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Iteration Based Low Complex Antenna Selection Algorithm for IEEE 802.16E Network

R. A. Yuvaraj[1] and L. Nithyanandan[2]

[1]*Department of Electronics and Communication Engineering, Christ College of Engineering and Technology, Puducherry, India.*
E-mail: rayuvaraj@gmail.com
[2]*Department of Electronics and Communication Engineering, Pondicherry Engineering College, Puducherry, India.*
E-mail: nithi@pec.edu

Abstract

In this paper, Iteration based low complex antenna selection algorithm is considered to enhance capacity of the MIMO MC CDMA system in IEEE 802.16e network. The MIMO MC CDMA system increases transmission reliability and supports high data rate. The demand for quality of service increases the cost of hardware and complexity of signal processing in large antenna array system. Iteration based receiver antenna selection (IBS) algorithm is proposed to select optimal antenna based on the knowledge of channel state information. IBS algorithm selects an antenna which receives less correlated signal with maximum signal interference noise ratio at first and subsequent antenna selection are based on the SNR value. Simulation results presented in this paper demonstrate that the proposed antenna selection algorithm reduces computation complexity and increases capacity with increase in diversity.

Keywords: MIMO, MC CDMA, WiMAX, Receiver Antenna Selection.

INTRODUCTION

In wireless communication, research interests are focused on providing high data rate multimedia service to meet the demand of growing multiuser high speed network. The strength of the transmitted signal is determined by fading which reduce signal to noise ratio (SNR). The diversity order at the receiver can improve signal strength by combating fading. The MIMO system offers a higher channel capacity, then a SISO system for the same total bandwidth and transmission power.

Increase in the number of antennas increases capacity linearly at the cost of hardware complexity. The signals are processed through radio frequency (RF) chains that are integrated with an amplifier and analog to digital convertor at each antenna. Combining these signals from a large number of antennas require a large number of RF chains that increase hardware cost of the system [1]. To overcome the increase in hardware cost and to reduce the computational complexity, an optimal iteration based antenna selection algorithm has been proposed. The chosen antenna subset reduces computation complexity by retaining the benefits of antenna diversity [2].

The benefits of antenna subset selection in MIMO system are realized over frequency selective fading channels [3]. In MIMO system the base station cannot handle multi user simultaneously, binary practical swarm optimization techniques is employed to overcome real time signal processing computational complexity. Low complex constrained receiver sub antenna selection algorithm based adaptive Markov chain Monte Carlo technique is considered to maximize ergodic channel capacity and to minimize system bit error rate in low frequency selective fading MIMO OFDM system [4].

Norm based transmit antenna selection (NBA-TAS) at the receiver is performed to select transmitter antenna using space frequency block encoder. The number of antennas that has to be selected is completely based on channel matrix norm values of the norm based approach (NBA). This in turn reduced the feedback information [5]. In multiple element antennas, optimal subset is selected with respect to channel fading realization. Here the effect of uncorrelated fading remains low in flat fading channel environment due to optimal selection process [6]. In MIMO-OFDM, interference alignment by constrained per subcarrier antenna selection is adopted to overcome power degradation.

A greedy strategy for allocating optimal antenna subset of the individual user is also adopted to reduce computational complexity [7]. Unlike transmit antenna selection; receiver antenna selection suffers from power loss due to antennas that are not selected for multiplexing that is based on power indices [8]. The selection diversity gain is achieved by opting best antennas from total available receiver antennas. Hybrid selection or reduced complex MIMO selection scheme increase capacity by using best antennas selected out of all antennas at one link end, while all other antennas are employed at another link end [9, 10].

A simple receiver antenna per subcarrier selection scheme is adopted to achieve diversity gain by selecting a target receiver antenna based on its correlation value [11]. QR decomposition based channel matrix is used to improve capacity with optimal selected antennas. This scheme derives low computational complexity when compared with Norm based search (NBS) and Multiple Element antenna (MEA). There is performance degradation in deriving capacity while using NBS scheme at high SNR as it depends on the random search procedure and channel matrix norm values [12]. A constructive interference driven antenna selection scheme is used to nullify destructive interference components of the channel by predicting co-channel interference (CCI) and optimizing CCI between the sub stream of PSK transmission in a MIMO system [13].

Suboptimal antennas are identified with norm values to determine the level of uncorrelation among selected antennas [14]. The Cross entropy theory was derived to maximize capacity over the spatial correlated fading channel. This near optimal Cross entropy optimization (CEO) algorithm results are not affected by SNR and the relationship between transmit antenna and selected optimal receive antenna [15].

