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POWER ALLOCATION SCHEMES FOR MIMO-OFDM BASED COGNITIVE RADIO SYSTEMS BASED ON WATER FILLING TECHNIQUE

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Abstract— The water filling algorithm provides solution with the help of channel state information. MIMO is a promising high data rate integrates technology. It is well known the aptitude of MIMO can be significantly enhanced by employing a proper power budget allocation in wireless cellular network. In this paper the water filling algorithm has been implemented for allocating the power to the MIMO channels for enhancing the capacity of the MIMO network. The singular value decomposition and water filling algorithm have been employed to measure the performance of MIMO OFDM integrated system. MIMO is a promising high data rate interface technology. It is well known the capacity of MIMO can be significantly enhanced by employing a proper power budget allocation in wireless cellular network. When Nt transmit and Nr represented antennas are employed, outage capacity is increased. In MIMO OFDM we transmit different stream of data through different antennas. We show that as we increase the power budget in the water filling algorithm the mean capacity of the system increased. The capacity and SNR performance for SISO and MIMO system without and with water filling algorithm are also been demonstrated for comparison.

Keywords— Water filling technique, MIMO-OFDM, Cognitive radio

I. INTRODUCTION

Cognitive Radios are technologies that may be used to implement opportunistic sharing. Cognitive Radios are able to sense the spectrum to see whether it is being used by the Primary User. However this sensing operation may be rendered difficult due to a degraded wireless channel, which has prompted concerns from Primary users of the spectrum. In order to facilitate the deployment of Cognitive Radio technologies for the secondary usage of spectrum it is crucial to prove the reliable detection of Primary Users.[1] During an ongoing communication using temporarily available licensed spectrum, the involved Cognitive Radios have to continuously monitor the used spectrum for reappearing Primary Users. The Cognitive Radios can exchange sensing and setup information in a timely manner.

Orthogonal Frequency Division Multiplexing (OFDM) employs closely spaced narrowband orthogonal subcarriers for data transference, thus avoiding the problem of inter symbol interference associated with wideband frequency selective channels. The MIMO system has multiple transmit and receive antennas and Orthogonal Frequency-Division Multiplexing (OFDM) is used as it is sought as one of the solution for increasing the capacity and data rate of a system in an environment where the communication take place in a frequency-selective fading environments and there can be probably more chances for data corruption [2]. It has been found that Multiple-Input and Multiple-Output (MIMO) can be effectively used to increase the capacity of the system by a factor of the minimum number of transmitter and receiver antennas attached in the MIMO system as compared to a Single-Input Single-Output (SISO) system that has flat fading or frequency selective fading environment or narrowband channels, OFDM can also increase diversity gain and minimize the inter-symbol interference on a time-varying multi-path fading channel. When we know the parameters of the channel both at the transmitter end and at the receiver end, we can further increase the capacity of MIMO OFDM systems by assigning power at the transmitter according to the water filling algorithm to the channels.

The capacity of a MIMO system can further be increased if we know the channel parameters both at the transmitter and at the receiver and assign extra power at the transmitter by allocating the power according to the water filling algorithms to all the channels [3]. Water filling is the solution of several optimization problems related to channel capacity. The well-known water filling algorithm solves the problem of maximizing the mutual information between the input and output of a channel.

II. MIMO-OFDM SYSTEM

Orthogonal frequency division multiplexing is a popular wireless multicarrier transmission technique. It is a favorable candidate for next generation wired and mobile wireless system. The basic principle of OFDM is to split a high data rate stream into a number of low data rate stream so that the lower data rate can be transmitted simultaneously over a number of subcarriers. In OFDM, the amount of diffusion in time caused by multipath delay spread is decreased due to increased symbol

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duration for lower rate parallel subcarriers. The spectrum of OFDM is more efficient because of the use of closer channel space. Interference is prevented by making all subcarrier orthogonal to one another.

MIMO system utilizes space multiplex by using antenna array to enhance the efficiency in the used bandwidth. These systems are defined spatial diversity and spatial multiplexing. Spatial diversity is known as Tx -and Rx- diversity. Signal copies are transferred from another antenna, or received at more than one antenna. With spatial multiplexing, the system carriers' more than one spatial data stream over one frequency, simultaneously. In subcarriers MIMO-OFDM system, the individual data stream is first passed through an OFDM modulator. Then the resulting OFDM symbols are launched simultaneously through the transmit antenna. In a receiver side the individual received signal are passed through OFDM demodulator. The output of OFDM demodulator are decoded and rearranged to get desired output.

