# Energy Efficiency of MIMO-IFBC for Green Wireless Systems

**Divya R**
PG Student
Department of Electronics and Telecommunication
Mount Zion College of Engineering Kadammanitta, Kerala, India

*Abstract*— To design a reliable wireless system, its energy efficiency is an essential factor. As MIMO system has to suffer from fading, interferences and noises, the system should design in such a way that to compensate these problems. So interference alignment is included with MIMO interfering broadcast channel. This paper deals with the energy efficiency maximization of MIMO-IFBC system. When the energy efficiency is maximized, as it depends on power, the capacity of the system increases and thus the data rate also increases and cancels or minimizes interferences. Here the EE is compared and optimized for two SNR regions, that is, for high SNR and moderate SNR. For high SNR singular value decomposition is used with water filling power adaptation algorithm and EE is optimized. The optimization of EE and power allocation is easy to implement as noise and interference is less. In the case of high SNR the power is high and noise is low so EE can maximize using power allocation algorithms most commonly used is water filling algorithm. For moderate SNR regions, the power is less so by using DPC algorithm the distorted or low power signal at receiver can be boosted so power can increased and thereby EE get maximized. This paper focused mainly on the EE optimization of moderate SNR regions, and thereby a reliable MIMO-IFBC system with interference alignment for medium SNR is proposed.

***Key words:*** MIMO, SVD, Waterfilling, SNR, DPC, EE, Interfernce alignment

## I. INTRODUCTION

A multiple input multiple output system consists of multiple antennas at the receiver and transmitter. These multiple antennas can be used to improve the performance of the system through spatial diversity or increase the data rates by spatial multiplexing. One can also use some of the antennas for diversity and some for spatial multiplexing. The number used for diversity and spatial multiplexing depend on the application. MIMO systems can support higher data rates at the same transmission power and bit an error rate requirement that is for the same throughput requirement MIMO systems require less transmission energy. Wireless communication paradigm has evolved from single user single input single output and multiple input multiple output systems to multiuser

MIMO counterparts, which are greatly improving the rate per-

formance by transmitting to multiple users simultaneously. In multiuser multiple input multiple output systems, a base station equipped with multiple antennas serves a number of users. Energy efficiency is becoming an important concern in the design of future wireless networks both from environmental and economical point of view. Energy efficient design in cellular networks addresses the concerns of ICT related carbon emissions and leads to a reduction in the costs of running the network due to the reduction in the energy bill. MIMO can be subdivided into three main categories, precoding, spatial multiplexing, and diversity coding. Precoding is multistream beamforming[4], in the narrowest definition. Spatial multiplexing[4] requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. Diversity coding techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space time coding. When we design a new system it should need or satisfy certain conditions, that the proposed system should meet all the requirements. It should be capable of taking all the good parameters of previous systems and also have to compensate all the limitations[1]. In the case of wireless systems or communication system, a system should be green wireless system, that means, reliable, capable of eliminating noises and all kinds of interferences, have good capacity and low cost. If the energy efficiency of a system is maximum then that system has a high capacity, so such a system with completely eliminating interferences[10] using IA and considering different SNR regions is proposed. The capacity of the system is improved by optimizing the energy efficiency.