Particle swarm optimization solves non convex integer programming characteristics that are due to discrete binary receiver antenna subset selection factor. Here the best antennas are selected by the nature of particle searching to maximize capacity [16, 17]. Average BER performance of MIMO OSTBC system employing Transmit Antenna Selection (TAS), receive antenna selection (RAS) and joint transmit and receive antenna selection (JTRAS) with two or more transmit antenna were analyzed by using moment generation function (MGF) based closed form SNR gain expression. M-ary quadrature amplitude modulation (M-QAM) and phase-shift keying (PSK) modulation transmission schemes were adopted to check the coding and diversity gain of the system. The diversity gains of the antennas are preserved over flat Rayleigh fading channels [18].

In [19], an enhanced decremental transmit suboptimal antenna selection algorithm is used for spatial multiplexing with zero forcing receivers in correlated Rayleigh fading channel. Transmit antenna selection algorithm employs channel scaling techniques to exploit channel gain by targeting minimum BER and fast suboptimal antenna selection algorithm is employed to minimize computational complexity.

The effect of Co channel interference and outdated channel information (OCI) are studied in [20] over Rayleigh distribution. A low complex decremental selection algorithm is used to achieve maximum channel capacity in the absence of channel state information at the transmitter side, as the diversity order of the full antenna system is equal to selected sub optimal antenna system at high SNR. This selection algorithm utilizes joint MMSE and V-BLAST architecture in MIMO spatial modulation system [2, 21].

In this paper, iteration based low complex receiver antenna selection algorithm is proposed for achieving optimal capacity of the system over Rayleigh fading channel in IEEE 802.16e. Iterative solutions for selecting optimal antenna are initiated with an empty set. Based on the SNR gain value, antennas that have higher contribution towards system capacity is selected first. The process is repeated to add the rest of the contributing antennas. It is assumed that channel state information is available on the transmitter side.

The rest of the paper is organized as follows. In section II MIMO MC CDMA system model is described. In Section III Iteration based antenna selection algorithm is described along with its computational complexity. In section IV discussion of simulation results was carried to validate the performance of the proposed algorithm with NBS and MEA selection procedure. Finally, in section V conclusion are drawn.

SYSTEM MODEL

Figure. 1 Shows MIMO MC CDMA system with antenna selector at receiver with transmit and receive antenna in the flat Rayleigh fading channel. The signal at receiver side is given by [2]

$$y = Hx + v \tag{1}$$

Where y is received signal vector $y = [y_1 .... y_{N_R}]^T \in \subset^{N_R \times 1}$ to the transmitted signal vector $x = [\mathrm{x}_1 ..... \mathrm{x}_{N_T}]^T \in \subset^{N_T \times 1}$ and v is independent and identical distributed entry with variance N_o and zero mean, i.e., $v \in \subset^{N_T \times 1}$ [18].

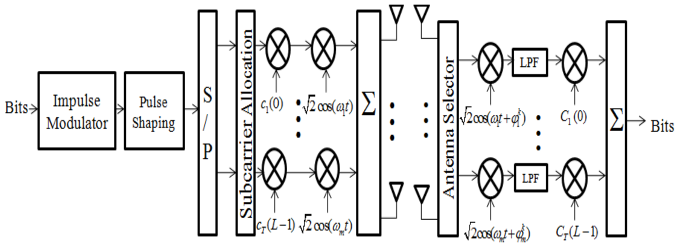

Figure 1: Receiver antenna selector in MIMO MC CDMA.

Let H denotes channel matrix with element $h_{j,i}$ $(j = 1.....N_R, i = 1.....N_T)$ are complex fading coefficient between j^{th} receive and i^{th} transmit antenna.

$$H = \begin{pmatrix} h_{1,1} & \cdots & h_{1,\mathrm{N}_T} \\ \vdots & \ddots & \vdots \\ h_{N_R,1} & \cdots & h_{N_R,N_T} \end{pmatrix} \tag{2}$$

The impulse response for k^{th} tap channel matrix can be written as [21]

$$H_\tau = \sum_{k=0}^{k-1} H_k \delta(\tau - k) \tag{3}$$

Where H_k is uncorrelated, $h_k(n_r, n_t)$ or $\sum_{k=0}^{k-1} N_o = 1$ for $n_r = 1.....N_R$ and $n_t = 1.....N_T$. $\delta(.)$ is the kronecker delta function. The uncorrelated channel frequency response matrix for n^{th} sub channel is given by

$$\boldsymbol{H}_n = \sum_{k=0}^{k-1} \boldsymbol{H}_k e^{-j\pi nk/(0.5N)} \tag{4}$$

