which is written as:

$$p_s = \mathbf{w}_s^H\mathbf{w}_s \tag{9}$$

where, w_s is the transmit beamforming weight vector. With this knowledge, the minimum power strategy problem can be expressed as:

$$\begin{aligned}&\min\sum_{s=1}^{K}p_s\\&s.t\ SINR_s\geq\gamma_s\ \ s=1,2,...,K\end{aligned}\tag{10}$$

where, γ_s represents the minimum desired SINR for secondary users. This formulation can also be written as:

$$\begin{aligned}&\min\sum_{s=1}^{K}\mathbf{w}_s^H\mathbf{w}_s\\&s.t\ \frac{w_s^H R_s w_s}{\sum_{j=1,j\neq s}^{K}w_j^H R_s w_j+\sigma_s^2}\geq\gamma_s\ \ s=1,2,...,K\end{aligned}\tag{11}$$

Since all the beamforming vectors are involved in the constraints, it is therefore necessary to find a global solution for the whole system.

The constraints involve quadratic non-convex functions of the variables. However, we can modify this into the SDP standard formulation. This can be done by changing the vector variables w_s into matrix variables:

$$\mathbf{G}_S\cdot\mathbf{G}_S=\mathbf{w}_s^H\mathbf{w}_s\tag{12}$$

The trace on the Eq. (12) we obtain as:

$$\mathbf{w}_s^H\mathbf{w}_s=Tr\left[\mathbf{w}_s^H\mathbf{w}_s\right]\tag{13}$$

Similarly we can obtain the results of the $\mathbf{w}_s^H\mathbf{R}_s\mathbf{w}_s$ by applying the trace as:

$$\mathbf{w}_s^H\mathbf{R}_s\mathbf{w}_s=Tr\left[\mathbf{R}_s\mathbf{w}_s\mathbf{w}_s^H\right]=Tr\left[\mathbf{R}_s\mathbf{G}_S\right]\tag{14}$$

However, according to the OTBF principal, the signals transmitted to a meticulous user need to be orthogonal to the signals from other users in the system, i.e., for *kth*:

$$Tr\left[\mathbf{R}_s\mathbf{G}_S\right]=0,s\neq j\tag{15}$$

$$\begin{aligned}&\min\sum_{s=1}^{K}Tr[\mathbf{G}_s]\\&s.tTr[\mathbf{R}_s\mathbf{G}_s]-\gamma_s\sum_{j=s,j\neq s}Tr[\mathbf{R}_s\mathbf{G}_s]\geq\gamma_s\sigma_s^2\ \ s=1,2,...,K\\&Tr[\mathbf{R}_s\mathbf{G}_s]=0,j\neq s\\&\mathbf{G}_s=\mathbf{G}_s\geq 0\end{aligned}\tag{16}$$

Taking all these points into consideration, we now arrive at the final formulation for minimum power strategy as given below:

$$\begin{aligned}&\min\sum_{s=1}^{K}Tr\left[\mathbf{G}_s\right]\\&s.tTr\left[\mathbf{R}_s\mathbf{G}_s\right]\geq\gamma_s\sigma_s^2\ \ s=1,2,...,K\\&Tr\left[\mathbf{R}_s\mathbf{G}_s\right]=0,j\neq s\\&\mathbf{G}_s=\mathbf{G}_s{}^H\geq 0\end{aligned}\tag{17}$$

To achieve the second goal of this strategy we maximize the minimum received SINR at each receiver under the constraint of limited transmission power. Let us suppose that the total transmission power available at the base station is P. Then, the Maxi-min SINR problem can be stated as:

$$\begin{aligned}&\max\min SINR_s\\&s.t\sum_{s=1}^{K}p_s\leq P\ ,s=1,2,..,K\end{aligned}\tag{18}$$

Putting the value of the $SINR_s$ in (18) we get:

$$\begin{aligned}&\max_{w_s}\min_{1<s>K}\frac{\mathbf{w}_s^H\mathbf{R}_s\mathbf{w}_s}{\sum_{j=s,j\neq s}\mathbf{w}_j^H\mathbf{R}_s\mathbf{w}_j+\sigma_s^2}\\&s.t\sum_{s=1}^{K}\mathbf{w}_s^H\mathbf{w}_s\leq P\ ,s=1,2,..,K\end{aligned}\tag{19}$$

However, finally introducing the intermediate variable, we can organize the Eq. (18) in such a way that it can be solved by using the Semi Defenite Programming (SDP). Introducing a minimum SINR per user as an intermediate variable t = min $SINR_s$, the above problem can be formulated as:

$$\begin{aligned}&\max t\\&s.tTr\left[\mathbf{R}_s\mathbf{G}_s\right]\geq\gamma_s\sigma_s^2\ \ s=1,2,...,K\\&Tr\left[\mathbf{R}_s\mathbf{G}_s\right]=0,j\neq s\\&\sum_{s=1}^{K}Tr\left[\mathbf{G}_S\right]\leq P\\&\mathbf{G}_s=\mathbf{G}_s\geq 0\end{aligned}\tag{20}$$

Equation (19) can be solved by using the CVX-Optimization tool for finding the SINR for each user under some constraint on the limited power.

