Hybridization of ANN and GA with Adaptive Mutation: A Proficient Technique for Optimal Transmit Antenna Subset Selection for MIMO-OFDM Systems

Madan Lal* and Dr Ashok De**

Abstract—**The integration of Orthogonal Frequency Division Multiplexing (OFDM) technique along with Multiple Input Multiple Output (MIMO) systems seems to be under focus and also serves as a challenging research in the field of broadband wireless communication during topical dates. The resulting MIMO-OFDM system maneuvers the following high data rate wireless transmission of OFDM as well as maximized system capacity of MIMO. Even with these advantages, a foremost issue that influence the MIMO-OFDM system is the hardware perplexity aroused due to the mounted quantity of transmits and receives antennae. In prior works, a technique on the basis of Genetic Algorithm (GA) along with adaptive mutation is being proposed; still, the technique undergoes computational complexity. To surmount these disadvantages, in this paper, a hybrid technique is proposed to choose the optimal transmit antenna subset. The proposed hybrid technique is developed by blending of Artificial Neural Network (ANN) and GA with adaptive mutation. In the work, a training set is generated using GA with adaptive mutation and the generated training set is used to train the ANN using Back Propagation (BP) algorithm. The well-trained ANN selects the optimal transmit antennas when the required number of antennas to be selected and the desired Signal to Noise Ratio (SNR) level are given. The implementation results show that the proposed hybrid technique effectively selects the optimal transmit antennas with good ergodic capacity and less computational complexity.**

***Index Terms*—MIMO-OFDM, transmit antenna selection, ANN, GA with adaptive mutation, ergodic capacity, SNR, BP.**

I. Introduction

Current and upcoming wireless applications such as digital video/audio broadcast, video telephony, virtual reality and premium multimedia data services are determined of wireless communication networks which have high quality and high data-rate links [2]. The research of MIMO has been motivated due to the increase in the requirement for high transmitting data rates and quality and acts as a powerful method that has the potential to achieve overwhelming bit rates [4][5].

The MIMO systems are consistently appealing to narrowband channels wherein regardless of having small antenna spacing (approximately a half-wavelength), multi-path targets at constructing independent channels [6]. In short, they offered a consistent wireless communications, spectrally proficient and high-speed. Furthermore, OFDM which is an accepted method for broadcasting signals over wireless channels and used for conflicting the frequency selectivity of wireless channels at high data-rate transmissions [10] is utilized [15]. Consequently, the integration of OFDM with MIMO is accepted as a strong contender for the next generation bandwidth-efficient wireless systems. And by this means, a wide frequency bandwidth can accordingly be separated proficiently into multiple channels at independent sub-carriers. [6][13]. The MIMO-OFDM technology strengthens the importance of both the MIMO system (i.e. resistance to delay spread) and the OFDM methodology (i.e. good transmission capacity) [1].

Universally, antenna selection or antenna subset selection diminishes power consumption that is in particular relevant for mobile devices. Furthermore, the antenna (subset) selection advances to convene significant gains in performance and capacity by utilizing diversity at the transmitter- and/or the receiver [2]. In the beginning, antenna selection techniques were made, only for systems with single transmit antenna and multiple receive antennas that are used for standard diversity intentions at the receiver. Whereas in these days, various algorithms have been proposed for the selection of optimal antenna subset from multiple transmit and receive antennas that provides specific channel realization in MIMO-OFDM systems [8]. They facilitate to minimize the intricacy trouble of a higher-order MIMO-OFDM system, though sustaining few of its advantages in a MIMO-OFDM system of lower order [16]. Numerous antenna selection algorithms were surviving in the literature, and are generally grouped into three types. They are such as, transmit antenna selection, receive antenna selection, or joint (i.e. transmit and receive antenna) selection [12]. Still, transmit antenna selection (TAS) is a successful means to acquire excellent system performance with low complexity [20].

Utilizing TAS, a single antenna or a subset of the antenna array is ideally chosen for the transmitter. Therefore, in a TAS based system, full diversity boons can be preserved because, all the transmit antennas are under utilization [21].

*Corresponding Author : Madan Lal, Professor and Head, Department of Electronics and Communication Engineering, Bhai Gurdas Institute of Engineering and Technology, Sangrur -148001, Punjab, India. (e-mail: madansharma.20@gmail.com).

**Prof. (Dr.) Ashok De, Principal, Ambedkar Institute of Technology, Government of Delhi, Delhi, India

This motivates us to do the research work in offering efficient optimal transmit antenna selection technique for MIMO-OFDM systems. In the previous work, we have proposed an effective optimal transmit antenna subset selection technique using GA with adaptive mutation. Despite the work minimizes the computational complexity by fast convergence rate, we propose a hybrid technique for the optimal transmit selection that further reduces computational complexity with good ergodic capacity. Here, by blending of ANN and GA with adaptive mutation, the optimal transmit antenna subset for MIMO-OFDM systems can be effectively selected with reduced computational complexity. The rest of the paper is organized as follows. Section II reviews some of the recent research works related to the transmit antenna subset selection on OFDM-MIMO system, section III constructed by the steps of the proposed hybrid technique for selecting optimal antenna subset, with the required mathematical formulations. Section IV details the discussion on the simulation results and Section V concludes the paper.

II. Recent Research Works: A brief review

Hajime Suzuki et al. [22] have presented an analysis of performance measurements from a MIMO-OFDM IEEE 802.11n hardware implementation at 5.2 GHz with the help of four transmitters and four receivers. Two spatial multiplexing systems were being compared of which the first one has employed a zero-forcing (ZF) detector and the next one was a list sphere detector (LSD). The evaluated results have revealed that the inconsistency can be legitimized by the insertion of transmitter noise inside the channel model. This effect was not incorporated in current MIMO-OFDM channel models. The calculated values from their hardware implementation have exposed a gainful packet transmission at 600 Mbit/s with 15 bit/s/Hz spectral efficiency at 73% coverage for ZF and 84% coverage for LSD with an average receiver signal to noise ratio (SNR) of 26 dB.

