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Enhancement of capacity using search algorithm for MIMO system

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Abstract— Wireless communications system are in constant evolution, multiple applications are used that require different performances, according to the knowledge of the standard used, the correct frequency band, the regulated power....This information are essential for the functioning of the MIMO system and thus contributes to its improvement.

In this paper we choose to improve the capacity of MIMO system in two kind of channels: fading channel as reference and fading channel with noise power. We propose in this research to apply pre-coding in the transmitted side and a post-coding in the received side without any channel state information (no CSI) at both sides. Two different techniques are used to evaluate the performance of the capacity witch are: zero forcing (ZF) and (MSSE) the minimum mean square error.

Index Terms— fading channel, fading channel with noise power, MIMO system, minimum mean square error, svd decomposition, pre-post coding, zero forcing.

1 INTRODUCTION

MIMO system can solve several problems related to the limited radio spectrum and the increase in communication spectral. MIMO technology can also improve the performance of radio communication such as capacity, data rate, Bit Error Rate (Ber)…

In this prospective we choose MIMO system with fading channel using noise power at the transmitted side. In addition, an algorithm of research is applied to increase the capacity of MIMO system.

As known the perfect results can be achieved with full knowledge of channel state information in both sides. In this study we worked with no channel state information and we applied the singular value decomposition technique (SVD), which can provide fading sub-channels and a diagonalizable channel matrix of MIMO system. With the appropriate pre and post coding at both transmitted and received side, the capacity can be enhanced to get better result. Every result is evaluated with different techniques, in this case we used zero forcing (ZF) based on the inversion of the matrix H and the minimum mean square error (MMSE).

This information provides us with the essential data that we can work with and which allow us to make the improvements we need for our MIMO system.

2 MIMO SYSTEM MODEL

In this paper we have consider a MIMO system with a transmitted array of Nt=8 antennas and a received array of Nr=8 antennas which is the basic of LTE [4].

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The multiple antenna are represented en general with a transmitted and received array of (NtxNr) antennas as the following figure:

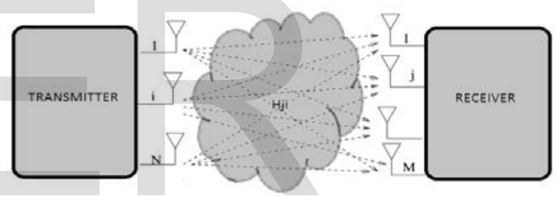

Fig.1. MIMO system

The MIMO system is established with the knowledge of various elements such as the number of array antennas on both transmitter and receiver side, the nature of the channel, the environment to which it belongs….
The relation between these components is given by:

$$y = Hx + n \qquad (1)$$

Where y is the received vectors obtained by multiplying the channel matrix H with the transmitted vectors x in addition to n which is the additive Gaussian noise.

In this study we focused on the channel matrix H which is the essential component in the MIMO system, where each exchange of information between the transmitter and the receiver is performed. This matrix can be written as:

$$H = \begin{bmatrix} h_{11} & h_{21} & \dots & \dots & h_{M1} \\ h_{12} & h_{22} & \dots & \dots & \dots \\ . & . & \dots & \dots & \dots \\ . & . & \dots & \dots & \dots \\ h_{1M} & h_{2M} & \dots & \dots & h_{MM} \end{bmatrix} \qquad (2)$$

Where h_{ji} is the coefficients of the complex gaussian channel, allowing to modulate the gain in a system with fading between the i^{th} transmitting antenna and the receiving j^{th} ème antenna.

2.1 MIMO capacity

The MIMO capacity can be found with two different ways, ergodic capacity or outage capacity. In this paper we chose to work with the ergodic capacity in the fading channel with a noisy power and without channel state information, it is expressed as following:

$$C = E\left\{log_2 det(I_{Nr} + \frac{\rho}{Nt} HH^H)\right\} \quad (3)$$

Where:

- C: is the ergodic capacity;
- INr :is the identity matrix depending on the number of antennas at the receiver side;
- $\frac{\rho}{Nt}$: is the signal to noise ratio define also as SNR;
- H: is the matrix channel.