2.1 Spatial Multiplexing

In an OFDM-based MIMO system, spatial multiplexing is performed by transmitting independent data streams on a tone-by-tone basis with the total transmit power split uniformly across antennas and tones. Although the use of OFDM eliminates ISI, the computational complexity of MIMO-OFDM spatial-multiplexing receivers can still be high. The transmission of multiple data stream over more than one antenna is called spatial multiplexing [4]. The advantages of spatial multiplexing is linear capacity gains in relation to the number of transmit antenna.

2.2 MIMO Channel Matrix

The matrix describes the channel behavior on a particular subcarrier (n) for a particular user (k). Here k and n represents the number of users and subcarrier respectively. Which as follows

$$H=\begin{pmatrix} H1,1 \; H1,2 \ldots\ldots\ldots H1,n \\ H2,1 \; H2,2 \ldots\ldots\ldots H2,n \\ Hk,1 \ldots\ldots\ldots\ldots\ldots Hk,n \end{pmatrix} \_\_\_\_\_\_\_\_\_\_ (1)$$

Where Hk, n is already defined.

2.3 Capacity

Capacity is the measure of maximum information that can be transmitted reliably over a channel. Claude Elwood Shannon developed the following equation for theoretical channel capacity.

$$Csiso= B \log(1+SNR) \_\_\_\_\_\_\_\_\_\_\_\_ (2)$$

It includes the transmission bandwidth B and signal to noise ratio. The Shannon capacity of MIMO system depends on the number of antenna. For MIMO the capacity is given by the following equation,

$$Cmimo= NB(1+SNR) \_\_\_\_\_\_\_\_\_\_\_\_ (3)$$

Where N is the minimum of Nt (number of transmitting antennas) or Nr (number of receiving antennas).

III. WATER FILLING ALGORITHM

The process of water filling algorithm is similar to pouring the water in the vessel. The unshared portion of the graph represents the inverse of the power gain of a specific channel. The Shadow portion represents the power allocated or the water [5]. The total amount on water filled (power allocated) is proportional to the Signal to Noise Ratio of channel.

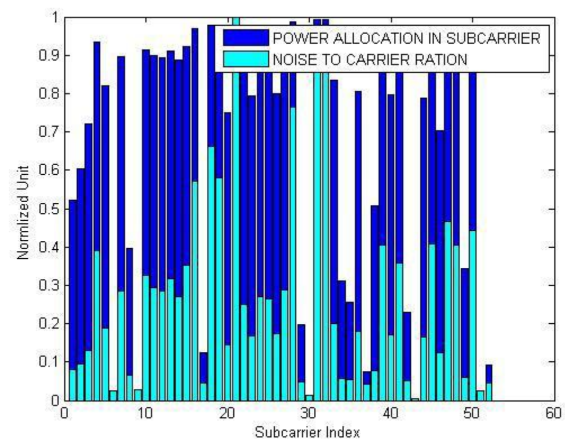

Fig : Water Filling Algorithm Model

Power allocated by individual channel is given by the eq. 1, as shown in the following formula,

$$\text{Power allocated} = \frac{Pt+\sum \frac{1}{Hi}}{\sum channel} - \frac{1}{Hi} \quad \_\_\_\_\_\_\_\_\_\_ (4)$$

Where Pt is the total power of MIMO system which is allocated among the different channels and H is the channel matrix of system. The capacityof aMIMO is the algebraic sum of the capacities of all channels and given by the formula below.

$$Capacity=\sum_{i=1}^{n} \log(1 + power\ allocated * H) \_\_\_\_ (5)$$

We have to maximize the total number of bits to be transported .As per the scheme following steps are followed to carry out the water filling algorithm.

Algorithm Steps:-

1. Take the inverse of the channel gains.

2. Water filling has non uniform step structure due to the inverse of the channel gain.

3. Initially take the sum of the total power Pt and the inverse of the channel gain. It gives the complete area in the water filling and inverse power gain.

$$Pt + \sum_{i=1}^{n} \frac{1}{Hi} \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (6)$$

4. Decide the initial water level by the formula given below by taking the average power allocated.

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$$\frac{Pt+\sum_{i=1}^{n}\frac{1}{Hi}}{\sum channel} \qquad (7)$$

5. The power values of each sub channel are calculated by subtracting the inverse channel gain of each channel.

$$\text{Power allocated}=\frac{Pt+\sum_{i=1}^{n}\frac{1}{Hi}}{\sum channel} - 1/Hi \qquad (8)$$

In case the power allocated value become negative stop iteration.