Hongyuan zhang and Rohit U.Nabar [23] have given an accurate diversity gain analysis for transmit antenna selection in MIMO-OFDM systems along with linear receivers. In a frequency-selective fading (as opposed to a frequency-flat fading) channel one of either two methods of antenna selection might be practiced. They have termed those methods as bulk selection and per-tone selection. A diverse complexity-performance tradeoff has presented by every method from an implementation perspective. They demonstrated that the above said two methods have recognized the equal diversity order using a rigorous mathematical derivation. In addition, the coding gains recognized by both the selection methods were as well verified and was contrasted utilizing simulation. As a whole, their work has substantiated the significance of antenna selection technology in MIMO-OFDM systems, and facilitated a complete procedure for antenna selection policies in real-world scenarios, from both the following performance as well as complexity perspectives.

Joon Hyun Sung et al. [24] have exhibited that it was more adequate to utilize a combination of eigen beam forming and a fixed (non-adaptive) rate allocation rather than the water-filling procedure to advance the zero-outage capability of the MIMO-OFDM channel. The fixed allocation was independent of specific channel realization and it relay upon the statistics of the channel. They have founded that the capacity penalty induced by the fixed allocation stretches near to zero as the number of antennas grow huge. Statistical outcomes have proved that the convergence was rapid; for example, the fixed allocation bears an SNR penalty of less than 0.2 dB for a 6-input 6-output Rayleigh-fading MIMO-OFDM channel at 8 bits per signaling interval, while the channel was considered to be uncorrelated among antennas and channel taps.

Mohammad Torabi [25] has demonstrated that the sub-carrier-by-sub-carrier antenna selection scheme for a MIMO space–frequency block coded (SFBC), OFDM system articulated amidst a turbo product code. He scrutinized the coding and diversity advantage of the SFBC-OFDM system with antenna selection with the help of an average SNR gain, outage probability and BER analysis validated by statistical replication. The system consummation belonging to various types of the proposed scheme was measured and contrasted. It has been revealed that the proposed scheme was of significantly improved in its efficacy of the conventional SFBC-OFDM systems.

Wilzeck and Kaiser [26] have argued that the antenna (subset) selection techniques were viable to minimize the hardware difficulty of MIMO systems, though maintaining the prosperity of higher-order MIMO systems. Most studies of antenna selection schemes were on the basis of frequency-flat channel models that were contradictory to broadband MIMO systems which employed spatial-multiplexing. In broadband MIMO systems aspiring to afford high-data-rate links, the bestowed signal bandwidth was characteristically higher than the coherence bandwidth of the channel and therefore the channel will be of frequency selective nature. Inside their work they have facilitated a synopsis of a joint transmitter- and receiver-side antenna subset selection method for frequency selective channels and redistributed them in MIMO-OFDM systems and MIMO single-carrier (SC) systems which bestowed frequency domain equalization (FDE).

S. Salari et al. [27] have arrived with a reduced-complexity scheme for Maximum Likelihood estimate for the following Carrier-Frequency Offset (CFO) as well as channel coefficients in MIMO-OFDM transmission within a specified training sequence. Their scheme was proficient to embrace every Space-Time Coded (STC) transmissions. To assess the efficiency of their scheme, the Cramer-Rao Bounds (CRB) was attained for CFO and also the channel estimators. Illustrations exposed that their scheme achieved approximately perfect efficacy while contrasting with the CRBs in each ranges of Signal-to-Noise Ratios for the following channel and also the frequency offset estimates.

Shreeram Sigdel and Witold A. Krzymien [28] have anticipated a selection algorithm which maximizes the average output SINR for all the subcarriers. A system to enumerate selection gain in frequency selective channel has been argued. Through simulating practical fading environments using various delay spreads the consequence of delay spread on the selection gain has been studied. In concurrence with the transmit antenna selection, the results of the variable signal constellation sizes and the quantity of transmitted streams on the bit error rate (BER) efficiency of the proposed system was also examined. Experimentations exposed that considerable development in the system efficiency was attained by utilizing transmit antenna selection algorithms particularly for low to moderate interference power.

III. Proposed Hybrid Technique For The Selection Of Optimal Antennas Using ANN And GA With Adaptive Mutation

The recent communication systems exploit the integration of MIMO and OFDM systems so as to enjoy the high quality transmission with high data rates link. Still, the effectiveness relies on the optimal antenna selection techniques as the multiple transmit and receive antennas are used in the system. In this paper, we propose a hybrid technique to optimally select the transmit antenna subset so that the performance of the MIMO-OFDM systems is improved by good ergodic capacity with reduced hardware complexity. To accomplish this, the proposed technique is developed by blending of ANN and GA with adaptive mutation. This hybridization not only improves the performance of the systems by aforesaid parameters, but also, it reduces the computational complexity. The proposed technique is comprised of three main stages, namely, generation of training set using GA with adaptive mutation, training of ANN by BP and evaluation of the network. The proposed technique is detailed in the further sub-sections.

A. Generation of training set using GA with adaptive mutation

To generate the training set for the ANN, it is essential to generate possible combinations of the transmitter antennas to select the optimal antenna subset to achieve very high ergodic capacity. The training set is consists of adequate size of the optimal antenna subset and SNR values as inputs and the antennas to be chosen as the outputs.