The capacity can be enhanced by a different use of the matrix channel H, in our case we proposed to insert the pre-coding and the post-coding method. This technic can only be realized from the decomposition of the matrix channel.

2.2 Decomposition methods

The decomposition of the channel is a crucial step which can provide us the necessary part that we can work with to improve the capacity. Surely there is various decomposition methods as singular value decomposition (SVD), geometric mean decomposition (GMD), LU, QR and others.

In the previous study we compared those methods and we found that the SVD technique gives good result, which is why we chose to work with the SVD decomposition. [1]

The mean role of SVD decomposition is to subdivide the MIMO channel into several parallel sub channel SISO, and also provide a diagonalizable MIMO channel.

The SVD decomposition can be applied in the MIMO equation (1), where H can be written as:

$$H = UDV^H \quad (4)$$

U and V are unitary matrix and D is a diagonal one. The decomposition of the signal is given by:

$$\Sigma = U^H(UDV^H)V,$$
$$\tilde{n} = U^H n, \tilde{x} = Vx, \tilde{y} = U^H y \quad (5)$$

These equations above (5) lead as to a different writing of (1) which is:

$$\tilde{y} = \Sigma\tilde{x} + \tilde{n} \quad (6)$$

With this final writing (6) we can use the pre and post-coding algorithm to the MIMO system.

3 SEARCH ALGORITHMS

By definition, the search algorithm is a type of algorithm that is based on a criterion set applied to solve a problem, and obtaining suitable results.

In this paper we create three algorithms based on MIMO system (8×8) with a fading channel with noise power, decomposed with SVD decomposition and with no CSI. From this prospective we insert the pre and post coding matrix into the system with the mean factor of being strictly positive.

To evaluate the effect of our search algorithms in the ability to improve the ergodic capacity we decided to compered with the two knowing technique ZF and MMSE

3.1 Pre and post-coding technique

Before treating the pre and post-coding technique we must know where they stand in the transmission chain of MIMO system. The figure below explain it clearly.

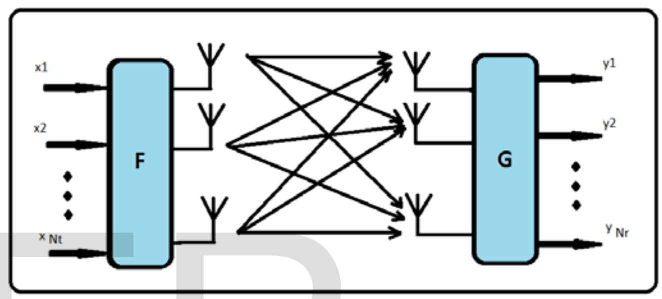

Fig.2. MIMO system with pre and post-coding [3]

Even with the new model, we are defiantly working with the SVD decomposition applied to the first equation (1) which remain the same.

The next step would be to insert the pre and the post-coding matrix referring to the two blocks above F and G.

$$y = GHFx + Gn \quad (7)$$

As knowing the capacity would only need the channel matrix (H) to be executed, in this case we will work with the equivalence channel matrix (Heq) instead of the regular matrix H, which given by:

$$Heq = GHF \quad (8)$$

3.2 The search algorithm

In this study we worked with the same search algorithms using in [1], the only different is, that they are applied in two different channel: fading channel as reference [1] and fading channel with noise power.

In both cases we are looking for ways to improve the capacity of the processed system.

These algorithms are:

- Algorithm based on additional matrix given by the SVD decomposition
- Algorithm based on a diagonal matrix given also with the SVD decomposition
- Algorithm based on the inversion of matrix also given by the SVD decomposition.