For each time slot, only a set of selected receive antennas is considered for computation. The function indicating optimal selected receiver antenna L_r is given by

$$W_z = \{A_j\}_{j=1}^{L_r}, \{A_j\} \in \{0,1\}; \ z = 1,2,....,Z \quad (5)$$

Where j is index of rows of H_n and A_j is j^{th} row of H_n selected. Hence, after selecting an optimal antenna, the received signal is given by

$$[y]_{W_z} = [\mathrm{H}_n]_{W_z} x_n + [v]_{W_z} \quad (6)$$

Where $[y]_{W_z} \in \subset^{L_r \times 1}$ & $[\mathrm{H}_n]_{W_z} \in \subset^{L_r \times N_T}$ denotes the data received and channel response matrix for selected antennas. $[\mathrm{x}_n]_{W_z} \in \subset^{N_T \times 1}$ denote the transmitted data and $Z = \binom{N_R}{L_r}$ gives all possible optimal set of antennas selected set.

The capacity of the system with optimum selected antenna can be obtained by [22, 23]

$$C_S(W_z) = \varepsilon\{C_{oS}(W_z)\} \quad (7)$$

$$C_{OS}(W_z) = \frac{1}{(N/2)} \sum_{n=1}^{N} \log_2(\det(I_{L_r} + \frac{\rho}{N_T}[\mathrm{H}_n]_{W_z}[\mathrm{H}_n]^H{}_{W_z})) \quad (8)$$

N is the total number of subcarrier, ρ is SNR per subcarrier and I_{N_r} is $N_r \times N_r$ identity matrix.

The gain and SNR of the received signal is obtained from [18]

$$\gamma = \frac{\gamma_s}{N_T R_{cr}} \sum_{j=1}^{N_R} \sum_{i=1}^{N_T} |hj,i|^2 \quad (9)$$

Where $\gamma_s = \frac{E_b}{N_0}$ is average SNR receiving antenna, E_b is bit energy at the transmitter, N_0 is complex additive white Gaussian noise and R_{cr} is code rate.

The received SNR for the selected antenna at the receiver is given by

$$\gamma_{RAS} = \frac{\gamma_s}{N_T R_{cr}} \sum_{j=1}^{Lr} \sum_{i=1}^{N_T} |hj,i|^2 \quad (10)$$

Where $h_{j,i}$ is the selected channel response matrix and L_r is number of optimal selected antenna at the receiver.

Hence the gain of receiving optimal antenna is given by

$$g_{RAS} = \frac{1}{N_T N_r} \sum_{j=1}^{Lr} \sum_{i=1}^{N_T} |hj,i|^2 \quad (11)$$

The BER expression for MIMO MCCDMA system employing receiver antenna selection is given by [24]

For M-QAM

$$BER_{QAM} = \frac{4}{\beta}(1 - \frac{1}{2^{(\beta/2)}})\,\mathrm{Q}(\sqrt{\frac{3\gamma_s \sum_{j=1}^{Lr}\sum_{i=1}^{N_T}|hj,i|^2}{N_T R_{cr}(2^{(\beta/2)} - 1)}} \quad (12)$$

For MPSK

$$BER_{PSK} = \frac{2}{\beta}\,\mathrm{Q}(\sqrt{\frac{2\gamma_s \sin^2(\frac{\pi}{2^{(\beta/2)}})(\sum_{j=1}^{Lr}\sum_{i=1}^{N_T}|hj,i|^2)}{N_T R_{cr}}} \quad (13)$$

Where $\beta = \log_2(M)$, is a bit per symbol.

Iteration based receiver antenna selection (IBS) algorithm

In a practical scenario, computational complexity of determining maximum channel capacity is high due to exhaustive search that includes a complete antenna array. This degrades the system performance and reduces the efficiency of the antennas. Faster and less complex computation algorithm is required to analyze the data that result to maximize the system capacity without affecting the overall efficiency. Here a complete set of transmitting antennas are considered. At the receiver, L_r out of N_R receiving antennas are considered. The total number of optimal receiving antenna subset is equal to $\binom{N_r}{L_r}$.

IBS algorithm shown in Figure.2 selects the optimal antenna from the received signal through the switch. Based on the norm of channel matrix, antenna subset selections are based on ranking order. Initially IBS algorithm is with an empty set, at each step of iteration, an optimal antenna with high SNR is allowed to contribute to the system capacity maximization. The process is repeated and the following contributing antennas were added in descending order with respect to SNR value.