## II. LITERATURE SURVEY

A wide variety communication system is available, but we always search for a reliable and fast system when compare with all the existing systems. There are some familiar communications systems which can be consider as the existing systems. Channel selection[3] in MIMO which is a comparison between two algorithms brute force algorithm and channel selection algorithm based on SINR. User selection in MIMO which uses brute force algorithm and zero forcing algorithm. IA techniques for Multi cell MIMO which implements an interference alignment using multiple access channel broadcast algorithm. Users undergo inter cell interference (ICI) as well as inter user interference (IUI) since multiple base stations (BSs) simultaneously serve their corresponding multiple users, which causes the significant degradation of sum rate performance. Hence, multiple input multiple output (MIMO) has been engaged as a promising technique to alleviate the interference. Recently, interference alignment (IA) has been developed as a transmission technique to exploit the maximum degrees of freedom in MIMO interference channel and the upper bound of the capacity in the high signal to noise ratio (SNR) regime contrary to other schemes. To design mth column of the transmit precoding matrix[2] for the kth user in the ith cell to nullify the IUI channel, the effective ICI channels, and the ISI channels, there requires $d(K-1)+(d-1)+1+Lm[k,i]$ antennas. Here two different interference channel selection algorithms are used. One is the optimum interference channel selection algorithm (OICS-A)[2] which provides the best sum rate performance among all possible ICI columns and SINR based interference channel selection algorithm (SICS-A)[2] to reduce the computational complexity of OICS-A while achieves a sum rate improvement[2]. A multiuser system with interference from multiple transmitters has attracted a lot of attention in recent times. The paper explained an Interference Alignment (IA)[2] scheme to achieve maximum degrees of freedom in a K transmitter and K receiver time varying interference channel (IFC) with single antenna at each transmitter and receiver. For a system having multiple antennas and identical antenna configuration at each node, IA can be achieved with constant channels also. However, the closed form solution for the precoder to achieve IA is known only for the three user IFC with global channel knowledge at each node. Since this closed form solution does not take sum rate maximization into account, in the precoder is optimized to jointly achieve IA and sum rate maximization. For the general case (K ≥3), by using reciprocity of the network two iterative algorithms have been proposed in which require only local channel knowledge at each node. Consider a cellular network, referred to as Interfering Broadcast Channe[2]l, in which each base station supports multiple users. The IFC supports single user in each cell and hence there is only ICI while IFBC can support multiple users, therefore there is IUI as well as ICI at each receiver. To deal with these interferences a design of the

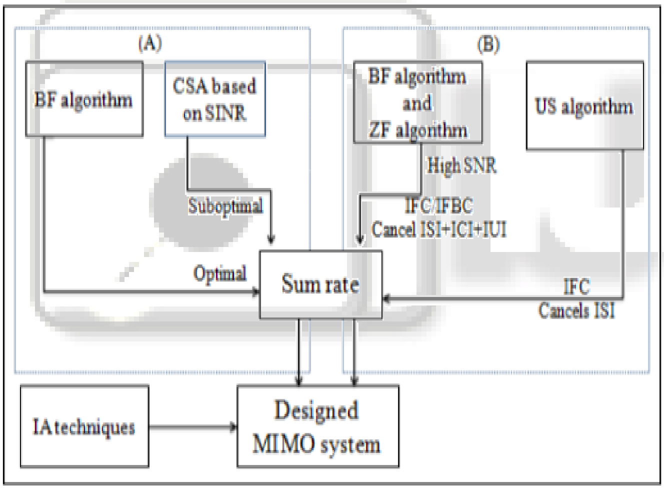


Fig. 1: System design model of existing papers

transmitter and receiver beam-former by a coordinated Zero-forcing (ZF)[2] scheme to mitigate both IUI and ICI in a multiple input single output IFBC. In the coordinated ZF scheme was extended to MIMO-IFBC by considering multiple antennas at each receiver. The user selection problem has been addressed to improve the achievable sum rate of the MIMO-IFBC system. A suboptimal user selection algorithm is proposed to reduce network reciprocity concepts and orthogonality between the desired signal space and interference space in the reciprocal system to select the users. An existing suboptimal algorithm based on the sum rate criteria is also extended to MIMO-IFBC. Simulation results show that the sum rate achieved by the orthogonality based algorithm and the extended sum rate based algorithm is close to the optimal sum rate. The complexity of these algorithms turns out to be linear with respect to the number of users in each cell as compared to exponential for brute force search. Here also energy efficiency, capacity and SNR constraints are not considered.

