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Performance Enhancement of MIMO Channel Capacity for Antenna Selection using SVD-Water Filling Technique

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Abstract: Nowadays MIMO systems have been widely studied for wireless communication. MIMO technology in combination with OFDM is an attractive solution for providing high data rates with reduced errors and high QOS. It can be thought of as a combination of modulation and multiple access schemes that segment a communication channel in such a way that many users can share it. This requires Antenna arrays at the transmitter and receiver to enhance the system capacity on frequency selective channels resulting in a Multiple Input Multiple Output (MIMO) configuration. As there are several antennas at receiver and transmitter, MIMO systems can be employed for diversity. This spatial multiplexing method transmits several parallel information streams at same transmit power. A number of design trade-offs must be considered when developing an OFDM based system. This paper explores MIMO system model, MIMO receivers, SVD of MIMO channel and system capacity, Beam forming techniques, method of MIMO system design including physical channel measurements, space time coding techniques, frequency synchronization, and finally types of distortions in Shannon capacity technique and possible remedies to avoid those distortions.

Keywords: MIMO, Water Pouring, SVD, AST

I. INTRODUCTION

Over the last decade, the massive demand for high data-rate wireless applications has motivated the study and design of new communication technologies. Among all of them, multi-antenna Schemes have been shown to provide remarkable benefits in terms of spectral efficiency. In order to achieve channel capacity bounds, some sort of pre-processing on the transmit side must be encompassed. Unless reciprocity between the forward and reverse links can be assumed, a feedback channel is required to convey channel state information. In such a context, transmit antenna selection emerges as an effective alternative requiring a low amount of information in the feedback channel. The objective of this paper is to improve channel estimation accuracy in MIMO-OFDM system because channel state information is required for signal detection at receiver and its accuracy affects the overall performance of system and it is essential for reliable communication. MIMO-OFDM system is choose in this paper because, it has been widely used today due to its high data rate, channel capacity and its adequate performance in frequency selective fading channels. For this purpose a 2×2 system designs and by using LMS, LLMS algorithm to reduce the Leaky factor and enhance BER performance.

II. PROBLEM STATEMENT

The simplest idea for antenna selection in MIMO-systemsis extensive search (ES). It investigates all possible MIMO system.

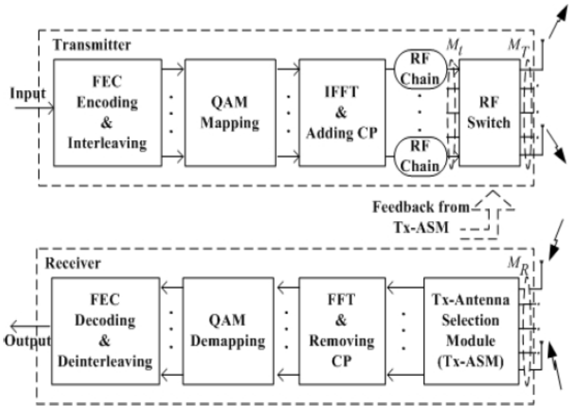

Figure 1.1 Block diagram of the transmit antenna selection

$\binom{MT}{Mt}$transmit antenna subsets to estimate the ergodic capacityusing (5) so as to obtain the maximum. However, becauseof singular value decomposition (SVD) computations, thiscapacity based selection criteria results in high complexity(O(NM2RMt)). Hence, it is usually substituted by a normbasedselection criteria [5]. The norm criteria has low complexity(O(NMRMt)). But, even though employing this criterion,the antenna selection with ES algorithm is still not suitablefor practical systems due to its high computational complexity. Thus, a low complexity transmit antenna subset selectionalgorithm is required for a practical implementation.

III. SYSTEM MODEL

Fig. 1 shows a MIMO-OFDM system with MT transmit andMR receive antennas over an L-tap frequency selective channel.

Let hl be an MR x MT matrix, which denotes the channelresponse matrix in time domain of the l-th significant delayed path, for l = f0; : : : ;L ¡ 1g. Assume that hlis an uncorrelated channel matrix whose entries hl (mr;mt) follow the independently and identically distributed (i.i.d.) complex Gaussiandistribution CN(0; 1).