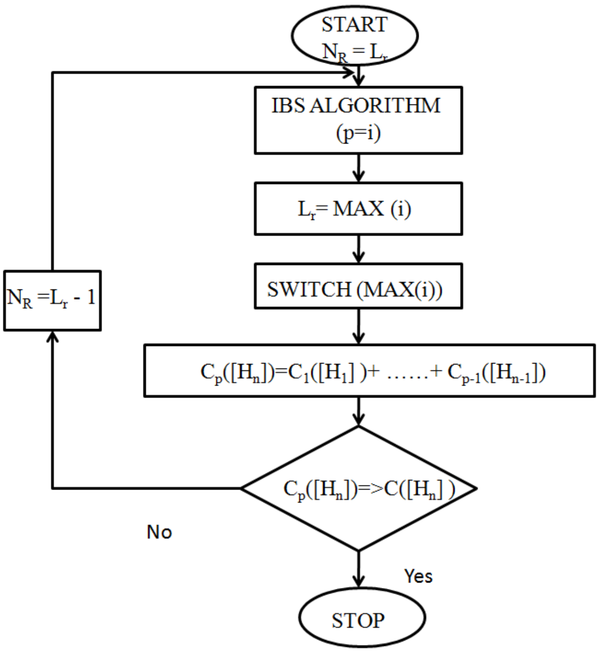

Figure 2: Flow chart of Iteration based receiver antenna selection (IBS) algorithm

The signals from selected antennas are processed through RF chain. The subset of optimal antenna selected at receiver is given by $N_r = \{L_1, L_2, ..., L_{r-1}, L_r\}$.

Let $[H_n] = \max\{[H_1], [H_2], ..., [H_{L_r}]\}$ be the sub matrix of H the channel matrix based for selected receiver antenna.

Without the iteration procedure, the channel capacity of the selected n^{th} receiver antenna is given by

$$C_p([H_n]) = max\{\log_2 \det(I_{L_r} + \frac{\rho}{N_T}[H_n]_{(N_R - L_r)} [H_n]^H_{(N_R - L_r)})\} \quad (14)$$

Where H_n is selected antenna subset of H channel matrix and p is the number of iterations.

The process is repeated to add antenna that contribute to maximize capacity. The obtained capacity value is compared with a threshold value to stop the iteration process, when the resultant capacity is greater than equal to the MIMO channel total capacity.

$$C_p([H_n]) \geq C([H_n]) \quad (15)$$

For first iteration when p=1, from the entire set of receive antenna array the antenna that contribute with high SNR is considered to determine the capacity. The channel matrix for selected antenna is determined by its corresponding rows and columns value.

The capacity value of the selected antenna is given by

$$C_1([H_1]) = Max\{\log_2 \det(I_{L_r} + \frac{\rho}{N_T}[H_1]_{(N_R - 1)} [H_1]^H_{(N_R - 1)})\} \quad (16)$$

$$C_1([H_1]) < C([H_n]) \quad (17)$$

The next iteration p=2 process is initiated, when the SNR value of the selected antenna is not sufficient to produce the maximum capacity when compared to a threshold value.

$$C_2([H_2]) = Max\{\log_2 \det(I_{L_r} + \frac{\rho}{N_T}[H_2]_{(N_R - 2)} [H_2]^H_{(N_R - 2)})\} \quad (18)$$

The capacity determined from second iteration is added to the previous iteration value

$$C_2([H_2]) = C_1([H_1]) + Max\{\log_2 \det(I_{L_r} + \frac{\rho}{N_T}[H_2]_{(N_R - 2)} [H_2]^H_{(N_R - 2)})\} \quad (19)$$

$$C_2([H_2]) = C_1([H_1]) + C_2([H_2]) \quad (20)$$

$$C_2([H_2]) + C_1([H_1]) > C([H_n]) \quad (21)$$

From (21), if capacity determined from selected antenna is low, then iteration process with next antenna with high SNR is initiated else the process will be terminated.

The capacity of MIMO MCCDMA is improved further through this continuous process of selecting best contributing antenna from the set. The computational complexity of the system is further reduced as it sticks on to the best selected contributing antennas towards capacity analysis.

Table.1 shows IBS algorithm and its computational complexity for each step in order. The order of computation is given by the number of elements in the selected channel matrix used for multiplication and the number of times it is multiplied within the loop. When the selected number of optimal antenna is less when compared to full antenna set, then the complexity order of computation is given by (22)

$$O(\max\{N_T, N_r\} N_T * L_r) \quad (22)$$

SIMULATION RESULT AND DISCUSSION

The performance of the proposed Novel Iteration Based receiver antenna selection algorithm in the MIMO MCCDMA system in Mobile WiMAX is simulated and evaluated using

MATLAB. We assume that fixed set of antennas are available at transmitter side.

Capacity vs SNR and BER vs SNR are analyzed with 256 subcarriers, four Transmitting antennas and four selected receiving antennas from sixteen antennas on receiving side.