3.3 Evaluation technique

Zero Forcing: it is a simple receiver that is based on the inversion of the matrix H of the channel. it is necessary that H is square and invertible[2], it is represented by:

$$S = (H^H H))^{-1} H^H \quad (9)$$

If the matrix H of the channel is a complex matrix, the transpose becomes Hermitian [2] as:

$$S = (H^H H)^{-1} H^H y = H^{\dagger} y \quad (10)$$

Minimum Mean Square Error: it is a receiver that minimizes the overall error due to the noise contribution and mutual interference signals which makes it more resistant to noises, but does not perfectly separate the sub-channels [2].
The MMSE is a linear receiver it can be writing as:

$$S = X^H y \quad (11)$$

So the MMSE expression is giving by:

$$S = (H^H H + \frac{n_T}{\rho} I_{nR})^{-1} H^H y \quad (12)$$

4 SIMULATION AND RESULTS

This research is precisely done to obtain the search algorithm which can enhance the MIMO capacity. Therefor we divide this work into three section.

- The first one contained a comparative study between MIMO capacity over Rayleigh fading channel and Rayleigh fading channel with noise power.
- The second one treated the capacity of MIMO channel using the three algorithm of search only for the fading channel with noise power.
- The last one evaluate the performance of our search algorithms with ZF and MMSE techniques.

For each result, a comparative study is done based on the fading channel with and without noise power.

4.1 First study

As said before in this section we compared the capacity of MIMO system with and without noise power. The noise power is insert at the transmitter side.

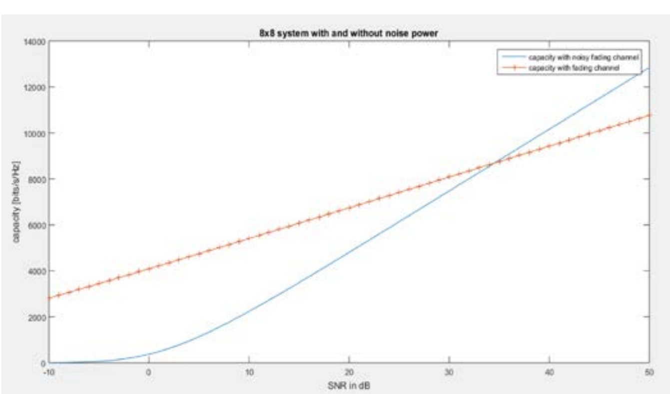

Fig.3. MIMO capacity for fading channel with and without noise power

For a SNR ranging between -10dB and 50 dB the capacity was treated over 8X8 MIMO system. The results are displayed above.

First of all, we can see that the capacity for both channel are increased with the ratio signal to noise (SNR).

As we can notice, the two curves of the capacity are not similar, this amounts to power noise applied at the transmitted side, this makes the MIMO system (fading channel with noise power) more powerful compared to the reference (fading channel). For instances, with 50 dB of SNR we obtained better capacity. It proves that with a large SNR the useful signal became most important than the noise.

4.2 Second study

In this part, the capacity of the three research algorithm are treated over a Rayleigh fading channel with noise power, than compared with capacity without any coding.
The Same interval of SNR is applied here.

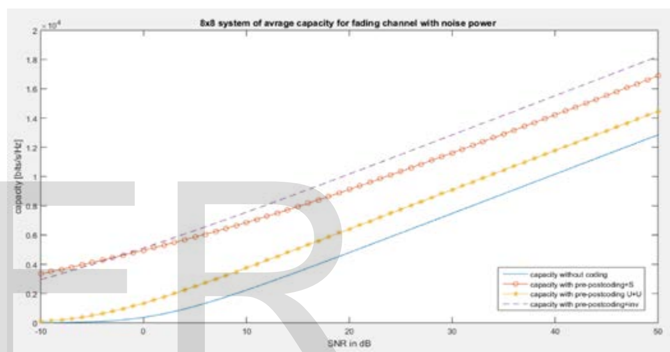

Fig.4. MIMO capacity using the search algorithms

At first sight we can see that there is an improvement of capacity with the three search algorithms, moreover the capacity is actually increased with the ratio signal to noise.

The MIMO capacity with no coding is used as reference. As we can notice, it provides the lowest value of the capacity next to the others curves matches with search algorithms.

First improvement was made by the capacity using the algorithm based on additional matrix, otherwise it remains low face of the other capacities.