The channel frequency responsematrix of the n^{th} subcarrier for our N-tone MIMO-OFDMsystem can be described using another MR x MT matrix Hn:

$$\mathrm{Hn} = \sum_{l=0}^{L-1} \mathrm{hl} e^{-j2\pi nl/N} (1)$$

Therefore, the received signal for the n-th subcarrier atthe receiver is:

$$r_n = \mathrm{HnSn} + \mathrm{Vn}\ (2)$$

where snis the transmitted data for the n^{th}subcarrier, andvn ~ CN(0, IMR) is additive white Gaussian noise satisfying $\varepsilon\{\mathrm{VnV}^{H}{}_{n'}\}$= IMRδ[n-n’]Here, ε{•}and $\{\bullet\}^{H}$standfor the statistical expectation and the Hermitian operation, respectively.We further assume that perfect channel state information(CSI) is available at the receiver but not at the transmitter.

Additionally, the total available power is assumed tobe allocated uniformly across all space-frequency sub-channels[7]. So, the mutual information of the N-tone MIMO-OFDMsystem is:

$$c = \frac{1}{N}\sum_{n=0}^{N-1} \log[\det(I_{MR} + \frac{\rho}{M_T} \mathrm{Hn}\, H_n^H)]\ (3)$$

Where N is the total number of OFDM subcarriers, ½ is theSNR per subcarrier. Det(.) and IMR denote the determinantoperation and theMRxMR identity matrix, respectively. Theergodic capacity of this system is [7]:

$$C = \varepsilon\{c\}\ (4)$$

In the selection based MIMO-OFDM system, only a subset oftransmit antennas Mt (Mt ≤ MT) are used at each time slot.

We assume that the antenna subset index is sent back to thetransmitter from the receiver through an error free and delayfree feedback channel. The ergodic capacity associated withantenna selection is modified as:

$$\mathrm{Csel}\ (\mathrm{wq}) =$$

$$\varepsilon\{\frac{1}{N}\sum_{n=0}^{N-1} \log[\det(I_{MR} + \frac{\rho}{M_T} [\mathrm{Hn}]\mathrm{wq}\ [H_n^H\ ]\mathrm{wq})]\}(5)$$

Where [Hn]wq∈ C^{MRxM}tdenotes the channel frequency responsematrix of the n^{th} subcarrier after selection. Here, wqis the indicator of the selected subset of the transmit antennasand can be defined by

$$\mathrm{wq}=\{\mathrm{Ii}\}_{i=1}^{MT},\ \{I_i\}\in\{0,1\};\ q=1,2\ ,\ldots\ldots\ldots Q.(6)$$

Wherei is the index of the columns of Hnand the indicatorfunction Ii indicates whether the i^{th} column of Hn(the i^{th}transmit antenna) is selected. Q is the number of all possibleantenna subsets and can be defined by Q $=\binom{MT}{Mt}$. Thus (2) can be modified as

$$[\mathrm{rn}]\mathrm{wq}= [\mathrm{Hn}]\mathrm{wq}[\mathrm{sn}]\mathrm{wq}+ [\mathrm{vn}]\mathrm{wq}(7)$$

Where, [rn]wq∈ C^{MRx1}, [sn]wq∈ C^{Mtx1} and [vn]wq∈C^{MRx1} denote the received data, transmitted data and theAWGN noise for the n^{th} subcarrier associated with the selection,respectively.

MIMO COMMUNICATION SYSTEMS WITH SVD

A MIMO wireless system is a communication link where both the transmitter and the receiver are equipped with multiple antennas.

In Fig.1 2, we show a typical MIMO wireless system with M transmits antennas and N receives antennas. Usually, the MIMO signal model is represented in matrix form as follows:

$$r = Hs + n$$

where r ∈ $C^{N\times1}$ is the received signal vector, H ∈ C N×M is the channel matrix whose elements are the channel responses between each pair of antennas, s ∈ $C^{M\times1}$ denotes the transmitted symbols and n ∈ $C^{N\times1}$ stands for an additive Gaussian noise vector of complex, random variables with zero mean and unit variance, n ∼ CN (0, IN).