Let A be the set of antennas to be chosen, ρ be the set of SNR values and S be the size of the optimal antenna subset and the set values are noted below,

$$S = \{s_0, s_1, s_2, \cdots, s_{n_{sub}}\} \quad (1)$$

$$\rho = \{\rho_0, \rho_1, \rho_2, \cdots, \rho_{n_{SNR}}\} \quad (2)$$

$$A = \{A_0, A_1, A_2, \cdots, A_{n_{Tx}-1}\} \quad (3)$$

The input set is given as in (1) as well as (2) to the GA, the optimal antennas to be chosen (as in (3)) can be attained. This can be achieved by utilizing the optimal transmit antenna subset selection technique with the help of GA using adaptive mutation [30]. In this contribution, we have made an increased convergence rate of the proposed technique by adaptively mutating the chromosomes. The procedure for generating the training set is explained as we proceed

At first, N_p numbers of random chromosomes are provoked in which each of them have a length of N_{Tx}. Afterward, every chromosome in the population pool of size N_p is verified utilizing the fitness function (ie) given below

$$F_j = \arg\max_{X^{(j)}} C\left(X^{(j)}\right) \quad ; 0 \le j \le N_p - 1 \quad (4)$$

In (4), $C\left(X^{(j)}\right)$ represents the ergodic capacity when the j^{th} chromosome is selected and it is given by

$$C\left(X^{(j)}\right) = E\left(\frac{1}{N_s}\sum_{i=0}^{N_s-1}\log\left(\left|I_{N_{RX}} + \gamma . Q(X^{(j)})\right|\right)\right) \quad (5)$$

$$\text{where, } Q\left(X^{(j)}\right) = H_i^{(j)}\left(H_i^{(j)}\right)^H \quad (6)$$

Following the identification of fitness values for every chromosome, they are fed to the following process namely genetic operations, crossover, mutation and selection. Herein we adopt an adaptive mutation technique to speedup the convergence of the optimal solution rather using ordinary mutation operation. Supplementary to the mutation, the surplus genetic operations, crossover and selection follows a non-adaptive procedure. The mutation is thereafter made more adaptive in the proposed transmit antenna selection technique by varying the mutation point dynamically. With respect to the fitness of the obtained children's mutation point, the mutation point is made to undergo variations dynamically. The fitness function that investigates each mutation point proceeds below,

$$F_M^{(k)}(q) = 1 - \frac{C\left(M_q^{(k)}\right)}{\sum_{q=0}^{N_u^{(k)}-1} C\left(M_q^{(k)}\right)} \quad ; N_p \le k \le 2N_p - 1 \text{ and } 0 \le q \le N_u^{(k)} - 1 \quad (7)$$

where, , $C\left(M_q^{(k)}\right)$ represents the ergodic capacity of the $M_q^{(k)}$ and $N_u^{(k)}$ number of mutation points are possible The best mutation point for each chromosome is obtained as

$$M_{best}^{(k)} = \arg\min_{M_q^{(k)}} F_M^{(k)}(q) \quad (8)$$

The ideal mutation points thus attained outputs new children chromosomes for the analogous parent chromosomes. In the selection operation, the N_p randomly generated chromosomes and the N_p new chromosomes are positioned in a selection pool on the basis of their fitness values. In the selection pool, the chromosomes that have excellent fitness dwell in the top positions of the pool. Amid the $2N_p$ chromosomes, the first N_p chromosomes that are located at the top of the selection pool are chosen for the forthcoming generation. With the chosen chromosomes, the process is iterated from the crossover till it compasses the termination criteria. The whole process is terminated, when the number of generations reaches the peak generation G_{max}, and the chromosome, at the top of the selection pool is chosen as the best chromosome

Therefore the attained best chromosome is the optimal antennas to be selected A_{00} for the input pair (s_0, ρ_0). Thus, the process is reverted for each and every one of the combinations of input pairs $(s_0,\rho_1),(s_0,\rho_2),\cdots,(s_0,\rho_{n_{SNR}}),\cdots,(s_{n_{sub}},\rho_{n_{SNR}})$ and hence the training set is generated. Thus generated training set is shown in (9) and it is utilized to train the neural network

$$T_{RS} = \begin{bmatrix} (s_0,\rho_0) & (s_0,\rho_1) & (s_0,\rho_2) & \cdots & (s_0,\rho_{n_{SNR}}) \\ (s_1,\rho_0) & (s_1,\rho_1) & (s_1,\rho_2) & \cdots & (s_1,\rho_{n_{SNR}}) \\ \vdots \\ (s_{n_{sub}},\rho_0) & (s_{n_{sub}},\rho_1) & (s_{n_{sub}},\rho_2) & \cdots & (s_{n_{sub}},\rho_{n_{SNR}}) \end{bmatrix} \begin{bmatrix} A_{00} & A_{01} & A_{02} & \cdots & A_{0n_{SNR}} \\ A_{10} & A_{11} & A_{12} & \cdots & A_{1n_{SNR}} \\ \vdots \\ A_{n_{sub}0} & A_{n_{sub}1} & A_{n_{sub}2} & \cdots & A_{n_{sub}n_{SNR}} \end{bmatrix} \quad (9)$$

From (9), it can be seen that for the given input pair (s_0, ρ_0), the desired output is A_{00}, where, $A_{00} = [a_{000} \; a_{001} \; a_{002} \cdots a_{00N_{Tx}-1}]$ in such a way that $a_{ijk} \in [0,1]$ and $\sum_{k=0}^{n_{Tx}-1} a_{ijk} = s_i$ here, $0 \le i \le n_{sub}-1$, $0 \le j \le n_{SNR}-1$, $0 \le k \le N_{Tx}-1$ and s_i belongs to the pair (s_i, ρ_j).

The pair $(s_{n_{sub}}, \rho_{n_{SNR}})$ indicates that the $s_{n_{sub}}$ number of antenna has to be selected for the SNR value $\rho_{n_{SNR}}$ and the process repeated until the $s_{n_{sub}}$ SNR values (as stated earlier). Hence the training set T_{RS} is generated and it is used to train the ANN.

