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Capacity Analysis of MIMO OFDM System using Water filling Algorithm

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Abstract -**In present correspondence we develop a proposed water filling algorithm for MIMO fading channel (Rayleigh Fading channel). Orthogonal Frequency Division Multiplexing (OFDM) become the chosen modulation technique for wireless communication. Multiple access points or small base stations send independent coded information to multiple mobile terminals through orthogonal Code division multiplexing channels. 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 .The singular value decomposition and water filling algorithm have been employed to measure the performance of MIMO OFDM integrated system. 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 proposed work investigated with Mat lab.**

***Key Words*: Orthogonal Frequency Division Multiplexing (OFDM), Multiple input multiple output (MIMO), Singular value decomposition (SVD), Water filling algorithm**.

I. Introduction

The growing demand on wireless communication services has created the necessity to support higher and higher data rate. Wireless communication systems face high level of ISI which originates from multipath propagation and inherent delay spread. A multipath based technique such as orthogonal frequency division multiplexing (OFDM) can be used to eliminate ISI and to improve capacity and spectral efficiency(bps/Hz) in wireless system[12]. In addition, MIMO systems are promising techniques to increase performance with acceptable bit error rate (BER) by using a number of antennas [13]. A MIMO-OFDM system transmits OFDM modulated data from multiple antennas at the transmitter. Data transmitted with subcarriers at different antennas are mutually orthogonal. The receiver extracts different data stream from different subcarriers after OFDM demodulation and MIMO decoding. Flat fading MIMO algorithms reduce computational requirement and make MIMO-OFDM attractive for mobile applications [11]

With respect to single-input single-output (SISO) systems, multiple-input multiple output (MIMO) systems over narrowband space-channels have been proved to be able to dramatically increase the spectral efficiency. However, narrowband MIMO systems severely suffer from the inter symbol interferences (ISI) over frequency-selective fading wideband channels. Orthogonal frequency division multiplexing (OFDM) is a multicarrier communication technique that is widely used, for e.g. in system such as Wi-Fi (802.11a/g/n) and WiMax (802.16). Orthogonal frequency division multiplexing (OFDM) techniques transmit high rate data-stream over numerous sub-channels in frequency-domain and each sub-channel is a narrowband flat-fading channel. Thus, MIMO-OFDM systems have the potential to achieve high spectral efficiency over wideband channels, i.e., achieve high capacity. To achieve a high system capacity for multimedia applications in wireless communications, various methods have been proposed in recent years. Among them, the multiple input – multiple output (MIMO) system using multiple antennas at both the transmitter and the receiver has attracted a lot of research interest due to its potential to increase the system capacity without extra bandwidth. Multiple input- multiple-output (MIMO) exploits spatial diversity by having several transmit and receive antennas. Previous work has shown that the system capacity could be linearly increased with the number of antennas when the system is operating over flat fading channels. In real situations, multipath propagation usually occurs and causes the MIMO channels to be frequency selective. To combat the effect of frequency selective fading, MIMO is generally combined with orthogonal frequency-division multiplexing (OFDM) technique. OFDM transforms the frequency-selective fading channels into parallel flat fading sub channels, as long as the cyclic prefix (CP) inserted at the beginning of each OFDM symbol is longer than or equal to the channel length. The channel length means the length of impulse response of the channel as discrete sequence. The signals on each subcarrier can be easily detected by a time-domain or frequency-domain equalizer. Otherwise the effect of frequency-selective fading cannot be completely eliminated, and inter-carrier interference (ICI) and inter-symbol interference (ISI) will be introduced in the received signal. Equalization techniques that could flexibly detect the signals in both cases are thus important in MIMO-OFDM systems.

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II. MIMO OFDM SYSTEM MODEL

In this section a model we have given the model for multiuser MIMO OFDM transmission, with its block scheme a brief summary provided about the OFDM and MIMO scheme.

Orthogonal frequency division multiplexing is a popular wireless multicarrier transmission technique. It is a promising 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 dispersion in time caused by multipath delay spread is decreased due to increased symbol 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.

A. Spatial Multiplexing

The transmission of multiple data stream over more than one antenna is called spatial multiplexing [10]. The advantages of spatial multiplexing is linear capacity gains in relation to the number of transmit antenna

B. 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-

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

Where Hk,n is already defined.