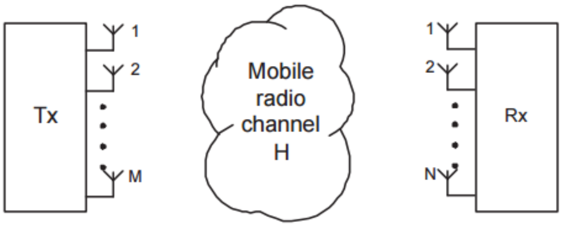

Figure 1.2: Block diagram of a MIMO wireless system

We define ¯γ as the received SNR at any receive antenna and, due to the noise normalization, it is equal to the total transmit power at the transmitter.

Concerning CSI, it is commonly assumed perfectly known at the receiver (this can be easily arranged by training), whereas different considerations are adopted for the knowledge at the transmit side.

We start by considering the case where CSI is completely known at the transmitter. In this case, the transmitter configuration can be adapted to all the channel realizations. The mutual information between vectors s and r conditioned on H and expressed in terms of bits/s/Hz is given by:

$$I(s; r) = \log 2 \det (IN + HQH^{H})$$

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IV. PROPOSED IMPLEMENTATION

Proposed algorithm

Based on the theoretical assumptions, we haveconstructed the following algorithms (later converted as mfiles).

The first algorithm depicts receive diversity techniquewith MRC under Rayleigh fading channel.

The working procedure for the same is as follows:

1. Start.
2. Assume No of frames, No of Packets, set Digital Modulation method as QPSK and SNR limit in db.
3. For first iteration, assume No of Transmit and Receiveantennas as NT= NR=1.
4. For further iterations, let the Numbers of Tx/Rxantennas are either NT=1, NR=2 or NT=1, NR=4 andobtaining a parameter sq_NT= sqrt (NT).
5. From SNR in dB, each packet, L, No of frames, obtain Sigma as sigma=sqrt (0.5/(10^(SNR_dB/10)
6. Channel matrix H can be constructed from framelength, NR
7. For i=1:NRthen autocorrelation factor R is calculatedwith respect to number of iterations (i) as R (i) = sum (H(i))/sq_NT + sigma*(randn (L_frame,1)
8. The noise vector Z is calculated as Z = Z + R(i).*conj(H(i))
9. Plot SNR Vs BER.
10. Stop.

Similarly the working procedure for optimal antenna selection in MIMO system is as follows;

1. Start.
2. Select transmit/ Receive antennas as NT= NR=4; 3.
3. Calculate I=eye (NR, NR)
4. Assume SNR range SNR dBs.
5. Assume Q as antenna selection factor (sel_ant) from1to 4 and determine the length of SNR_dBs.
6. For Individual antenna selection SNR is assumed asSNR_sel_ant = 10 ^ (SNR_dB /10) / Q.
7. Obtain H asH = (randn (NR,NT) + j*randn (NR,NT))/sqrt (2)
8. If Q > NT | Q < 1 thenDisplay as ‘sel_ant must be between 1 and NT !’
9. Determine capacity from H (n) factor and Select capacity for maximum iterations.
10. Plot (SNR_dBs, sel_capacity)

The sub-optimal selection working procedure is as follows;

1. Start.
2. Determine Number of antennas to select as sel_ant=2.
3. Assume 0/1 for increasingly/decreasingly ordered Selection
4. Assume Number of Tx / Rx antennas as NT=NR=4.
5. Obtain, I=eye (NR, NR).
6. From SNR range (SNR_dBs)SNR with selection antenna is given bySNR_dBs = 10 ^ (SNR_dB/10) / sel_ant;
7. Determine selection_antenna_indicesupto [1:NT]
8. Calculate Channel matrix (H) as H = (randn (NR,NT)+j*randn(NR,NT))/sqrt(2);9. If sel_method==0 then, assume increasingly ordered Selection method.
10. For current_sel_ant_number =1:sel_antobtain H(n) aslog_SH(n) = log2(real(det(I+SNR_sel_ant*Hn*Hn’)))
11. The maximum capacity is depicted as Maximum capacity = max (log_SH);
12. With the help of selected antenna index andCurrent_del_ant_number determine increasing order Maximum capacity with n+1=Q antennas else repeatthe same procedure for decreasingly ordered selectionmethod with n-1=Q and determine maximum capacity
13. Plot SNR_dBVs capacity.