B. Training of ANN using BP

In the proposed hybrid technique for selecting the optimal antenna subset selection, 2-layer feed forward neural network (given in the Fig. 1) is designed and it is trained using BP training algorithm. The feed-forward network can be deemed as a graphical representation of parametric function that receives a set of input values and relates them to a consequent set of output values. The single network N is trained in our proposed approach; the network is for receiving the number of optimal antennas to be selected, the SNR values and outputs the selected optimal antennas. Hence, the network is configured with 2 input units and N_{Tx} hidden and output units.

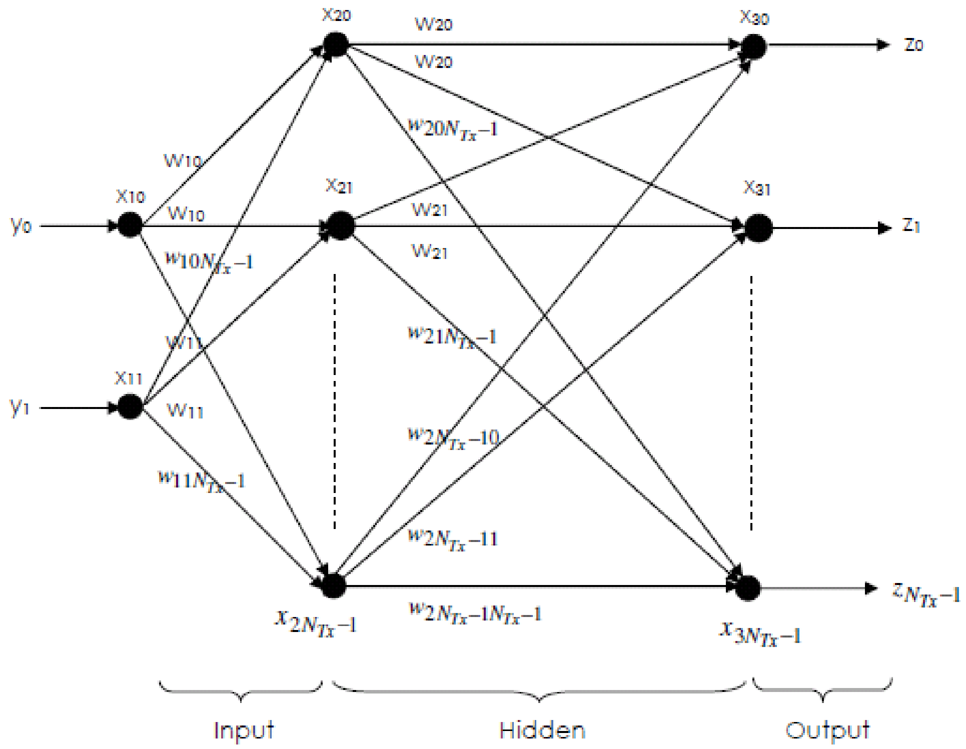

Fig. 1. Two inputs- n outputs Neural Network to obtain an optimal antenna subset for the number of antennas with different SNR

The BP algorithm, a most widely accessible algorithm is used to train the network. The number of antennas for the various SNR value and the chosen optimal antennas fulfilling all the necessary conditions are utilized to train the neural network. The destination is the number of antennas pointed by the subset (given as input to the network) that posse large ergodic capacity. The training steps are proceeded below,

Step 1: At first set the input weights of every neuron, apart from the neurons in the input layer.

Step 2: Affix the training samples y_1 and y_2 to network N.

Step 3: Employ the tansig transfer function given in (10) to the hidden layer and also to the purelin function, a neural transfer function to the output layer in which the two transfer functions computes the layer output taken from its net input. Establish the output at the output layers of the network as Z_m using purelin function.

$$Z'_m = \frac{2}{1+\exp(-2x_m)} - 1 \qquad (10)$$

where, Z'_m is the output of m^{th} neuron that proceeds sigmoid function and x_m is the total weighted input which can be computed as

$$x_m = \sum_{l=0}^{n_{Tx}-1} Z'_m w_{lm} \qquad (11)$$

Step 4: Identify error by considering the actual output of the network and the designated output by

$$\xi_m = Z_m(1-Z_m)(Z_m - d_m) \qquad (12)$$

The error computation for output layer and hidden layer is given in (12) and d_m denotes the expected output.

Step 5: Regulate the weights of all the neurons with the help of the calculated ξ_m as follows

$$\Delta w_{lm} = \xi_m . r_g . x_m \qquad (13)$$

In which, Δw_{lm} is the change of weight and r_g is the rate of learning, usually, 0.2 and 0.15 for output and hidden layers respectively. The alteration of weights starts from the output layer, hidden layer and then input layer.

Continue the process repeatedly till the error reaches a tolerable value $(\xi_m < 0.1)$ or the iteration fastens a maximum limit. When the training process is accomplished, the network is ready to chose the optimal antenna subset for any $\rho_{n_{SNR}}$ and $s_{n_{sub}}$.

C. Evaluation of the Network

Once the network gets learned well using the BP algorithm, the network is suitable for selecting the optimal antennas from the total number of antennas n_{Tx}. So, providing a subset size s_i and ρ_j, the well-trained neural network effectively endow with the optimal number of antennas to be used for transmitting the signal. The output of the network provides a binary value '1' to the selected antennas and '0' to the antennas that are not selected. For the obtained results, the ergodic capacity can be computed using (5). As the proposed technique is the hybridization of the ANN and adaptive GA, the antennas are selected with improved ergodic capacity, less hardware complexity and reduced computational complexity.