Table 1: Complexity order of IBS algorithm

IBS Algorithm	**Level of Complexity**
IBS Algorithm $(N_T, N_R, N_r, L_r, H_1 ... H_{L_r}, H_n)$ $N_r := \{1, 2, 3..., \mathrm{L}_r\}$ H- Complete channel set MIMO $[H_n]$ - Selected channel matrix set i- no of iteration $let\ F_1 = \{all\ rows\ of\ [H_n]\}\ and$	$\mathrm{O}(N_T * N_r)$
$\tilde{G}_1 = I_{N_r}$ $choose[h_1] = \arg\max_{h \in F_1} \|h\|_2$, $[H_1] = [h_1]$	$\mathrm{O}(N_T{}^2 * \mathrm{L}_r)$
$\mathrm{L}_r = Max(i)$ $for\ i = 1 : L_r$ $F_i = F_{i-1} - [\tilde{h}_{i-1}]$ $\tilde{G}_i = I_{N_r} - \frac{\rho}{L_r}[\tilde{H}_{i-1}] *$ $(I_{N_r} + \frac{\rho}{L_r}[\tilde{H}^{[H_n]}{}_{i-1}][\tilde{H}_{i-1}])^{-1}[\tilde{H}^{[H_n]}{}_{i-1}]$ $[\tilde{h}_i] = \arg\max_{h \in F_i}[h^{[H_n]}]\tilde{G}_i[h]$ $[H_i] = \left\{[\tilde{H}_{i-1}][\tilde{h}_i]\right\}$	$\mathrm{O}(\max\{N_T, N_r\}$ $N_T * (N_R - L_r))$
$\tilde{H} = \tilde{H}_{L_r}$ If $C_i([H_i]) < C([H_n])$ i=i+1 ; end $N_r := \mathrm{L}_r - 1$ If $C_i([H_i]) >= C([H_n])$ $C_i([H_i]) = C_1([H_1]) + .. + C_{i-1}([H_{i-1}])$ $[H_i] = ([H_1] + [H_2] + .. + [H_{i-1}])$ end end	$\mathrm{O}(\max\{N_T, N_r\}$ $N_T * \mathrm{L}_r)$

The simulation parameters are listed in Table 2.

Table 2: Simulation Parameters

Code rate	1/2, 3/4,5/6
Modulation	QPSK, 64-QAM
Spreading code length	32
FFT size	512
Antenna Array	N_T =4, N_R =16, N_r =4, L_r =2,4
Spreading codes	Walsh-Hadamard Code
Channel	Rayleigh fading channel

Capacity analysis with and without receiver antenna selector under different code rate

Figure.3 shows the Capacity vs SNR of MIMO MC CDMA system with 4x4 antenna array. QPSK modulation with code rate 1/2 and 3/4 are considered. At 10dB SNR, the system with antenna selector offers 4.3 bits/s/Hz capacity, which is less than the system without an antenna selector that provides 5.8 bits/s/Hz for code rate ½.

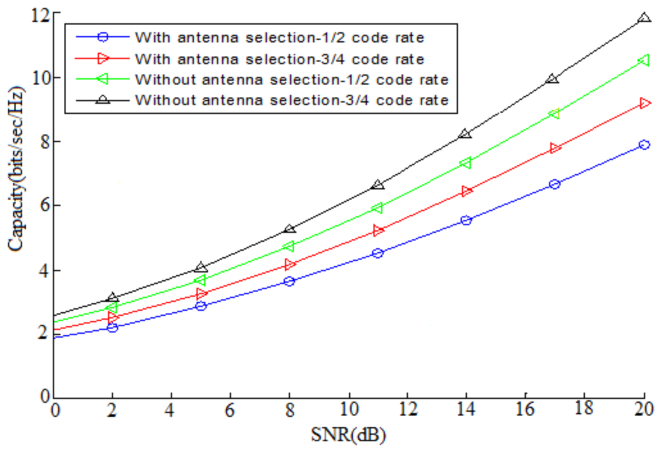

Figure 3. Capacity vs SNR comparison of IBS algorithm with and without antenna selection using QPSK modulation.

Similarly for ¾ code rate, system with antenna selector offers 5 bits/s/Hz capacity, which is less than the system without an antenna selector that provides 6.2 bits/s/Hz. Here the system with antenna selector receives smaller power and results in loss of information. The selected antenna experience better channel distribution than a MIMO channel.