The fundamental concept of interference alignment[5] is to align the interference signals in a particular subspace at each receiver so that an interference free orthogonal subspace can be solely allocated for data transmission. Since interference alignment techniques have attracted significant research interests and various algorithms have been proposed and analyzed, for example, MIMO interference network, X network, and cellular network. Initially, the interference alignment has been proposed to achieve optimal degrees of freedom in a SISO interference channel. The alignment of multi user interference at each receiver based on a carefully constructed signal structure, which was referred to as interference alignment in signal space[5]. For the interference alignment in signal space, transmit precoding technique is used to align the multi user interferences in the same interference space which is orthogonal to the desired. signal space at each receiver. Also provided an inner bound and an outer bound for the total number of degrees of freedom[8] for the K user MIMO Gaussian time varying interference channels with M antennas at each transmitter and N antennas at each receiver. In the case of K user, with M× N MIMO interference channel, it was showed that the total number of degrees of freedom is equal to min(M,N)K, if $K \leq R$ and min(M,N) R/(R+1)K, if $K > R$, where R = (max (M,N))/(min (M,N)) . An interference alignment scheme was provided for the deterministic channel model of the K user interference channel. The interference alignment scheme for a network with multiple cells and MIMO users under a Gaussian interference broadcast channel scenario. The grouping method in the multi cell scenario to jointly design the transmitter and receiver beamforming[5] vectors using a closed form expression without a need for iterative comput-ation. The grouping method can ensure no ICI and IUI at each user's receiver while reducing the number of antennas. PDF for the number of iterations of the proposed hybrid IA algorithm using the MAC-BC duality[5] complexity at the base station as compared to the conventional zero-forcing beamforming scheme. The hybrid IAt scheme based on the principle of MAC-BC duality[7]. That scheme removes the ICI using interference alignment while maximizes the total capacity of the corresponding cell using MAC-BC duality. Since, interference alignment is not perform explicitly to all users in the network, but the users within each cell are dealt with using capacity maximization, the number of transmit antennas required is generally lower than the existing grouping method[7].

## III. SYSTEM IMPLEMENTATION

A multi cell, multi user MIMO-IFBC system with IA is designed. For this two SNR regions is considered and each is designed with different algorithms, for high SNR operating regions, a grouping based IA scheme to jointly cancel intra and inter cell interferences and thus transform the MIMO-IFBC to a single cell MIMO scenario. A gradient based power adaptation scheme[1] is proposed based on water filling power adaptation and singular value decomposition to maximize EE for each cell. For moderate SNR cases, an approach using dirty paper coding (DPC) with the principle of multiple access channel and broadcast channel duality to perform IA while maximizing EE in each cell. Thus compared the performances of DPC and SVD[1] based algorithms and thus find outs a best method for EE optimization in moderate SNR regions. Simulation results demonstrate the superior performance of the proposed schemes over several existing approaches. It also shows that interference nulling based IA approaches outperform hybrid DPC-IA approach in high SNR region, and the opposite occurs in low SNR region. Interference alignment was first considered in as a coding technique for the two user MIMO X channel, where it was shown to achieve multiplexing gains strictly higher than that of the embedded MIMO interference channel (IC), multiple access channel (MAC) and broadcast channel (BC)[9] taken separately. On interference channels, the alignment can be accomplished for any number of users but as the number of users increases a larger signal space is needed for each user to recover nearly half of it. Degrees of freedom is an important capacity approximation in networks literature. To give a simple intuition of degrees of freedom of a network it is worthy to note that, the degrees of freedom of a network may be interpreted as the number of resolvable signal space dimensions. The capacity of a MIMO system can further be increased if we know the channel parameters both at the transmitter and at the receiver and assign extra power at the transmitter by allocating the power according to the water filling algorithms to all the channels. In the MIMO IFBC[1] system we use the proposed water filling algorithm and the results of this proposed algorithm are better as compared to the successive water filling algorithms. The process of waterfilling[6] is similar to pouring the water in the vessel. The total amount on water filled (power allocated) is proportional to the SNR of the channel. In telecommunications, dirty paper coding is a technique for efficient transmission of digital data through a channel subjected to some interference known to the transmitter. The technique consists of precoding the data in order to cancel the effect caused by the interference. The term dirty paper coding comes from Max Costa who imagined a paper which is partially covered with dirt that is indistinguishable from ink. The theorem says that if the writer knows where the dirt is to start with, she can convey just as much information by writing on the paper as if it were clean, even though the reader does not know where the dirt is. In this case the dirt is interference, the paper is the channel, the writer on the paper is the transmitter, and the reader is the receiver. In information theoretic terms, dirty paper coding achieves the channel capacity, without a power penalty and without requiring the receiver to gain knowledge of the interference state.

