Study of Fading MIMO Framework for Capacity Enhancement

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Abstract:
A proficient strategy to expand the channel limit of MIMO framework in the event of pragmatic fading channel has been intended for productive information transmission. Beneath practical fading environment, transmitted signal endures magnitude and phase disintegration. Consequently it gets to be basic to evade the impact of blurring in any correspondence channel and to make a proficient framework. Rayleigh blurring is considered and a correlation is being made among BPSK, QPSK and 16 QAM tweak system in Rayleigh blurring environment. A productive model is made in which information transmission can occur with slightest fading impact. Additionally channel limit of MIMO framework relies on number of half wave dipole antenna used in antenna array. At lower SNR values capacity increases directly and channel matrix coefficients are examined to provide an optimised channel. There are various other components which practically decide the overall channel capacity of MIMO framework like number of antenna components at both transmitting and receiving side, power input of an antenna, channel matrix coefficients and so on. In our proposed framework it is demonstrated that as number of antenna components increments there is huge expansion in channel limit.

Keywords: Multiple input multiple output (MIMO), MIMO capacity, Rayleigh fading, Antenna array

I. INTRODUCTION

The greatest challenge in the wireless technology is to beat the effect of Rayleigh fading. The multipath way of the channel prompts inter symbol interference (ISI) and as the data transmission involved expansions, the ISI becomes large. To adapt to this issue of multipath channel, different strategies for system modelling have been and consistently are being proposed by the analysts. MIMO is one of the generally utilized techniques. MIMO innovation has developed into a practical data transmission method which can evade the impact of fading up to certain percent. MIMO technology includes various antennas for information transmission at both transmitting and receiving side. MIMO innovation has pulled in consideration in wireless communication, since it offers critical expansions in information throughput and connection range without any increase in bandwidth and transmission power. It accomplishes this objective by spreading the same aggregate transmitting power over the antennas to accomplish an array gain that enhances the spectral efficiency (more bits every second per hertz of data transmission) and/or diversity gain up that enhances the reliability of the link ie. it decreases fading effect. Due to these properties, MIMO is a vital technique in our present day wireless communication standard for example, IEEE 802.11 b (Wi-Fi). MIMO framework has vast potential for maximization of channel limit and it can perform productively under different fading channels. Yet, there are numerous practical hardships to achieve an effective MIMO framework. So there is a need to enhance the channel capacity of MIMO system and attempt to figure the methods to decrease impact of Rayleigh and other fadings [1].

II. CHANNEL MODELLING OF MIMO SYSTEM

A MIMO channel model comprise of an array of antennas at both transmitting and receiving end.

Following parameters are considered in our model

No. of Transmitting Antenna = L

No. of Receiving Antenna = N

Power emanated by single transmitting antenna= PS (irrespective of estimation of L).

Average Power at output of every receiving antenna = S

Noise at receiver is unpredictable N dimensional AWGN with statistically independent power Sn in each of the N receiving antennas.

The channel matrix H is Rayleigh distributed with complex, zero mean and unit difference [2].

$$C = \frac{1}{2} \log_2(\det(I_n + \frac{SNR}{L}HH^H))$$  \[1\]

Where H is the channel matrix

SNR is the signal to noise ratio L is the no. Of transmitting antenna

$$HH^H$$ is the Hermition Transpose of matrix H

$$I_n$$ is the n x n identity matrix.

For the given MIMO channel model given, utilizing the estimation of general channel matrix, the channel capacity of a MIMO system is expressed as an element of channel array geometry of both receiver and transmitter. The effect of antenna array geometry is demonstrated as an expression of the channel capacity by making its matrix as a function of array manifold vector. In our model channel matrix is function of number of antenna elements in an array and the spacing between the antenna elements. The channel at time t is displayed by an nRxnT network.
At time t transmitted signal vector can be represented as

\[ \text{St} = \text{W[A]} \times \text{X[B]} \times t \]  

where \( \text{St} \) is the transmitted vector, \( \text{A} \) is the shaft shaping vector, and \( \text{B} \) is the encoded sequence in channel. The channel matrix here depends upon the structure of the antenna array (no. of elements) and the spacing within the antenna elements.

\[ H_t = \begin{bmatrix} H_{t11} & \ldots & H_{t1n} \\ \vdots & \ddots & \vdots \\ H_{tn1} & \ldots & H_{tnnt} \end{bmatrix} \]  

Where \( H_{tij} \) is the channel fading coefficient from the transmitting antenna \( i \) to the receiving antenna \( j \) at time \( t \).

\[ r_t = H_t(s_t + n_t) = w_t x_t + n_t \]  

where \( r_t \) indicates the signal got by the recipient antenna at time \( t \).

In multiple number of local multipaths the received signals from different transmitters follow different paths to reach the destination but due to Rayleigh fading interference occurs at the receiver because signals from different multipaths superimpose over a dominant signal at the time of their travel and causes interference.

