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MIMO Cognitive Radio with Low Cost Reception Using Beam Forming And Antenna Sub Array Formation

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Abstract—*A* Cognitive Radio is a Software Defined Radio (SDR).The Cognitive radio network is capable to sense and analyze its surrounding environment as well as reconfigure its operation in accordance with this radio environment. In this way, based on the available Channel State Information (CSI), the cognitive radio network may dynamically access the spectrum. MIMO based cognitive radio system enabled dynamically simultaneous usage of a radio spectrum for this beam forming signal processing technique is used. Beam forming is a technique in which the directionality of transmission and reception of radio signals can be controlled. Modern wireless technology depends on beam forming technology in order to provide higher data rates, improved coverage and also used to share the spectrum with the other users. Hardware complexity is one of the main issue in MIMO based wireless system which require N number of RF chains for N antenna systems. Antenna sub array formation (ASF) scheme is an optimization technique which can be used to reduce the RF chain required such a way the capacity can be improved. This will reduce the cost of the hardware much and we can realize low cost hardware system. Usually the two process of sub array formation and beam forming are done as separate process but in this paper the joint beam forming and sub array formation is done such a way the secondary user capacity will be improved and to avoid two computational complex process. Antenna sub array formation (ASF) scheme is employed to maximize the Signal to Interference Ratio (SINR) by using all antenna elements. In Antenna sub array formation the Radio Frequency chain is allocated to sub array of elements.

Keywords—*Antenna* Selection(AS),antenna subarrayformation(ASF), beamforming ,cognitiveradio(CR) multiple-input multiple-output(MIMO).

I. INTRODUCTION

Cognitive Radio (CR) can sense and reason its surrounding environment therefore the operating parameters can be adjusted dynamically and autonomously. This is done in order to co-exist with primary systems [8]. It also has the potential to improve the spectrum utilization. Cognitive Radio can be programmed automatically. They can also be controlled in an automatic manner. The Cognitive Radio is designed in such a way that its transceiver can use the wireless channel that is best among all channels. Therefore, in cognitive radio the available channels are detected automatically. Then, the transmission (or) reception parameters are changed. This is done because the more concurrent wireless communication can be allowed in a given spectrum band. This is a form of Dynamic Spectrum Management (DS) [8].

In MIMO there are multiple antennas and they are used for simultaneous transmission as well as reception. This is done with the help of a radio channel [9].The channel is referred as radio environment between transmitter and receiver. Multiple input is referred as multiple transmitter antennas because they input a radio signal into the channel

.Multiple output refers to multiple receiver antennas because they take output from the channel into the receiver. This is Single-output and also Multiple-input Multiple-output configuration can be considered [9].

Beam forming [11] is used to denote an array processing technique for estimating one or more desired signals. The output provided by each antenna element is weighted according to a certain criterion in order to distinguish the spatial properties of a signal of interest from noise and interference. The name beam forming comes from the early forms of antenna arrays that were used to generate beams, so as to receive signals from a specific direction and attenuate signals incoming from other directions. Beamforming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity. Through beam-forming, a MIMO can null out its interference to other receivers.

In traditional wireless communication services fixed spectrum allocation is called the major spectrum methodology. Different wireless services have been allocated to different bands. This is done in order to avoid interference [1]. Antenna selection scheme [2] has been proposed to reduce the hardware cost. In Multiple-input Multiple -output wireless communication can be improved in two ways they are Diversity methods and spatial multiplexing techniques. Without sacrificing spatial multiplexing gains sub-optimal Antenna selection methods which minimize the capacity loss in introduced. The idea is to have antenna elements given the number of Radio Frequency chains. But Antenna sub array formation [4] is employed to maximize the capacity by using all antenna elements. In Antenna sub array formation [4] [5] the Radio Frequency chain is allocated to the combined and weighted output of a sub array of elements. It means that Radio Frequency chain is not allocated to only single element. Therefore, the hardware complexity can be reduced.

II. SYSTEM MODEL

The MIMO Cognitive Radio system model consists of a primary and secondary link where the primary link consists of a primary transmitter as well as a primary receiver. The primary transmitter (PU-TX) consists of N1 antennas and the primary receiver (PU-RX) consists of M1 antennas. Similarly the secondary link consists of a secondary transmitter (SU-TX) with N2 antennas and a secondary receiver (SU-RX) with M2 antennas. To reduce the hardware cost the SU-RX has L Radio frequency chains (RF).The symbol $x \in \mathbb{C}^{N2X1}$ is transmitted to the SU-TX from SU-TX. Therefore, the signal that is received at the SU-RX will be

$$y_i = H_1 p + z + n_i$$

H_1 Represents the channel response matrix from secondary transmitter to the secondary receiver.z represents the received interference from primary transmitter. n_i Represents the additive white Gaussian noise vector. Therefore, the interference plus noise covariance matrix will be

$$C = I + H_2 H_2^{\dagger}$$

H_2 Represents the channel response matrix from the primary transmitter to the secondary receiver.Rayleigh channel matrix is used here. A circularly symmetric Complex Gaussian random variable is of the form,

$$h = h_{re} + j h_{im} \quad (3)$$

The real and imaginary parts are zero mean and independent and identically distributed(iid) Gaussian random variables with mean 0 and variance σ^2. The magnitude $|h|$ has a probability density defined as,

$$p(h) = \frac{h}{\sigma^2} e^{\frac{-h^2}{2\sigma^2}} \quad z \geq 0 \ , \quad (4)$$