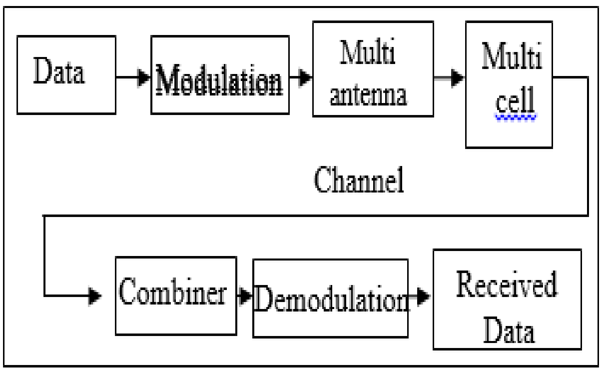


Fig. 2: Block diagram of proposed system implementation

MatLab is used as the simulation tool for implementing this project as, it is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include, math and computation, algorithm development, modelling, simulation and prototyping, data analysis, exploration, and visualization, scientific and engineering graphics, and also for application development, including Graphical User Interface building. The simulation results are to verify the theoretical findings and analyze the effectiveness of the proposed algorithms in terms of EE. Consider a MIMO system with two antennas and three multi cell. SNR is initialised at any range from low to high with a difference of 3 and assigned the data streams first compute the EE for SVD and DPC using one data stream and then with ds=2. Modulate the random signal generated using BPSK and it is simulated. In first simulation the performance of the proposed two schemes is investigated. The convergence behavior of the proposed approach is first evaluated by illustrating how the EE performance behaves with the number of iterations. EE converge after a particular iterations when β=2. However, the convergence procedure reduces, when a larger step size is chosen, i.e., β = 3. This result coincides with our theoretical findings where the computational complexity is inversely proportional to the square of the step size β2is shown in fig.3. Then evaluate the EE to transmission power relationship for the case with different total circuit power for both SVD-IA and DPC-IA. The EE versus transmission power relationship has been analyzed and infers that the proposed waterfilling based resource allocation algorithm for SVD-IA always leads to the maximum EE performance[1]. It implies that the proposed algorithm for DPC-IA can serve as an optimal inner layer step for EE maximization. Then in next simulation it compares and indicate the influence of circuit power on the EE-transmission power relation. From there, as expected, λEEopt [1]decreases with increased circuit power due to the higher power consumption. On the other hand, it can be observed that the respective PTopt increases. This is because in this case if the transmission power is small, the total power consumption will be dominated by the circuitry consumption. With the low achievable throughput, the EE will therefore be worse. The optimal EE will occur when the transmission power is comparable to the circuit power consumption, resulting in a higher PTopt[1], this can be observed from fig.4. Then evaluate the maximum EE under different minimum throughput requirement and different circuit power settings. The optimal EE is the same up to a certain minimum throughput requirement, but drops afterwards can be found in fig.5. When the minimum throughput requirement is low, the required transmit power is also low. Therefore, the most energy efficient design is to operate at a higher transmit power in order to achieve the optimal EE. This is why the optimal EE is constant for low minimum throughput requirements. The optimal operation is to simply fulfill that throughput requirement as in this case the higher the throughput, the lower the EE. This can also be observed that as the achievable throughput is exactly the minimum throughput requirement in those regions. In fig.6, the evaluation of the maximum EE considering different maximum transmission power in the BS. When the maximum transmission power is smaller than or equal to a certain value, the maximum EE for both SVD and DPC increase with Pmax.