IV. Results and Discussion

Our proposed hybrid technique for the selection of optimal transmit antenna subset using ANN and GA with adaptive mutation is implemented in the working platform of MATLAB (version 7.8) with the system configuration of Pentium IV (1.6 GHz processor), 512 MB RAM. We used ten transmit antenna and ten receiver antenna (i.e. $N_{Tx} = 10$ and $N_{Rx} = 10$) to evaluate the proposed technique. The proposed technique is evaluated by selecting various numbers of optimal antennas (i.e. $n_{Tx} = 2,4,6$ *and* 8) with different SNR values. The ergodic capacity has been computed to evaluate the performance of the system when the proposed technique is used. The results obtained for the selection of antenna subset for MIMO-OFDM systems using the proposed hybrid and GA with adaptive mutation techniques are compared in the Table I.

TABLE I: Results obtained for antenna selection using proposed hybrid technique and GA with adaptive mutation technique, given, $N_{Tx} = 10$, $N_{Rx} = 10$ and $\rho = 15\,dB$

S.No	n_{Tx}/N_{Tx}	Selected optimal antennas		Ergodic capacity bits/s/Hz		Computational time (sec)	
		GA with adaptive mutation	Hybrid GA-ANN	GA with adaptive mutation	Hybrid GA-ANN	GA with adaptive mutation	Hybrid GA-ANN
1	2/10	(7,10)	(5,8)	14.6209	14.4603	0.617983	0.183366
2	4/10	(1,3,5,8)	(4,5,6,8)	24.5600	24.0626	0.947995	0.190802
3	6/10	(1,2,5,7,8,9)	(2,3,4,6,8,10)	32.2162	31.1752	1.179996	0.180895
4	8/10	(2,3,4,5,6,7,8,9)	(1,2,3,4,6,7,9,10)	37.2265	36.6249	1.469510	0.195100

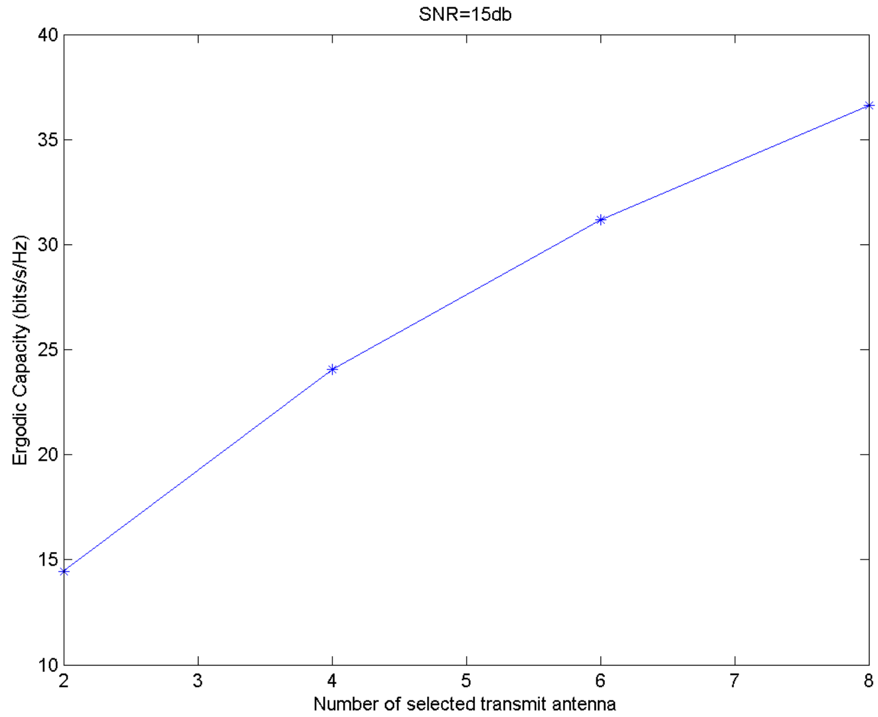

Fig. 2. Performance of the MIMO-OFDM system with the proposed hybrid technique for optimal transmit antenna subset selection, given that, $N_{Tx} = 10$, $N_{Rx} = 10$ and $\rho = 15\ dB$

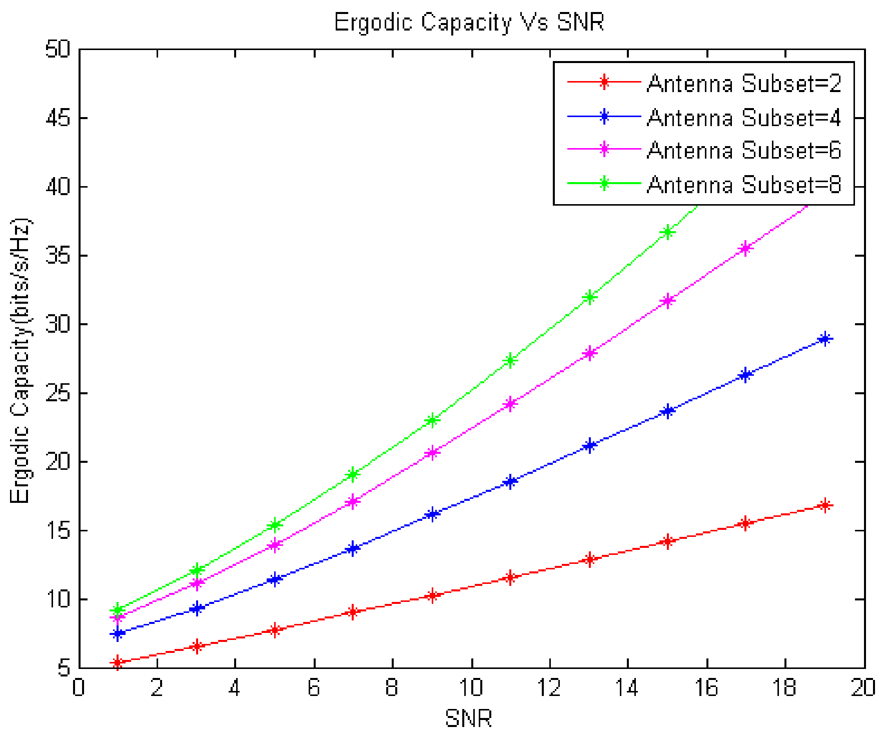

Fig. 3. Performance of the MIMO-OFDM systems using the proposed hybrid technique for the optimal transmit antenna selection, given that, $N_{Tx} = 10$, $N_{Rx} = 10$, $L = 3$ and for different ρ values.