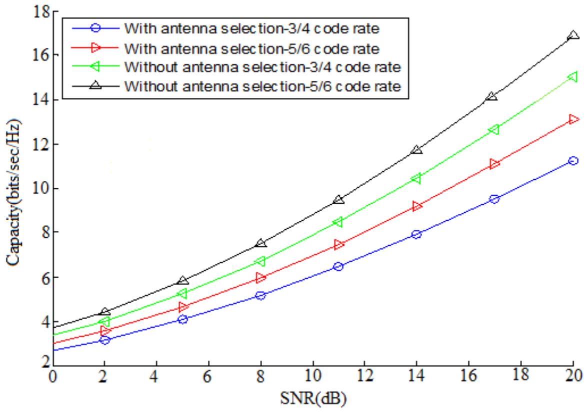

Figure 4. Capacity vs SNR comparison of IBS algorithm with and without antenna selection using 64 QAM modulation

Figure.4 shows the Capacity vs SNR of MIMO MC CDMA system with 4x4 antenna array. 64 QAM modulation with code rate 3/4 and 5/6 are considered. At 10dB SNR, the system with antenna selector offers 6 bits/s/Hz capacity, which is less than the system without an antenna selector that provides 7.9 bits/s/Hz for code rate 3/4. Similarly for 5/6 code rate, system with antenna selector offers 7.1 bits/s/Hz capacity, which is less than the system without an antenna selector that provides 8.8 bits/s/Hz. Here the system with antenna selector suffers from loss of information that cannot be made up by the improvement in channel distribution.

BER Comparison of various receiver Antenna Selection Algorithm

Figure.5 and 6 show the BER vs SNR performance of MIMO MC CDMA system under different selection algorithm for 4x4 antenna array. The proposed IBS algorithm is compared to Multiple Element Antenna (MEA) and Norm Based Selection (NBS) algorithm using QPSK and 64-QAM respectively.

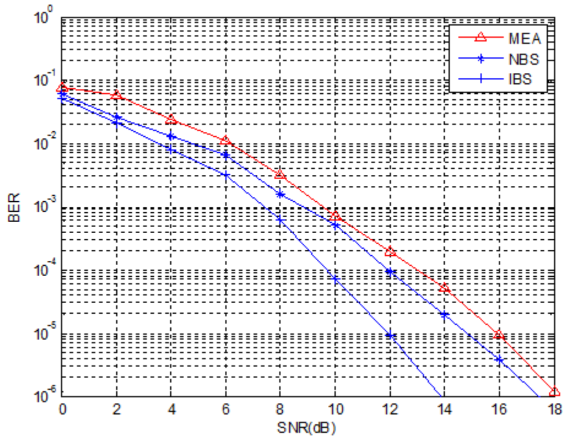

Figure 5. BER vs SNR comparison of IBS, NBS and MEA algorithm with 4x4 diversity using QPSK Modulation

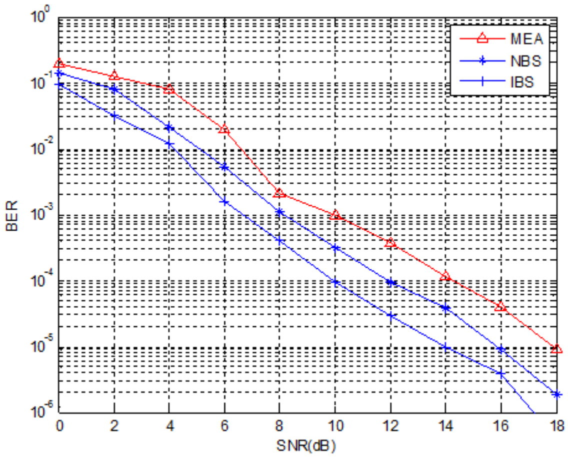

Figure 6. BER vs SNR comparison of IBS, NBS and MEA algorithm with 4x4 diversity using 64-QAM modulation.

The proposed IBS algorithm takes norm on fading channel matrix and selects the rows of channel matrix. It is evident that IBS algorithm reduces BER with the selected antenna when compared to MEA and NBS algorithm.

Capacity Comparison of various receiver antenna Selection Algorithm

Figure.7 shows the Capacity vs SNR performance of MIMO MC CDMA system under different selection algorithm for 4x4 antenna array. QPSK modulation with code rate ½ and 5/6 are considered for comparison. For ½ code rate, 3.9 bits/s/Hz, 6 bits/s/Hz and 7.7 bits/s/Hz are derived by MEA, NBS and IBS algorithm. For 5/6 code rate, 4.4 bits/s/Hz, 6.8 bits/s/Hz and 8 bits/s/Hz are derived by MEA, NBS and IBS algorithm respectively.