Once the optimal EE is reached, further increasing the maximum allowable transmission power will not improve the EE performance. Therefore network operators will need to ensure a sufficient available transmit power to operate at the most energy efficient manner. Power is the main factor to optimize the EE so then comparison of maximum EE obtained by the proposed algorithms using SVD-IA and DPC-IA at different SNR operating regimes. To show the EE loss by considering the inter cell interference in multi cell scenario, we compare with the optimal EE scheme in single cell multi user scenario. In other words, SC-MU is the upper bound on EE in multi cell scenario. So first consider the single data stream case (ds = 1) for the BS. For a moderate range of SNR, DPC-IA outperforms SVDIA in terms of EE. However, at high SNR regime, SVD-IA is better, this is because SVD-IA aims to fully utilize the available degrees of freedom for transmission and hence suitable for high SNR regime. Hence, DPC-IA scheme which only cancel the intercell users and tackle the intracell interference among users by designing the beamformers to maximize EE of each cell, is suitable low to intermediate SNR region. Furthermore, as expected, the maximum EE obtained by SC-MU is higher than both SVD-IA and DPC-IA. Nonetheless, DPC-IA achieves an optimal EE that is close to the SC-MU case at low to moderate SNR region, demonstrating the effectiveness of the proposed scheme. In the next simulation, we evaluate the maximum EE versus SNR in two algorithm implementations for SVD-IA and DPC-IA and thus combine them and compares. This also shows that even though IA generally performs better in high SNR region, the proposed IA schemes can achieve a close to optimal EE performance at low to moderate SNR range. Finally the case of two data stream ds=2 is evaluated. It shows a similar trend for all the solutions as for ds=1can be clearly simulated in fig.7. This reveals that the proposed DPC-IA is superior to the proposed SVD-IA when multiple data streams are transmitted.

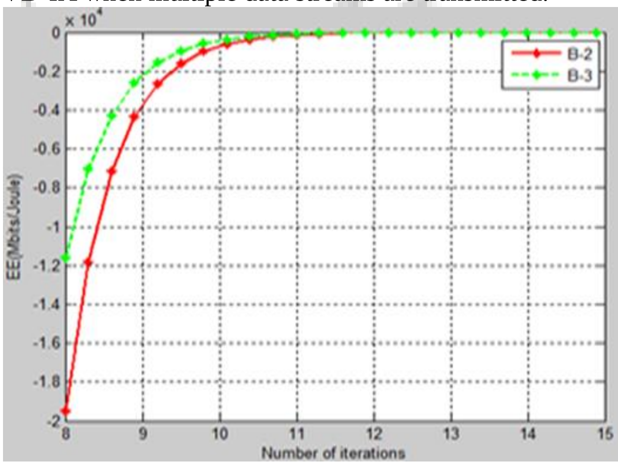

Fig. 3: EE performance with iterations

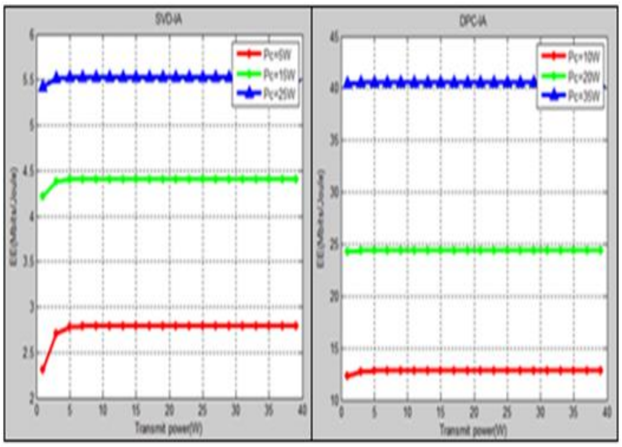
Fig. 4: Comparison of transmit power in terms of EE.