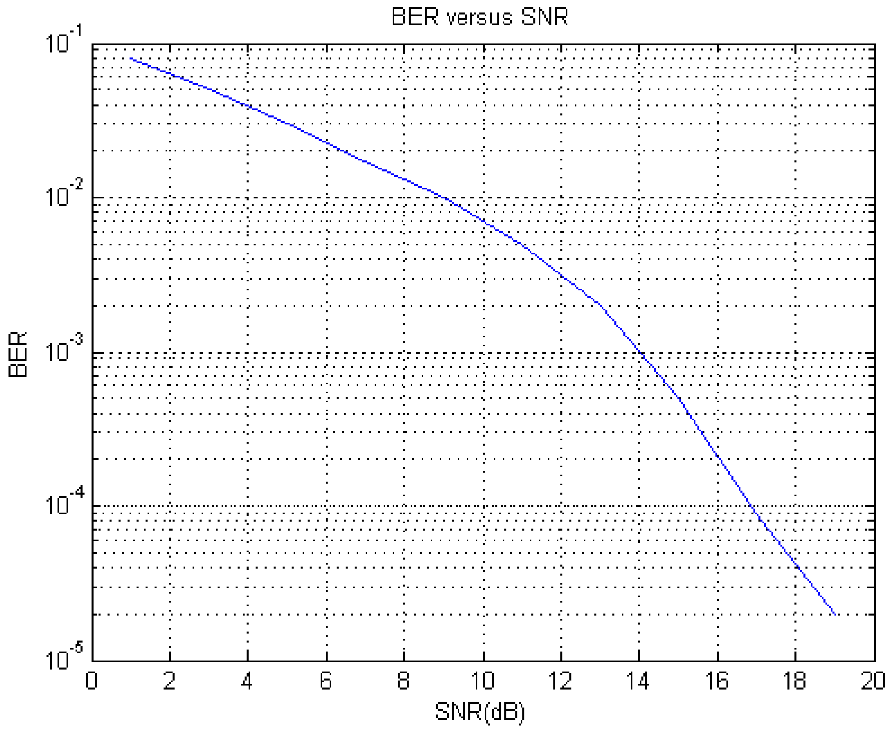

Fig. 4. BER versus ρ with $N_{Tx} = 10$, $n_{Tx} = 8$, $N_{Rx} = 10$ and $L = 3$ (MMSE receiver)