The second improvement of the capacity was made by using the algorithm based on a diagonal matrix, it is better than the first one but still under achieving the enhancement we are looking for.

On the other hand, the third algorithm that relies on the inversion of matrix had a good result, it overachieved the others algorithms.

The following table will give us the improvement in numbers and percentages that have been done with these algorithms for a SNR of 50dB:

TABLE I. THE IMPROVEMENT OF THE CAPACITY OF MIMO SYSTEM USING THE 3 SEARCH ALGORITHM

	MIMO system with no coding	*First Algorithm*	*Second Algorithm*	*Third Algorithm*
Capacity [bits/s/Hz]	12825	14441	16477	17995
The improvement %	-	12%	28%	40%

For an SNR of 50 dB we proved the enhancement done by the pre and post-coding matrix given by the three search algorithms, therefor these values will be compared with a MIMO system over fading channel without a noise power found in [1].

TABLE II. THE IMPROVEMENT OF THE CAPACITY OF TWO TYPE OF CHANNEL

	First Algorithm	*Second Algorithm*	*Third Algorithm*
Capacity of Fading channel without noise power %	14%	38%	48%
Capacity of fading channel with noise power %	12%	28%	40%

Looking at the table above, we can see the improvement that search algorithms have reached in MIMO system with different percentages, moreover, we can also notice that the percentage of fading channel is slightly improved over the fading channel with noise power which is perfectly natural, due to the noise presence in the power transmission.

4.3 Third study

The performance of the results found beforehand are evaluated by two techniques ZF and MMSE.

In the figure below, only the third algorithm is evaluated for giving the best result. First it is evaluated with the ZF then evaluated with the MMSE.

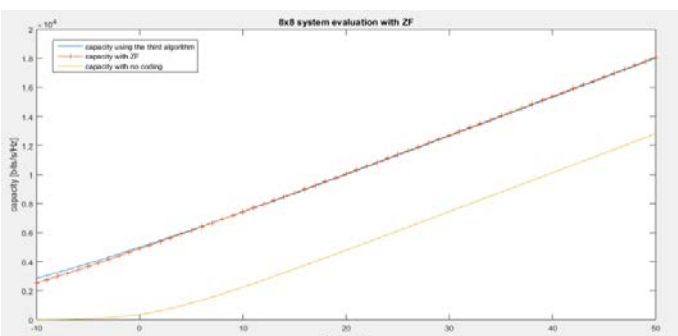

Fig.5. evaluation of MIMO capacity of the third search algorithms with ZF

The zero forcing technique and the third search algorithm have an almost identical curve of capacity, which proves that our pre and post-coding system is actually effective for the use of enhancement of the MIMO capacity.

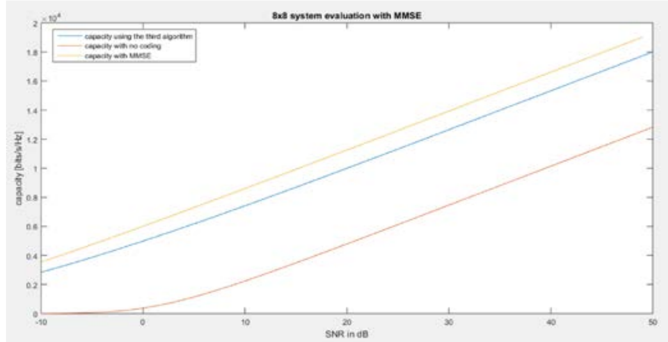

Fig.5. evaluation of MIMO capacity of the third search algorithms with MMSE

On the other hand, the minimum mean square error does not accord with the ZF which is logical, since it is always more efficient. But still the performance of the capacity using our research algorithm has proven the effectiveness for multiple application of the MIMO system.

5 CONCLUSION

The study established in this paper has allowed us to enhance the capacity of the Rayleigh fading channel with and without noise power applied on the transmitted side without CSI.

The three search algorithms achieved their role and were more than satisfied with what overcame the improvement of the capacity in the MIMO system.

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