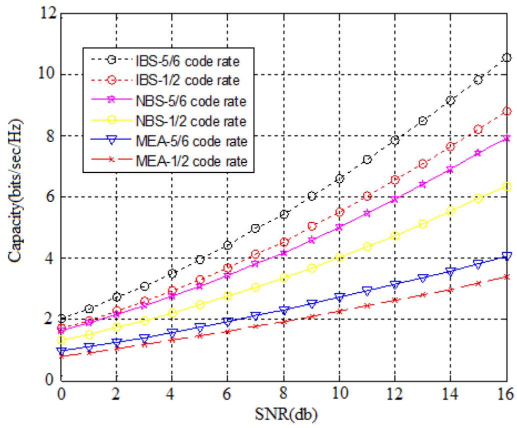

Figure 7. Capacity vs SNR comparison of IBS algorithm with NBS and MEA algorithm for 4x4 antenna system with QPSK.

This is because the suboptimal selection strategy implied in the algorithm removes receiver antenna and its corresponding rows of channel matrix. So at each stage a single row of channel matrix is removed, yielding a minimum loss in capacity.

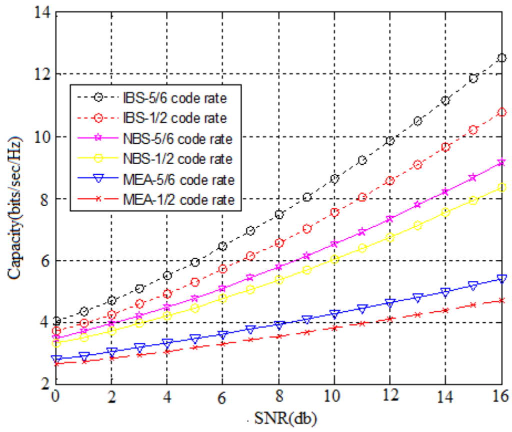

Figure 8. Capacity vs SNR comparison of IBS algorithm with NBS and MEA algorithm for 4x4 antenna system with 64 QAM.

Figure.7 and 8 show the Capacity vs SNR performance of MIMO MC CDMA system under different selection algorithm for 4x4 antenna array. In both the cases, it is observed that the performance of IBS algorithm is higher with reduced complexity than NBS and MEA.

CONCLUSION

In wireless communication, MIMO MC CDMA system based antenna selection provides impressive growth in gain-rate and reliability by combating fading to support high data rate. The adaptation of antenna selection comes with cost of increase in hardware complexity, size, complex computation and memory storage. In this paper, a Novel Low complexity iteration based receiver antenna selection algorithm has been suggested with MIMO MC CDMA system for Mobile WiMAX network. IBS algorithm selects the optimal antenna subset out of all available antennas on each iteration. Initially antenna with huge contribution to the capacity improvement is selected with respect to SNR value. If the capacity offered by the selected antenna is less is than the threshold value, the second optimal antenna with next SNR value is chosen. Since the designated antenna subset changes to the environment due to fading, the capacity degradation has been low due to smaller receiver power. This selection procedure results in reduction of the number of antennas on the receiver side in turn reduce the cost, size and hardware requirement. The computational complexity and memory storage of IBS algorithm are lower than NBS and MEA algorithm, as it converge to select optimal set from sub matrix i.e., row of channel matrix.

REFERENCES

[1] M. Naeem and D. C. Lee, "A Joint Antenna and User Selection Scheme for Multiuser MIMO System", Applied Soft. Computing, vol. 23, pp. 366-374, Oct. 2014.

[2] A. Gorokhov, D. A. Gore, and A. J. Paulraj, "Receive antenna selection for MIMO spatial multiplexing: theory and algorithms", IEEE Transactions on Signal Processing, vol. 51, no. 11, pp. 2796–2807, Nov. 2003.

[3] Q. T. Tran, S. Hara, A. Honda, Y. Nakaya, I. Ida and Y. Oishi, "A Receive Antenna Selection for MIMO-OFDM System", IEEE 17th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 1-5, Sep. 2006.

[4] Y. Liu, Y. Zhang, C. Ji, W. Q. Malik and D. J. Edwards, "A Low-Complexity Receive-Antenna-Selection Algorithm for MIMO–OFDM Wireless Systems", IEEE Transactions on Vehicular Technology, vol. 58, no. 6, pp. 2793-2802, July 2009.

[5] B. B. John, K. V. Babu, G. R. Reddy and B. Nallagatla, "A reduced MIMO (R-MIMO) system using norm based approach (NBA) for transmit antenna selection (TAS) ", in Proc. of IEEE International Conference on Communication and Signal Processing, pp. 1472-1475, Apr. 2014.

[6] A. Gorokhov, “Antenna selection algorithms for MEA transmission systems", in Proc. of IEEE ICASSP, vol. 3, pp. 2857-2860, May 2002.