IV. SIMULATION STUDY

The proposed scheme has been simulated to verify the effectiveness of the power allocation to different subcarriers. The simulation has been done on MATLAB and the model used for the simulation is as given below.

4.1 MIMO-OFDM Simulation Model

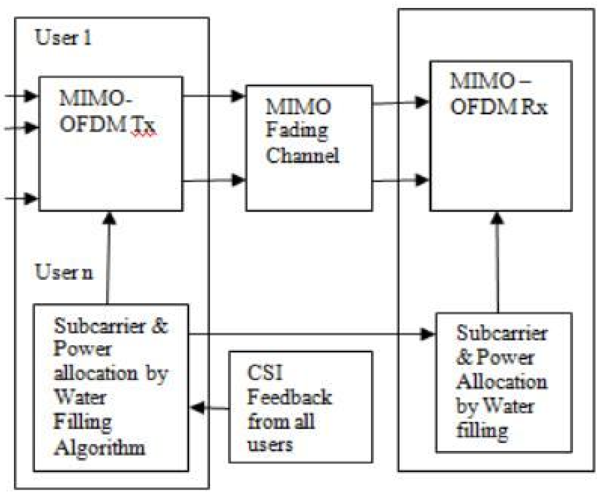

Fig 2: MIMO OFDM System Model

The subcarrier and power allocation is done at the transmitter side by knowing the availability of exact channel state information (CSI) in MIMO-OFDM as shown in figure 2.

Here each transmitter and receiver antenna is assigned to an individual OFDM transmitter and receiver. A system with K user and N subcarrier are considered in this work and that number of transmit and receive antenna are assumed to be N_t and Nr respectively. User K ($1\leq k \leq K$) on subcarrier n ($1\leq n \leq N$) is assigned a power $P_{K,n}$ and the corresponding channel state matrix is $H_{K,n}$ with dimensions N_t * Nr.

4.2 MIMO-OFDM Simulation Results

The Mean capacity vs SNR curve of SISO, SIMO, MISO, MIMO systems is shown in Fig 3, Fig 4 & Fig 5, Fig 6. These graphs depict that the 4 x 4 MIMO systems provides better Mean capacity. The results here indicate that the capacity of the system increases with the increase in the number of transmit and receive antenna. This indicates that a higher order MIMO system increases the system performance.