### III. ATENNA ELEMENTS versus CHANNEL CAPACITY

According to Gauss–Markov Model channel capacity of a MIMO framework is given by

\[ C = \frac{1}{2} \log_2(\text{det}(I_n + SNR H^H)) \]  

and Gauss–Markov equation can also be written as

\[ C = x + \log(1+\log(1+\text{SNR})) \]  

where \( x \) is an asymptotic parameter.

Equation 6 clearly indicates that there will be increase in channel capacity of MIMO system with a increase in SNR value. In this paper three systems are designed to obtain channel capacity results according to Shannon Hartley theorem and MIMO system. MIMO system have the capability to obtain higher channel capacity more than what theoretical given by Shannon Hartley theorem [4].

![Figure 1. Block diagram of a communication system](image1)

At low values of SNR capacity linearly increases whereas at high values of SNR capacity increases logarithmically.

#### 3.1 Antenna array of 8 elements

For an antenna array of 8 elements different values of SNR are applied in equation 3.3 and a curve is obtained as shown in figure 3.

![Figure 2. Plot of Gauss Markov capacity equation showing capacity variation versus SNR](image2)

It is found that MIMO system channel capacity is 22.5bits/Hz at SNR value of 10dB whereas theoretical capacity given by Shannon Hartley theorem is 4bits/Hz. This figure additionally gives data with respect to capacity at low SNR and high SNR. At low SNR values capacity increases directly with SNR values, however at high SNR values capacity increases logarithmically with SNR values. It is also clear that there is huge difference between Shannon’s limit and MIMO system.
framework. SISO framework channel limit may concur with Shannon’s hypothesis results [5][6].

3.2 Antenna array of 16 elements

For antenna array of 16 elements a curve is also obtained by using equation 5. This curve is obtained between channel capacity and SNR values as shown in figure 4.

![Figure 4](image1.png)

**Figure 4. Plot showing channel capacity of MIMO system and Shannon capacity for 16 antenna elements**

In this curve a comparison is also made between the channel capacity values of practical MIMO system and frivolous system.

3.3 Antenna array of 32 elements

For antenna array of 32 elements a curve is also obtained by using equation 5. This curve is obtained between channel capacity and SNR values as shown in figure 5.

![Figure 5](image2.png)

**Figure 5: Plot showing channel capacity of MIMO system and Shannon capacity for 32 antenna elements**

3.4 Comparison of various antenna elements

Comparing fig 3, fig 4 and fig 5 it can be concluded that as there is increase in antenna elements there is stark increment in the channel capacity of MIMO system. In comparison to the channel capacity of Shannon’s, it turn out to be clear that MIMO system utilizes such procedures which builds capacity when contrasted with hypothetical values. For better comparison of channel capacity of different antenna elements, above three figures are plotted in one figure demonstrating the impact of SNR, channel capacity and number of antenna elements inserted in an antenna array.

![Figure 6](image3.png)

**Figure 6. comparisons of various antenna arrays with Shannon maximum capacity**

From the Figure 6 it is clear that in order to obtain maximum capacity for a MIMO system the number of antennas required at both transmitter and receiver should be maximum.

<table>
<thead>
<tr>
<th>SNR in dB</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(bits/s/Hz)</td>
<td>8 antenna elements</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td>(bits/s/Hz)</td>
<td>16 antenna elements</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>53</td>
<td>61</td>
</tr>
<tr>
<td>(bits/s/Hz)</td>
<td>32 antenna elements</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>110</td>
</tr>
</tbody>
</table>

**Table 1. Table Channel capacity for SNR values for different antenna array**
Table 1 clearly presents the point results for the channel capacity of a MIMO system where three antenna arrays of 8, 16 and 32 half wave dipoles are considered in this paper. In the case of 32 half wave dipoles antenna capacity at SNR value of 2dB is found to be 34bits/s/Hz which increases to 90bits/s/Hz at SNR value of 10dB and reaches to 148bits/s/Hz at SNR value of 16 dB.

IV. CONCLUSION

In this paper we successfully demonstrated the capacity enhancement of MIMO system for different fading (Rayleigh) channels and we also presented a practical model whose capacity is much higher than the theoretical model in different fading environment. It is observed from the results obtained that channel capacity of MIMO system depends upon signal to noise ratio of the transmitted signal and number of antenna elements in an antenna array. At low values of SNR the increase in the capacity is linear whereas at high SNR it becomes logarithmic. Also increasing the half wave dipoles in an antenna array linearly increases the channel capacity. BPSK modulation technique comes out to be more efficient in Rayleigh. Among Rayleigh, Gaussian and AWGN channel, Rayleigh is the worst case fading. Hence multiple antenna increases channel capacity.

V. REFERENCES