This is called as Rayleigh random variable.

Now, relax-structured Antenna Sub Array Formation (RS-ASF) at the SU-RX. This is done to reduce hardware complexity. Therefore, after RS-ASF the received signal is,

$\hat{x}$=Ay_i (5) A represents the Antenna Sub array Formation matrix.

Also $A \in \mathbb{C}_k^{L \times M2}$.The subscript k denotes the number of non-zero elements in A. Also the elements in each row correspond to the complex weights for multiple antennas in a sub array.

$\hat{x}$ Represents L×1 column vector, where the elements in each row corresponds to a RF chain input.RF chain will have a down converter and an Analog to digital converter. Here, the multiple antenna outputs are complexly weighted and combined. The achievable capacity of the secondary link is given by

$$\mathrm{SINR}(A, T) = (AH_1TH_1^{\dagger}A^{\dagger}(ACA^{\dagger})) \quad (6)$$

$\dagger$ Represents the conjugate transpose and $T_{original} = E(pp^{\dagger})$ is the transmit co-variance matrix.Also, the transmit co-variance matrix will determine the beam forming that is employed at the SU -TX. Therefore by designing the optimal Antenna Sub array Formation (ASF) matrix A and also designing transmit co- variance matrix T the achievable capacity is maximized as follows [12].

$$\max_{F,T\geq 0} SINR(A,T)$$
$$\text{s.t. } T_r(T) \leq P \ , \ T_r(H_3 T H_3^{\dagger}) \leq \tau \ , A \in \mathbb{C}_k^{L\times M2} \quad (7)$$

H_3 Represents the channel response matrix from the secondary transmitter to the primary receiver. Also,$H_3 \in \mathbb{C}^{M1\times N2}$.$P$ And τ represents the transmit power and interference power constraint.

An iterative algorithm is used to solve (7) so the antenna sub array formation (A) matrix and also the transmit co-variance matrix (T) are optimized iteratively. For lth iteration A=A_l is fixed and the optimization problem is solved. But equation (7) is convex. Therefore a tool called as convex optimization tool is used to find the optimal solution of (5).The achievable SINR is found by (6) and then the SINR is maximized with the help of convex optimization tool.

III. BLOCK DIAGRAM

A. *Transmitter Block Diagram*

In transmitter block Information bits (b) are passed to Mapped for modulation.The information bits are modulated by using digital modulator.Then, the modulated bits are passed to beamformer where the signal (x) is multiplied by $\vec{u}$. Then the signals are passed onto transmitter for transmission. The signals are passed on L number of antennas for transmission.

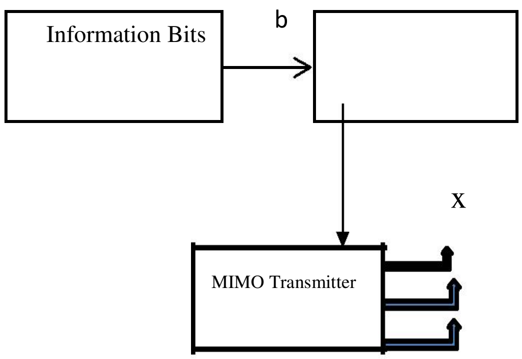

Figure1. Transmitter Block Diagram

B.Receiver Block Diagram

The signals transmitted by ε antennas are received by L antenna system then sub array is used to convert the L radio
frequency (RF) chains to M2 RF chains.Then, the signals are demodulated and the bits are obained.