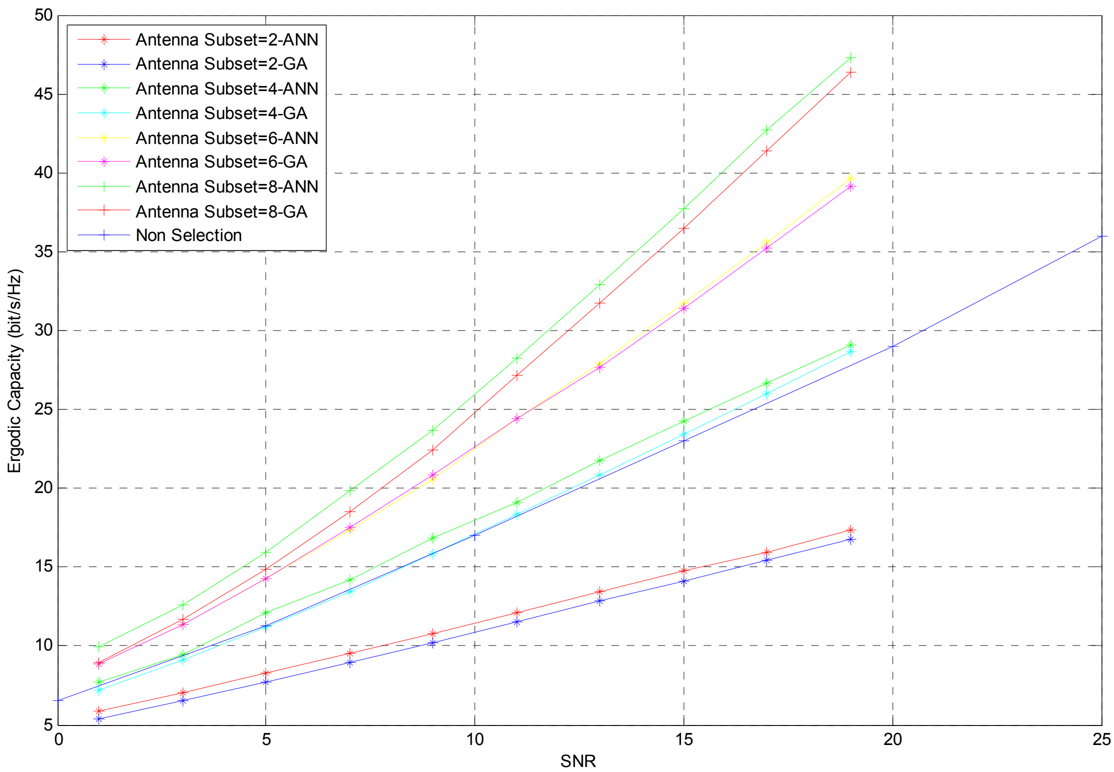

Fig. 5. Comparison of Ergodic capacity

In Table I, the comparison between the proposed hybrid technique and GA with adaptive mutation technique, which compares computational time and the ergodic capacities obtained for each antenna subset with $\rho = 15\,dB$, are given. It can be understood that in the proposed hybrid technique, the consumed computational time is less and also it accomplished a good means of ergodic capacity. Using the proposed hybrid technique, the ergodic capacity achieved for a MIMO-OFDM system for different optimal transmit antenna subset with $\rho = 15\,dB$ is plotted in Fig. (2), whereas the ergodic capacity obtained for each antenna subset with wide ranges of ρ is plotted in Fig. (3). From Fig. (2) and Fig. (3), it has been shown that a good capacity has been achieved for various values of ρ and antenna subsets with reduced computational complexity when compared to the antenna selection technique using GA with adaptive mutation. In the considered MIMO-OFDM system, we have selected QAM modulation and MMSE receiver to visualize the BER performance. The depiction is given in Fig. 4 with $N_{Tx} = 10$, $n_{Tx} = 8$, $N_{Rx} = 10$, $L = 3$ and for different ρ values. The performance of the ergodic capacity has shown better results when compared with the existing work [30] which is depicted in the Fig. 5

V. Conclusion

In this paper, we have proposed a hybrid technique to optimally select the transmit antenna subset for MIMO-OFDM systems. The hybrid technique has been made efficient by blending of ANN and GA with adaptive mutation. The implementation results have shown that the proposed technique effectively selects the optima transmit antenna subset in less computational complexity. Also, we have visualized the BER performance of the MIMO-OFDM systems by considering QAM modulation and MMSE receiver. This is mainly because of (i) hybridization of ANN and GA and (ii) incorporation of the adaptiveness in the GA operator, mutation. With the aid of the proposed hybrid ANN-GA technique, high performance MIMO-OFDM systems can be achieved with reduced hardware complexity.

References

[1] Khalida Noori and Sami Ahmed Haider, "A Layered MIMO OFDM System with Channel Equalization," Journal of Digital Information Management, Vol. 5, No. 6, pp. 361-363, 2007

[2] Andreas Wilzeck, Patrick Pan, and Thomas Kaiser, "Transmit And Receive Antenna Subset Selection For MIMO SC-FDE In Frequency Selective Channels," in Proceedings of the 14th European Signal Processing Conference, Sep. 4-8, Florence, Italy, 2006.

[3] M. Habib Ullah and A. Unggul Priantoro, "A Review on Multiplexing Schemes for MIMO Channel Sounding," International Journal of Computer Science and Network Security, Vol.9, No.6, pp. 294-300, 2009.

[4] Y. Wang, G. S. Liao, Z. Ye and X. Y. Wang, "Combined Beamforming With Alamouti Coding Using Double Antenna Array Groups For Multiuser Interference Cancellation," In proceedings of Progress In Electromagnetics Research Symposium, pp. 213–226, 2008.

[5] Fang Shu, Li Lihua, and Zhang Ping, "A General Stochastic Spatial MIMO Channel Model for Evaluating Various MIMO Techniques," International Journal of Applied Science, Engineering and Technology, Vol. 3, No. 3, pp. 152-156, 2007.

[6] Jishu DasGupta, Karla Ziri-Castro and Hajime Suzuki, "Capacity Analysis of MIMO-OFDM Broadband Channels In Populated Indoor Environments," in proceedings of IEEE International Symposium on Communications and Information Technologies, pp. 273-278, Oct. 17-19 , Sydney, 2007.

[7] Aamir Habib, Christian Mehlfuhrer and Markus Rupp, "Performance Comparison of Antenna Selection Algorithms in WiMAX with Link Adaptation," in Proceedings of 4th International Conference on Cognitive Radio Oriented Wireless Networks and Communications, pp. 1-5, Hannover, Germany, June, 2009.

[8] Inaki Berenguer, Xiaodong Wang and Vikram Krishnamurthy, "Adaptive MIMO Antenna Selection via Discrete Stochastic Optimization," IEEE Transactions On Signal Processing, Vol. 53, No. 11, pp. 4315-4329, 2005

[9] Panagiotis Theofilakos and Athanasios G. Kanatas, "Frobenius Norm Based Receive Antenna Subarray Formation For MIMO Systems," in proceedings of First European Conference on Antennas and Propagation, pp. 1-5, Nov. 6-10, Nice, 2006

[10] Gordon L. Stuber, John Barry, Steve W. McLaughlin, Ye (Geoffrey) Li, Mary Ann Ingram and G. Thomas, "Broadband MIMO-OFDM Wireless Communications," In proceedings of IEEE, Vol. 92, No. 2, pp. 1-21, 2004.

[11] E. Kurniawan, A. S. Madhukumar and Francois Chin "Sub Optimal Antenna Selection Method for MIMO-OFDM Systems," in proceedings of IEEE Vehicular Technology Conference, pp. 435-439, 22-25 April, Dublin, 2007

[12] Hani Mehrpouyan, Dr. Steven D. Blostein and Edmund C. Y. Tam, "Random Antenna Selection & Antenna Swapping Combined with OSTBCs," in proceedings of IEEE International Symposium on Signals, Systems and Electronics, pp. 177-180, July 30-Aug. 2, Montreal, 2007

[13] Tarkesh Pande, David J. Love and James V. Krogmeier, "Reduced Feedback MIMO-OFDM Precoding and Antenna Selection," IEEE Transactions on Signal Processing, Vol. 55, No. 5, pp. 2284-2293, 2007.

[14] Peter J. Smith, Tim W. King, Lee M. Garth and Mischa Dohler, "An Analysis of Low Complexity Algorithms for MIMO Antenna Selection," in proceedings of IEEE International Conference on Communications, Vol. 3, pp. 1380-1385, June, Istanbul, Turkey, 2006.