SIMULATION AND RESULTS

The secondary transmitter (STx) contains eight transmit antenna elements and each user, i.e., Secondary Receiver (SRx) and primary receiver (PRx) consist of a single antenna. The system be made up of two secondary users as well as one primary user. The spacing linking antenna elements are considered to be

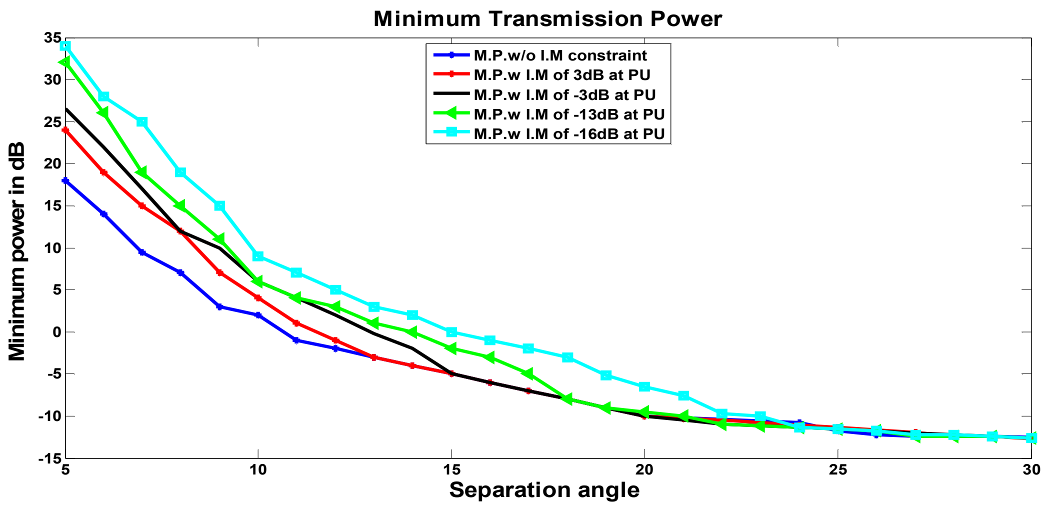

Fig. 3: Minimum transmission power

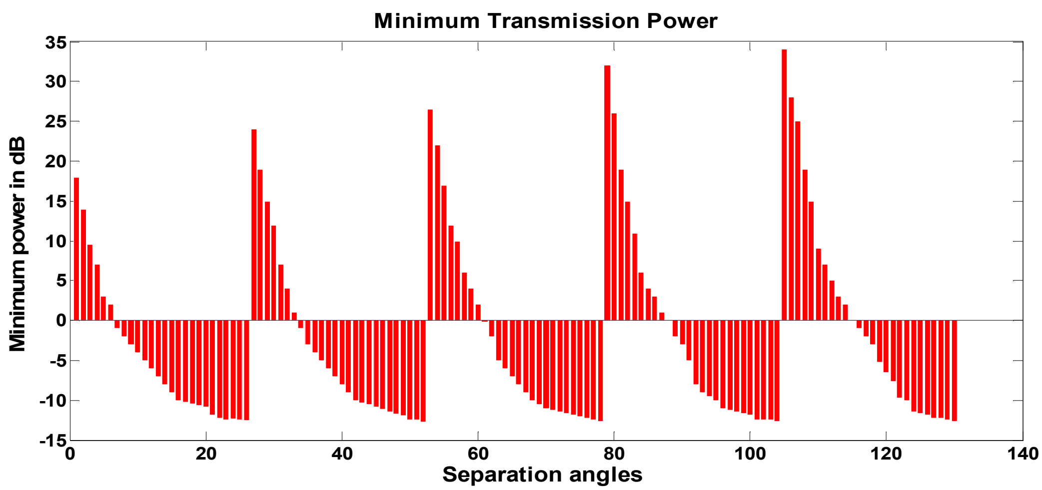

Fig. 4: Minimum transmission power

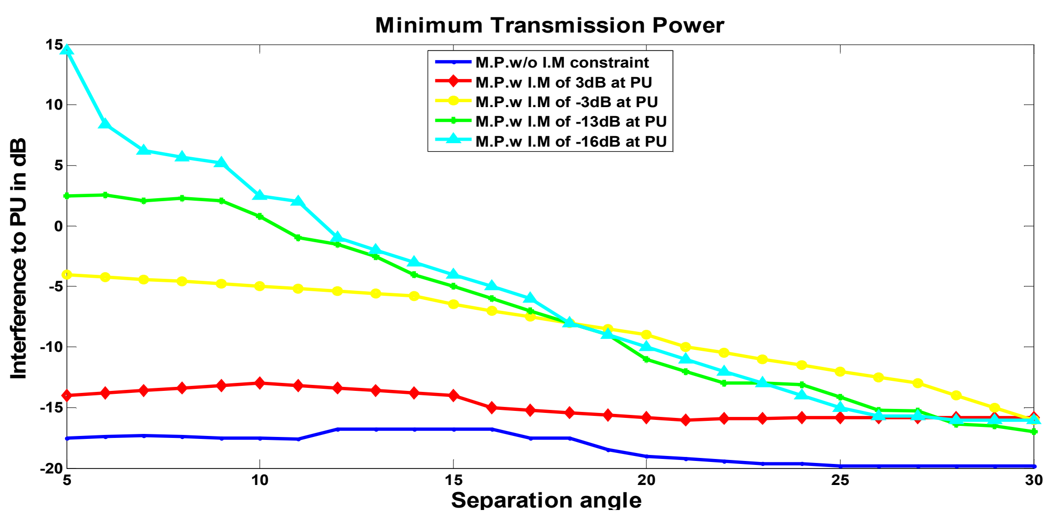

Fig. 5: Minimum transmission power with interference at PU

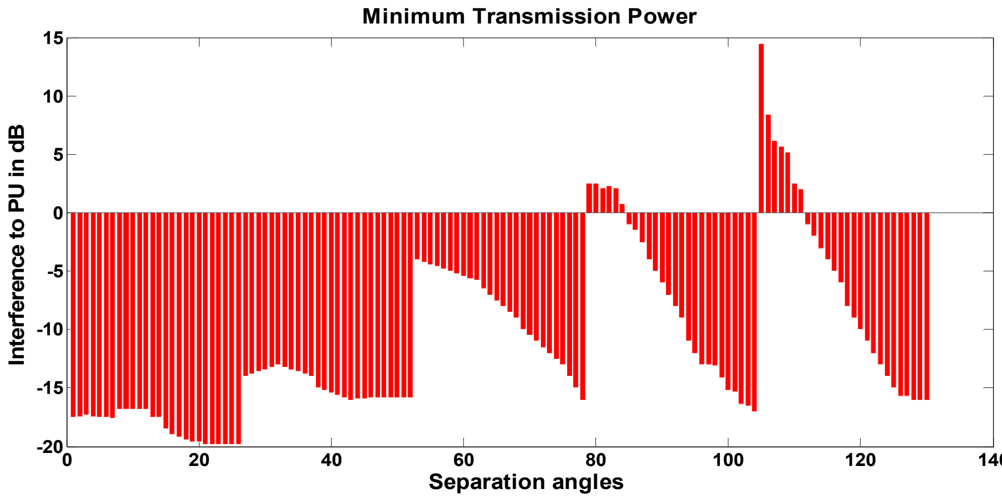

Fig. 6: Minimum transmission power with interference at PU

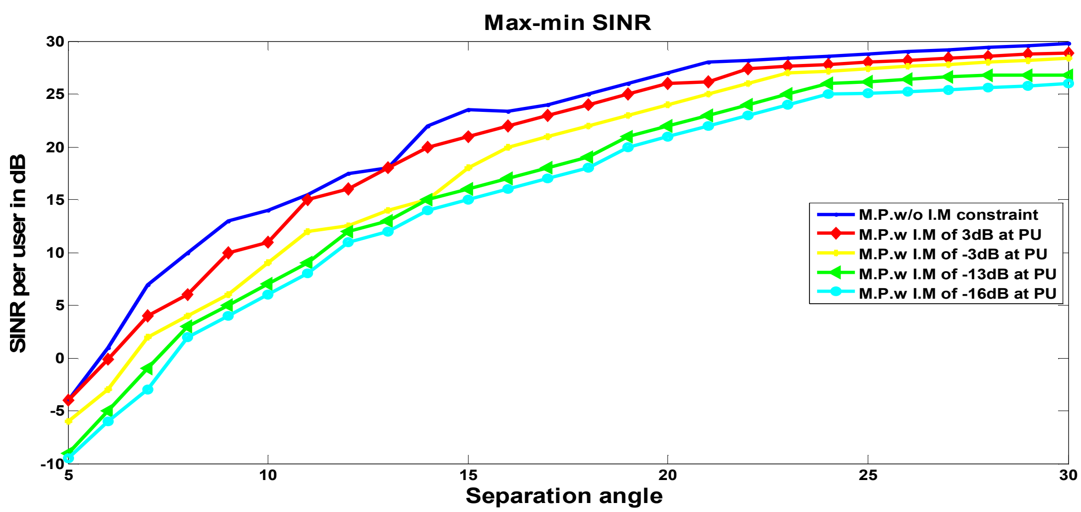

Fig. 7: Maximum-min SINR

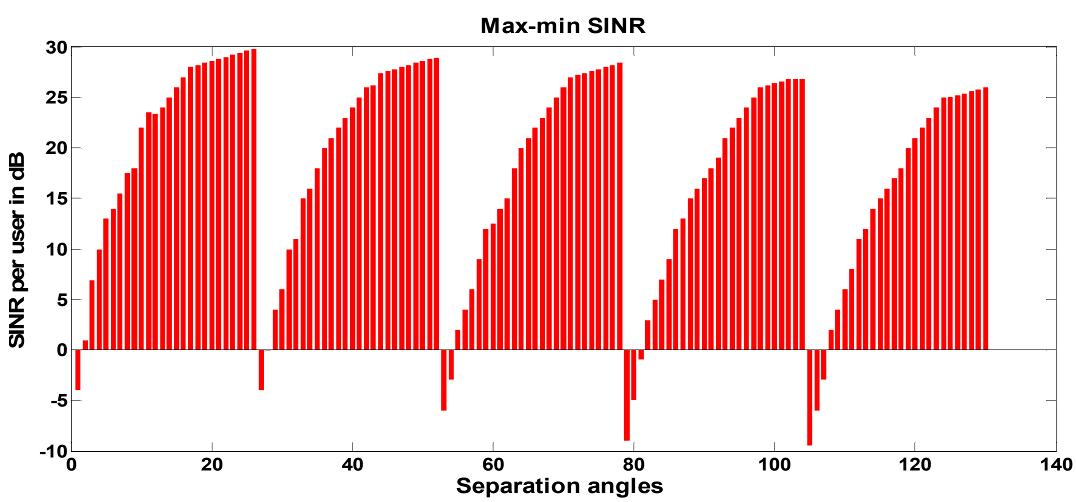

Fig. 8: Maximum-min SINR

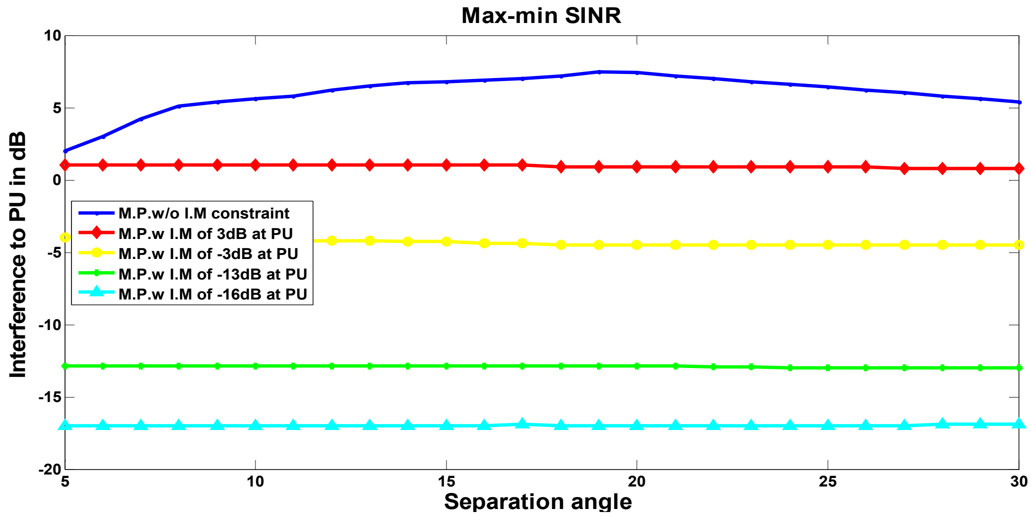

Fig. 9: Maximum SINR with interference

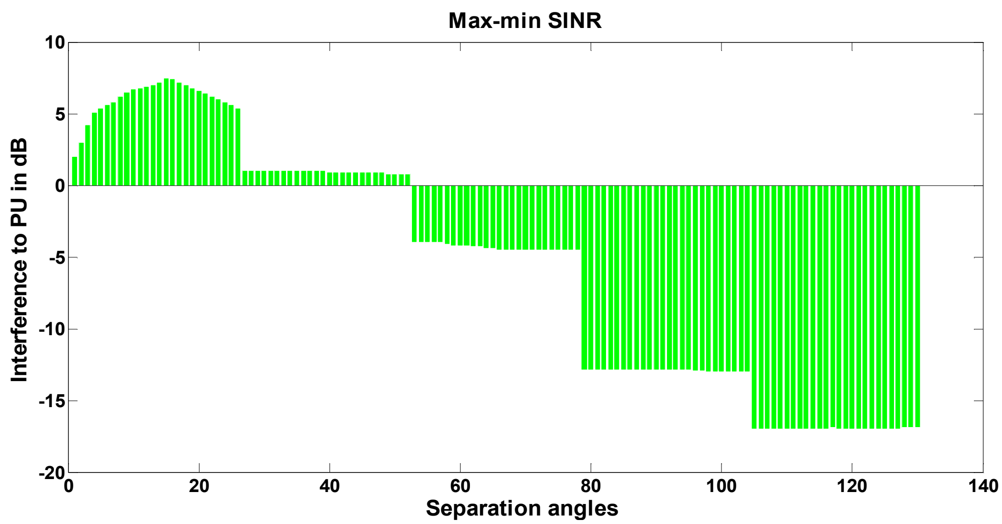

Fig. 10: Maximum SINR with interference