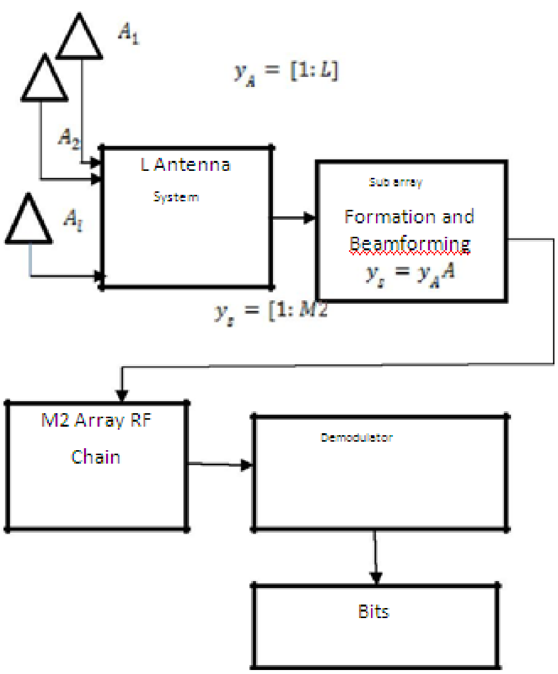

Figure2. Receiver Block Diagram

IV. SIMULATION RESULTS

For Symbol Error Rate Vs SNR for primary receiver (PU-RX) shown in Figure 3, signal-to-noise ratio (SNR) vs symbol error rate (BER) is plotted. The signals from the primary transmitter (PU -TX) to the primary receiver (PU-RX) and the signals from the secondary transmitter (SU-TX) to primary receiver (PU-RX) are combined at the primary receiver (PU-RX). In the same way the signals from the secondary transmitter (SU-TX)are combined at the secondary receiver (SU-RX). The symbol error rate of the secondary user is given in fig.4. For this Quadrature amplitude modulation (QAM) is used.

ITERATIONS

Rayleigh Channel Matrix	Iteration-1	Iteration-2	Iteration-3
H11	0.8696+0.0335i 0.6236+0.3112i	-0.43961.3174i 0.4188+0.7173i	0.5322+0.1043i 0.3616+0.6757i
H21	-0.3740-2.3702i - 0.4489+0.8687i	-0.0073 - 0.1798i 0.2260 +0.9406i	- 1.2040+0.8919i - 0.5295+0.5298i
H12	0.2094+0.3284i 0.5546 - 0.8472i	-0.3821- 1.3368i 0.1141 - 1.1196i	- 0.6833+0.7409i - 0.8743+0.6326i
H22	1.0772 - 1.1529i 0.4740+0.9200i	0.7878+ 0.3470i -0.3300- 1.2202i	-0.7608- 0.5124i 0.3878 - 0.5871i

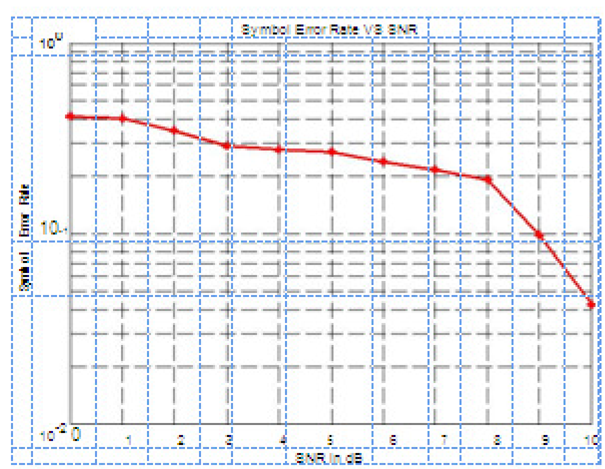

Figure3.Symbol ErrorRate Vs SNR for primary receiver (PU-RX)

[3]

[1] TABLE 1. RAYLEIGH CHANNEL MATRIX FOR THREE [2]

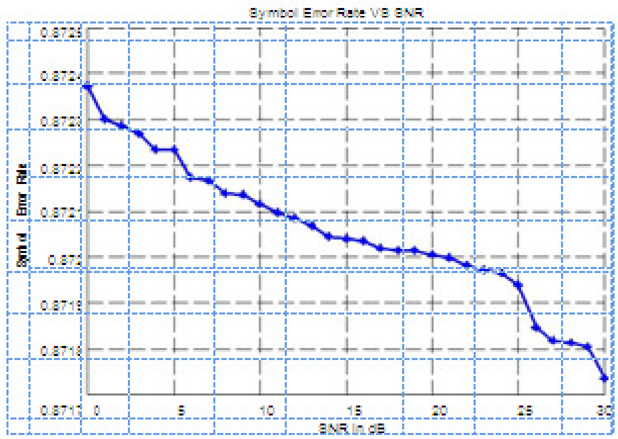

Figure4. Symbol Error Rate Vs SNR for secondary receiver (SU-RX)

V. Conclusion

Antenna sub array formation thus proves to be a promising technique for Multiple-input Multiple -output (MIMO) receiver. It maximizes the achievable SINR subject to peak transmit power (PTP) constraint at the secondary transmitter (SU-TX), peak interference power (PIP) constraint at the primary receiver (PU-RX).Therefore, the simulation results shows that Antenna sub array formation scheme (ASF) performs better than antenna selection (AS) scheme.

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