[15] Panagiotis Theofilakos and Athanasios G. Kanatas, "Reduced Hardware Complexity Receive Antenna Subarray Formation for MIMO Systems Based on Frobenius Norm Criterion," in proceedings of 3rd IEEE International Symposium on Wireless Communication Systems, pp. 262-266, Sept. 6-8, Valencia, 2006.

[16] S. Sadough, M. A. Khalighi, "Optimal Turbo-Blast Detection of MIMO-OFDM Systems with Imperfect Channel Estimation," IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 1-6, 3-7 Sept., Athens, Greece, 2007.

[17] IEEE, "IEEE 802.11n Wireless Local Area Networks" from http://grouper.ieee.org/groups/802/11/.

[18] IEEE, "IEEE Standard for Local and Metropolitan Area Networks; part 16: Air Interface for Fixed Broadband Wireless Access Systems," IEEE, Tech. Rep. 802.16-2004 part 16, Oct. 2004.

[19] 3GPP, "Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA)," 3GPP, Tech. Rep. 36.213 V8.2.0, Mar. 2008.

[20] Chang Soon Park and Kwang Bok Lee, "Statistical Multimode Transmit Antenna Selection for Limited Feedback MIMO Systems," IEEE Transactions on Wireless Communications, Vol. 7, No. 11, pp. 4432-4438, 2008.

[21] Meixia Tao, Qiang Li and H. K. Garg, "Extended Space-Time Block Coding with Transmit Antenna Selection over Correlated Fading Channels," IEEE Transactions on Wireless Communications, Vol. 6, No. 9, pp. 3137-3141, 2007.

[22] Hajime Suzuki, Thi Van Anh Tran, Iain B. Collings,Graham Daniels and Mark Hedley, "Transmitter Noise Effect on the performance of a MIMO- OFDM Hardware Implementation Achieving Improved Coverage", IEEE Journal on Selected Areas in Communications, vol. 26, no. 6, August 2008.

[23] Hongyuan zhang and Rohit U.Nabar, "Transmit Antenna Selection in MIMO-OFDM Systems: Bulk Versus Per-Tone Selection", in proceedings of IEEE International Conference on Communications, pp.4371-4375, May 2008.

[24] Joon Hyun Sung and John R. Barry," Approaching the Zero-Outage Capacity of MIMO-OFDM without Instantaneous Water-Filling", IEEE Transactions on Information Theory, vol. 54, no. 4, April 2008.

[25] Mohammad Torabi, "Antenna selection for MIMO-OFDM systems", Signal Processing, Vol.88, No.10, pp.2431-2441, 2008
[26] Wilzeck and Kaiser, "Antenna Subset Selection for Cyclic Prefix Assisted MIMO Wireless Communications over Frequency Selective Channels", EURASIP Journal on Advances in Signal Processing, 2008.
[27] S. Salari, M. Ardeilipour and M. Ahmadian, "Channel and Frequency Offset Estimation for MIMO- OFDM Systems", in proc. of Journal on Applied Sciences, vol. 8, no. 5, pp: 809- 815, 2008.
[28] Shreeram Sigdel and Witold A. Krzymien, "Performance evaluation of spatially multiplexed MIMO systems with subset antenna transmission in interference limited environments", Wireless Personal Communications: An International Journal, Vol.43, No.2, pp.623-644, October 2007.
[29] Madan Lal, "An Efficient Technique for Optimal Selection of Transmit Antenna Subset in MIMO-OFDM Systems using GA with Adaptive Mutation", European Journal of Scientific Research, Vol.38, No.3, pp.396-410, 2009.
[30] Yi Liu, Yangyang Zhang, Chunlin Ji, Wasim Q. Malik, Christopher J. Stevens and David J. Edwards, "Transmit Antenna Subset Selection for Mimo-Ofdm Wireless Communication Systems", In proceedings of IET Smart Antennas & Cooperative Communication Workshop, London, UK, Oct 2007

Asok De received his B.Tech. and M.Tech. degrees in 1978 and 1980 respectively from Department of Electronics and Telecommunications Engineering, Jadavpur University, Kolkata, India and his PhD degree in 1986 from Department of Electronics and Communication Engineering of Indian Institute of Technology Kharagpur, West Bengal, India. After spending several years at Research Level in IIT Kharagpur India, he joined Delhi University as a Faculty Member in 1986. His general research interests include application of multiple antenna systems and wireless communications. In these areas, he contributed over 70 papers published in referred journals and presented in various international conferences. He organized and chaired many international conferences. He has guided the Projects of 40 M.Tech. students, supervised 6 PhD students, and still 7 PhD students are under guidance. He received best technical paper award from SAMEER, Government of India. He did post doctoral work in University of Sheiffield, UK. He was professor of Delhi College of Engineering. He was also Head of Electronics and Communication Engg Dept of University of Delhi. He was member of Academic Council, Board of Management of GGSIPU. He was the founder Head of IT Dept of DCE. He is currently Principal of an Engineering College named Ambedkar Institute of Technology, Government of Delhi, Delhi, India since 2005.

Madan Lal received his three years Diploma from the Department of Electronics and Communication Engineering of Board of Technical Education, New Delhi in 1990. He received his B.Tech.(amie) from Department of Electronics and Communication Engineering of the Institution of Engineers (India) Kolkatta in 1996. He received his Master of Technology from National Institute of Technology, Bhopal in 1999. He is currently pursuing his Ph.D. degree from Department of Electronics and Telecommunication Engineering. He is a Chartered Engineer, He was the Principal of CRR Institute of Technology New Delhi from 2007 to 2008. He is presently Professor and Head, Department of Electronics and Communication Engineering of Bhai Gurdas Institute of Engineering and Technology, Sangrur, Punjab, India. He is a life member of the Institution of Electronics and Telecommunication Engineers, New Delhi. He is also a life member of Indian Society of Technical Education, New Delhi. He is also a life member of the Institution of Engineers Kolkatta. His area of interest is wireless communication and circuit theory.