C. 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:

$$C_{siso} = B \log(1+SNR) \qquad (2)$$

It includethe 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 :

$$C_{mimo} = NB(1+SNR) \qquad (3)$$

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

D. Singular Value Decomposition

The SVD techniques decouples the channel matrix in spatial domain in a similar to the DFT decoupling the channel in the frequency domain. If channel matrix H is the the T x R channel matrix. If H has indenpend rows and columns ,SVD yields:

$H = U\sum V^h$

Where U and V are unitary matrices and V^h is the hermitian of V. U has dimension of R xR and V has dimension of TxT.If T=R then $\sum$ become a diagonal matrix. If T>R, is made of RxR diagonal matrix followed by T-R zero column. If T<R, it is made of T x T disgonsl mstrix followed by R – T 0 rows. This operation is called the singular value decomposition of H In case where T ≠ R the number of spatial channels become restricted to minimum to T and R. if the number of transmit antenna > receive antenna U will be an RxR matrix, V will be a T x T matrix and $\sum$ will be made of square matrix of order R followed by T – R zero columns[10].

III. WATER FILLING ALGORITH

The process of water filling algorithm is similar to pouring the water in the vessel. The un shaded 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. The total amount on water filled (power allocated) is proportional to the Signal to Noise Ratio of channel .

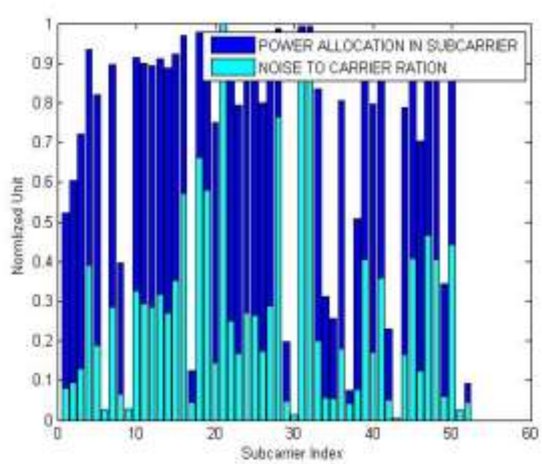

Figure 1 Water Filling Algorithm Model

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

Powerallocated = $\frac{Pt+\sum\frac{1}{Hi}}{\sum channel} - \frac{1}{Hi}$ (4)

Where Pt is the power udget 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= $\sum_{i=1}^{n}\log(1 + PowerAllocated * H)$ (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+$\sum_{i=1}^{n}\frac{1}{Hi}$
4. Decide the initial water level by the formula given below by taking the average power allocated

   $$\frac{Pt + \sum_{i=1}^{n}\frac{1}{Hi}}{\sum Channel}$$
5. The power values of each subchannel are calculated by substracting the inverse channel gain of each channel.

   Powerallocated=$\frac{Pt+\sum_{i=1}^{n}\frac{1}{Hi}}{\sum Channel} - \frac{1}{Hi}$

   In case the power allocated value become negative stop iteration.

IV. MODELLING AND SIMULATION

A. OFDM Simulation Model

1. Serial to Parallel Conversion

The input serial data stream is formatted into the word size required for transmission, e.g. 2 bits/word for QPSK, and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

2. Modulation of Data

The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase Shift Keying (PSK) format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0, 90, 180, and 270 degrees. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

3. Inverse Fourier Transform

After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

4. Guard Period

The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection.

However it was found that it was not required in any of the simulations as the timing could be accurately determined position of the samples. After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

4. Receiver

The receiver basically does the reverse operation to the transmitter. The guard period is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

Figure 2 OFDM Model used for Simulation

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1 MIMO Channel Configuration

MIMO configuration uses multi-element antenna arrays at both transmitter and receiver, which effectively exploits the third (spatial) dimension in addition to time and frequency dimensions. This architecture achieves channel capacity far beyond that of traditional techniques. In independent Rayleigh channels the MIMO capacity scales linearly as the number of antennas under some conditions. However, some impairments of the radio propagation channel may lead to a substantial degradation in MIMO performance. Some limitations on the MIMO capacity are imposed by the number of multipath components or scatterers. Another limitation on the MIMO channel capacity is due to the correlation between individual sub-channels of the matrix channel. Increase in the correlation coefficient results in capacity decrease and, finally, when the correlation coefficient equals to unity, no advantage is provided by the MIMO architecture.

For fixed linear matrix channel with additive white Gaussian noise and when the transmitted signal vector is composed of statistically independent equal power components each with a Gaussian distribution and the receiver knows the channel, its capacity is

$$C = \log_2\left(det\left(I_N + \frac{\rho}{N} H * H^H\right)\right) bits/s/H_z \qquad (6)$$

2 MIMO OFDM Simulation result

A MIMO system that we consider here has 4 transmit and 4 receive antenna and the system and the fading here is assumed to be flat. 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.