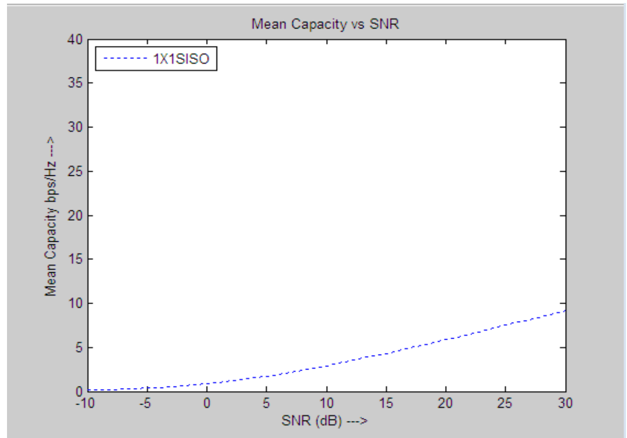

Fig 3 : SISO OFDM capacity Vs SNR without water filling Algorithm

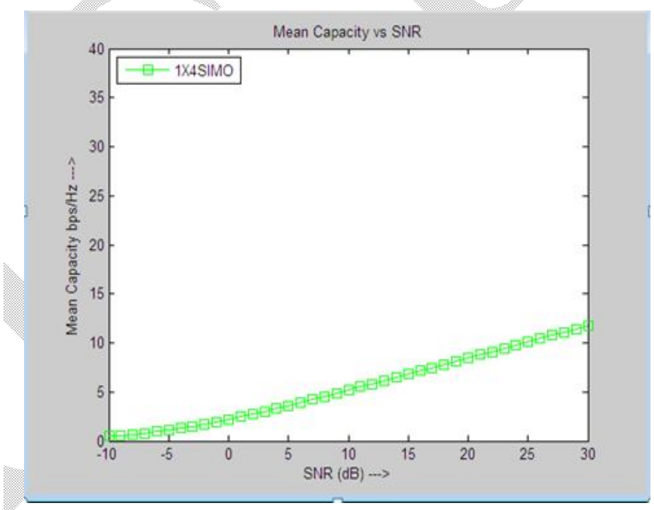

Fig 4 : SIMO OFDM capacity Vs SNR without water filling Algorithm

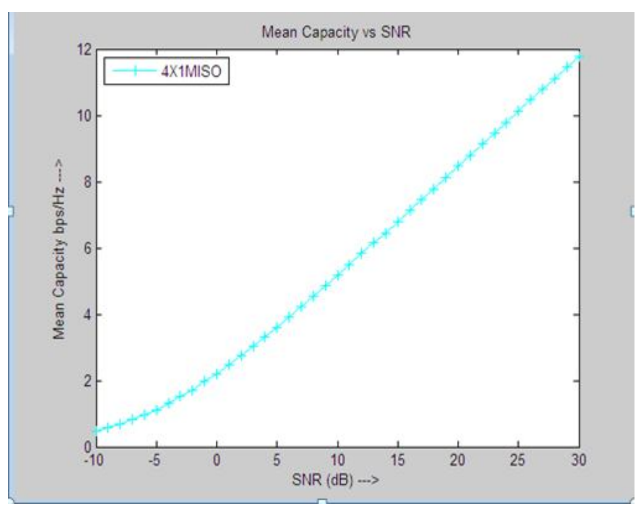

Fig 5 : MISO OFDM capacity Vs SNR without water filling Algorithm

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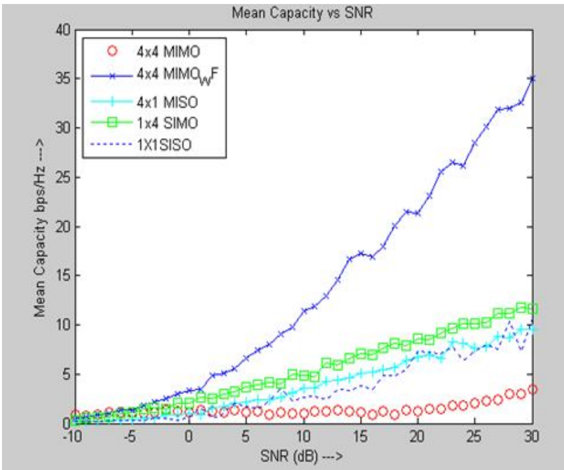

Fig 6: Comparison of MIMO OFDM with and without water filling Algorithm

From Fig 6, it has been analyzed the capacity of Multiple input Multiple output system without water filling algorithm is 4 bps and with water filling it is 35 bps. In MIMO-OFDM without water filling algorithm the total power is allocated equally between all the subcarrier.

But water filling algorithm allocates power among all subcarrier according to the channel gain of channel. Fig 7, it shows that Water filling gain (vs) SNR output. The gain will be gradually decrease by allocate the power.

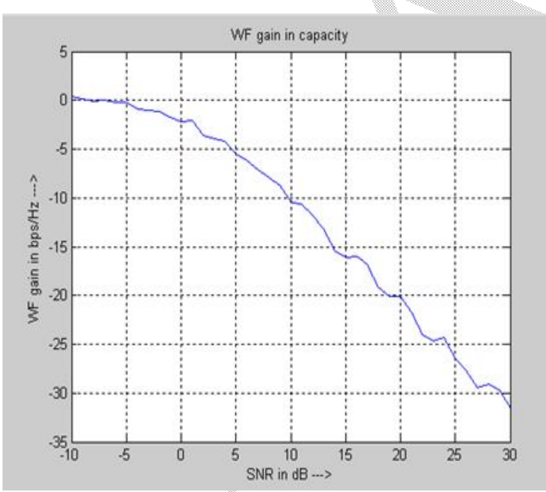

Fig 7 : Water filling gain (vs) SNR

V. CONCLUSION

MIMO OFDM system based water filling algorithm has been simulated in order to enhance the capacity and SNR performance of MIMO OFDM system. An improved method has been proposed for subcarrier and power allocation in multicarrier and multi antenna systems with the aim of maximizing the capacity.

Capacity of MIMO OFDM without water filling is 4 bps and with water filling it is 35 bps at the same value of SNR (-10dB to -1dB)

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