0.5 λ. The Angle of Departure (AoD) for the Primary user is 10°, for Secondary User 1 it is 20°, while Secondary User 2 moving between 25 to 50°. The angle spread for each user is considered to be 2° around its main angle of departure. Randomly generated the channel vectors up to 1000 times in conjunction with taking the statistical mean.

First we take the minimum power strategy in cognitive radio. For this purpose we set the minimum required SINR per secondary user equal to 10dB. In a meticulous study of this strategy, we consider diverse values of the Interference Margin (IM) for the primary user, these are approximately 3dB, -3dB, -13dB and-16dB. The blue line in the Fig. 3 shows the minimum total transmit power without taking into consideration the constraint of maximum allowable interference to the primary. The additional plots are achieving by considering the constraint of interference to the primary at values refer to above. Note in the Fig. 3 that as we tighten the constraint, i.e., lower the maximum allowed interference to primary users, the minimum required total transmission power increases. The reason for this is that the weights are assigned in such a way that interference to primary remains below the constraint. This is achieved by directing the beam slightly away from the primary user, thus deviating from ideal beam direction for the secondary user. Therefore, in order to maintain the SINR above the constraint of 10dB, power has to be increased. Interference to the primary user constantly stays below the threshold. Minimum power strategy in cognitive scenario only affects the performance of the secondary users. Figure 4 show histogram of the minimum transmission power verses the separation angles. As the separation angles increase with respect to the interference margin the minimum power decreases.

The Figure 5 show the minimum interference power which is always below the set interference margin while the Fig. 6 show the histogram which show the interference due to interference margin verses the separation angles.

The Figure 7 shows the SINR per user verses the separation angles. It is clear that as we increase the separation angles SINR at the secondary user increases. The Figure 8 show the histogram of the SINR per users against the separation angles with respect to different constraints.

The Figure 9 shows the interference to the primary user vs. the separation angles while the Fig. 10 show the histogram of the interference power at the primary verses the separation angles in the presence of the Max SINR condition.

CONCLUSION

In this study, we make an effort to optimize the QoS for secondary users in conditions of minimum transmission power and maximum SINR per user. We started through implementing downlink orthogonal transmit beamforming in MU-MISO network and tried to optimize two design criteria. Optimization has been carried out using SDP. However, in conditions of interference caused to the primary user, the performance of the Maximin SINR strategies is far superior than the performance of Minimum Transmission Power Strategy. In future most constraint can be added to the interference caused by the primary users onto the secondary users. This interference can also be suppressed as much as possible. The current arrangement can be enhanced to change the Multiuser Multiple input Single output (MU-MISO) cognitive radio network into the Multiuser, Multiple input Multiple output (MU-MIMO) cognitive radio networks.

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