MIMO COMMUNICATION SYSTEMS WITH SVD AND WATER POURING METHOD PROCEDURE

1. Start
2. Received noisy data signal as a vector of length (2T)
3. Demodulated the data vector using PSK or AST-scheme
4. Determine logic state vectors (h’s) between the demodulated received symbols and the state table output data bits
5. Initializing time, t = K, at state 0.
6. After Initializing time, t = K, at state 0
7. Apply Water pouring Technique
8. SVD of the channel matrix HK.
9. Search 0 logic in h’s vector till no of subcarrier size
10. Store number of state node and order of determined zero logic state to detect the transmitted bit at this time instant
11. The transmitted bit x at this time instant, t= K , is detected
12. Match array of 8 × 8 antennas as a full rank Rxx&(Rimp),
13. If NO then move on step number 8.
14. If yes then move to next step.
15. Decrement time t=K-1& search about the zero logic state in the (h) vector location that have order the same as the state node number which is stored previously.
16. End

Parameter	**Values**
Transmitting Array	[1 2 3 2 5 4 3 5]
Receiving Array	[1 2 2 4 3 5 4 5]
N0(allocated signal power)	0.0001
Channel Model	Relaying fading channel
No of Iteration	1000
SNR	[-10:3:25]
Antenna Array	8x8 and 4x4

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V.RESULT

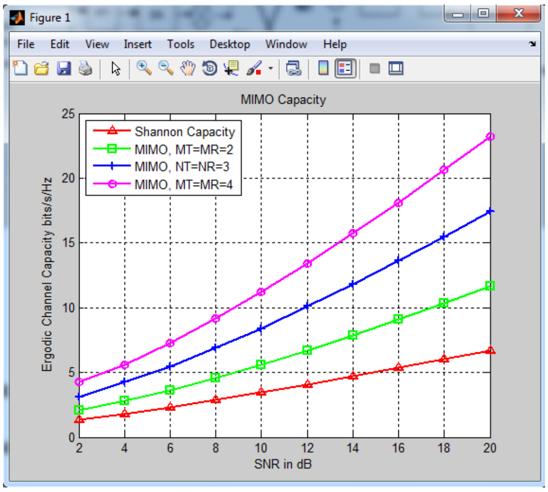

Figure 5.1: Ergodic channel Capacity vs SNR for the MIMO capacity

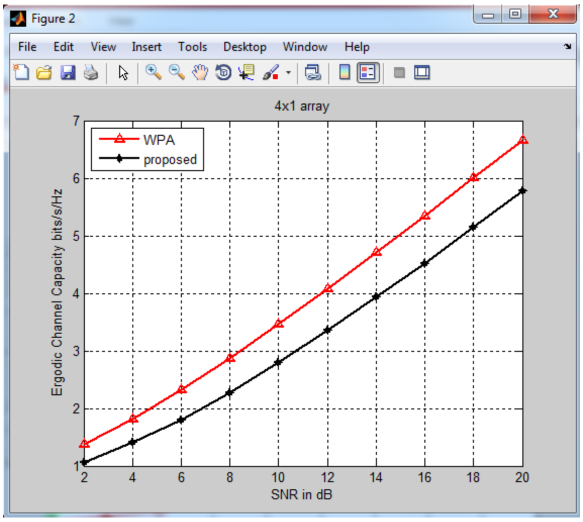

Figure 5.2: Ergodic channel Capacity vs SNR for the 4*1 array in WPA and Proposed systems