[7] M. El-Absi, S. Galih, M. Hoffmann, M. El-Hadidy and T. Kaiser, "Antenna Selection for Reliable MIMO-OFDM Interference Alignment Systems: Measurement-Based Evaluation", IEEE Transactions on Vehicular Technology, vol. 65, no. 5, pp. 2965-2977, May 2016.

[8] S. Sanayei and A. Nosratinia, "Capacity of MIMO Channels With Antenna Selection", IEEE Transactions on Information Theory, vol. 53, no. 11, pp. 4356-4362, Nov. 2007.

[9] A. F. Molisch, M. Z. Win and J. H. Winters, "Capacity of MIMO systems with antenna selection", in Proc. of IEEE International Conference on Communications, Vol.2, pp. 570-574, June 2001.

[10] A. F. Molisch, M. Z. Win, Yang-Seok Choi and J. H. Winters, "Capacity of MIMO systems with antenna selection", IEEE Transactions on Wireless Communications, vol. 4, no. 4, pp. 1759-1772, July 2005.

[11] T. Murakami, K. Ujihara, Y. Takatori, M. Mizoguchi and F. Maehara, "Downlink multiuser MIMO-OFDM transmission using simple receive antenna selection", in Proc. of IEEE ISAP, pp. 604-605,Oct. 2016.

[12] M. Gharavi-Alkhansari and A. B. Gershman, "Fast antenna subset selection in MIMO systems", IEEE Transactions on Signal Processing, vol. 52, no. 2, pp. 339-347, Feb. 2004.

[13] P. V. Amadori and C. Masouros, "Interference-Driven Antenna Selection for Massive Multiuser MIMO", IEEE Transactions on Vehicular Technology, vol. 65, no. 8, pp. 5944-5958, Aug. 2016.

[14] S. Jung and B. W. Kim, "Near optimal low complexity antenna selection scheme for energy efficient correlated distributed MIMO systems", International Journal of Electronics and Communications, vol. 69, pp. 1039–1046, July 2015.

[15] Y. Zhang, C. Ji,W. Q.Malik, D. C. O’Brien, and D. J. Edwards, "Receive antenna selection for MIMO systems over correlated fading channels", IEEE Transactions on Wireless Communications, vol. 8, no. 9, pp. 4393-4399, Sep. 2009.

[16] Y. Hei, W. Li, and X. Li, "Particle swarm optimization for antenna selection in MIMO system", Wireless Pers. Commun., vol. 68, no. 3, pp. 1013–1029, Feb. 2013.

[17] Jian Dong, Yujia Xie, Yi Jiang, Fang Liu, Ronghua Shi and Dahong Xiong, "Particle swarm optimization for joint transmit and receive antenna selection in MIMO systems", IEEE International Conference on Communication Problem-solving, pp. 237-240, Dec. 2014.

[18] Fan, B., Sun, W. and Shen, , "Performance analysis of orthogonal space-time block coding with reduced-complexity antenna selection", IET Conference Proceedings, pp. 1–4, Nov. 2006.

[19] S. Kim, "Performance of decremental antenna selection algorithms for spatial multiplexing MIMO systems with linear receiver over correlated fading channels", IET Communications, vol. 11, no. 6, pp. 855-863, May 2017.

[20] A. M. Salhab and S. A. Zummo, "Performance of Nth-best antenna selection diversity systems with co-channel interference and outdated channel information", IET Communications, Vol. 8, No. 10, pp. 1674–1683, July 2014.

[21] Y. Liu, Y. Zhang, C. Ji, W. Q. Malik and D. J. Edwards, "A Low-Complexity Receive-Antenna-Selection Algorithm for MIMO–OFDM Wireless Systems", IEEE Transactions on Vehicular Technology, vol. 58, no. 6, pp. 2793-2802, July 2009.

[22] H. Bolcskei, D. Gesbert and A. J. Paulraj, "On the capacity of OFDM-based spatial multiplexing systems", IEEE Transactions on Communications, vol. 50, no. 2, pp. 225-234, Feb. 2002.

[23] C. Y. Chen, A. Sezgin, J. M. Cioffi and A. Paulraj, "Antenna Selection in Space-Time Block Coded Systems: Performance Analysis and Low-Complexity Algorithm", IEEE Transactions on Signal Processing, vol. 56, no. 7, pp. 3303-3314, July 2008.

[24] M.Torabi, S. Aissa, and M.R.Soleymani, "On the BER Performance of Space-Frequency Block Coded OFDM Systems in Fading MIMO Channels", IEEE Transactions on Wireless Communications, vol. 6, pp.1366-1373, Apr. 2007.