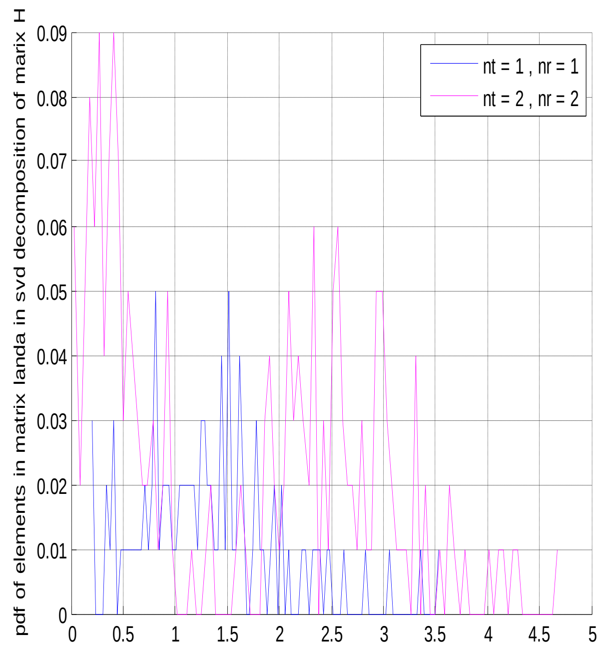

Figure 3 OFDM Model used for Simulation

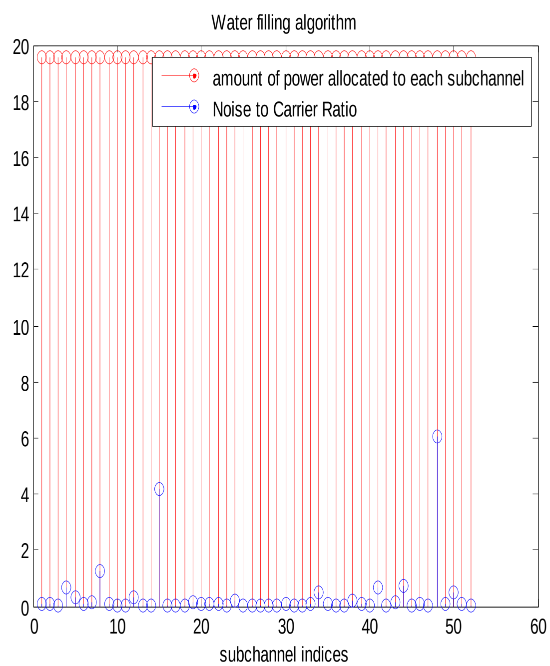

Figure 4 Power allocated to 52 sucarriers

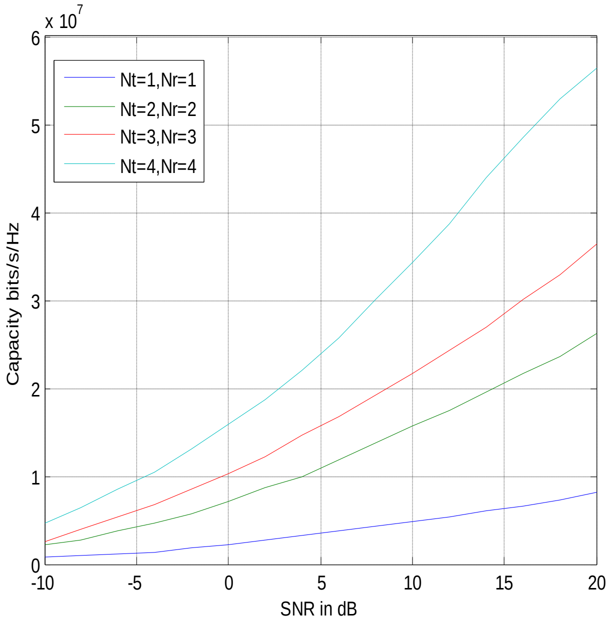

Figure 5 Comparison of channel capacity of different MIMO system

V. Conclusion

In this paper, we have presented the MIMO OFDM model using MATLAB. The results of simulation form the model will enable the researches to choose water filling algorithm for their requirements. MIMO has helped to ISI problem. The Results indicates that the Capacity is enhanced significantly by transmitting the different stream of data through different antennas at same frequency. The water filling algorithm allocates the more power to subcarrier for that noise level is high. Capacity is increased with increase in number of antenna

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