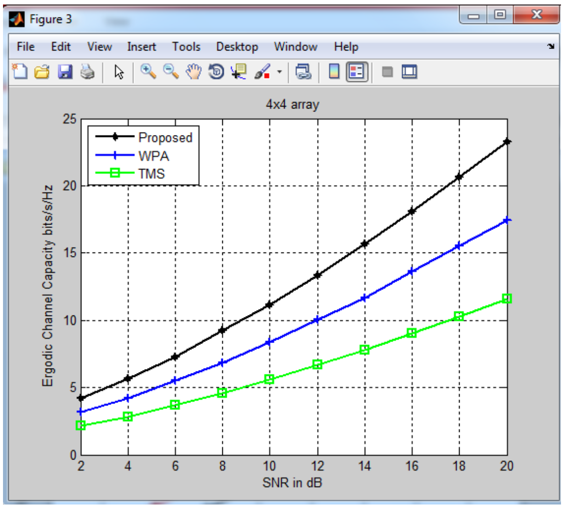

Figure 5.3: Ergodic channel Capacity vs SNR for the 4*4 array in TMS, WPA and Proposed systems

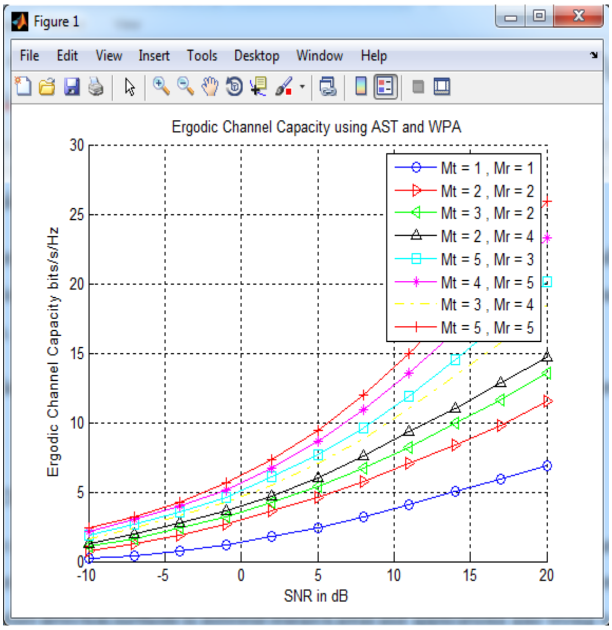

Figure 5.4: Ergodic channel Capacity vs SNR for the various MT transmit and MR receive antennas

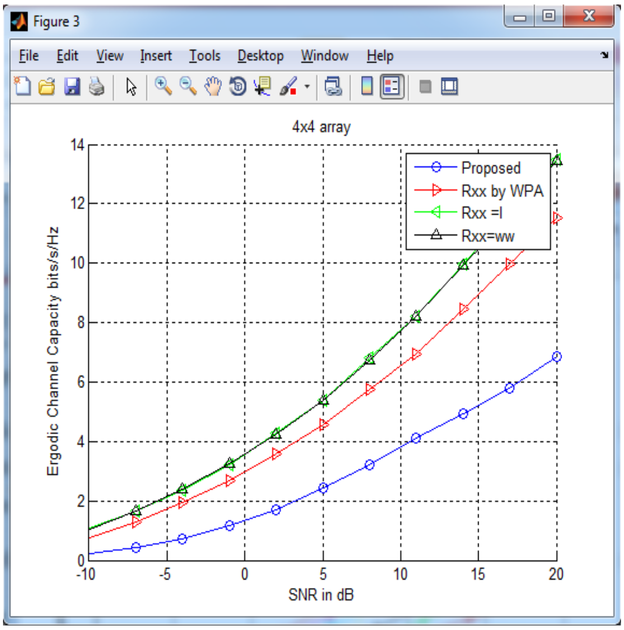

Figure 5.5: Ergodic channel Capacity vs SNR for the covariance Matrix

PARAMETERS	BASE PAPER VALUES[1]	PROPOSED VALUES
SNR	0-20dB	22dB-25dB
Bandwidth Efficiency	17bps/Hz	35.71bps/Hz
Antenna Array	4×4	Maximum (8×8)

Table 5.1 Comparison between Base Paper Values and Proposed Values

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VI. CONCLUSION

The performance of Multiple-input Multiple-output (MIMO) systems can be improved by employing a larger number of antennas than actually used or selected subset of antennas. Most of the existing antenna selection algorithms assume perfect channel knowledge and optimize criteria such as Shannon's capacity on bit error rates. The proposed work examines Antenna diversity and optimal/ sub optimal receive strategy in antenna selection. The numerical results for BER, Information capacity with SNR are obtained using mat lab.

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