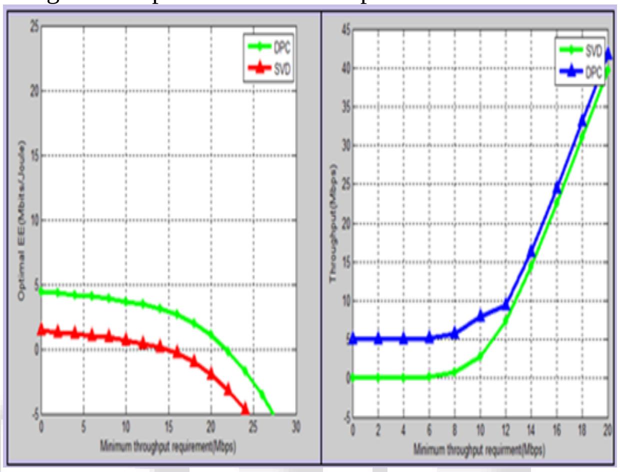

Fig. 5: Throughputs and EE curves

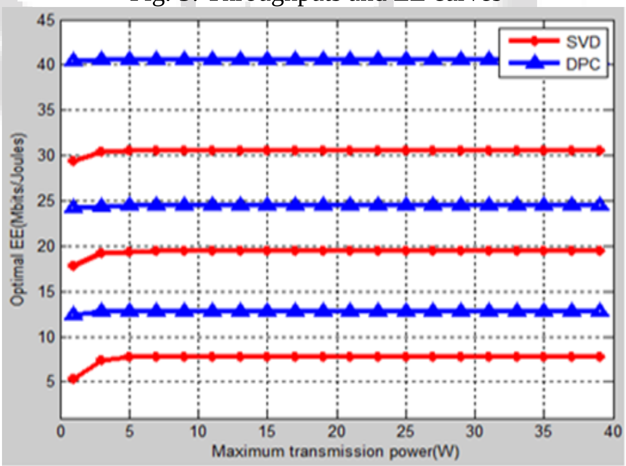

Fig. 6: Maximum transmit power with EE for SVD and DPC

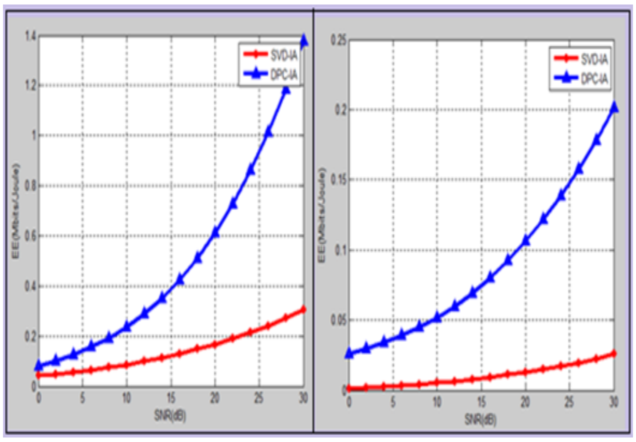

Fig. 7: Comparison of SNR for ds=1 and ds=2.

When we propose a new system it should have more advantages than the existing one then only we can consider the system is good. This system has advantages such as, it can operate in all SNR[1] regions, increased data rate, eliminates interferences, easy to implement, cost effective, proved with simulation that DPC-IA algorithm is best and suitable for the design of a low SNR MIMO-IFBC system. This system has many applications in day to day life. Mainly it focus to be applicable in wireless communication such as, mobile operators, for implementation of base stations, new architectural design in MIMO scenario, it can be used for every wireless system with low SNR, in broadcast channel with interferences and interference alignment and for all long distance communication.

## IV. Conclusion

In this paper, it is discussed about the EE optimization problem for multi cell MIMO-IFBC with IA and proposed two schemes to optimize EE for different SNR regions. For high SNR region, a grouping based IA scheme is selected to cancel inter and intra cell interference and transform the MIMO-IFBC to a single cell single user MIMO scenario. A gradient based power adaptation scheme has been proposed based on the water filling approach and SVD to maximize EE for each cell. For a moderate range of SNR, we propose a method using

DPC to perform IA while maximizing EE in each cell. Simulation results demonstrate that the proposed schemes outperform several existing approaches in all SNR range. More importantly, the proposed DPC-IA scheme achieves an optimal EE that is close to the single cell scenario at low to medium SNR range, which is normally the energy efficient operating region. Finally reached to a conclusion that DPC -IA algorithm is suitable and it is the effective algorithm for the design of a MIMO-IFBC system with IA in a low SNR region. Thereby the EE of low SNR regions can be optimized and can minimizes the overall effect of interferences is proved using simulation results.

## V. Future Scopes

Future advancements in this system can be implemented in terms of its bandwidth limitations and frequency reusing in cooperating with SNR and ISI. This system can also be implemented by using any other tools. Other algorithms can also be used to avoid the effect of interferences. As a new dimension to this work some future works can be preferred for its modification, like its estimation can be done by least mean square estimator, add the equalization technique of feedback equalizer and interleaved coded modulation can be done. For error detection and correction a turbo encoder can be used as a channel encoder. Instead of STBC technique space frequency block coding (SFBC) can be used, and also sequential parametric complex approximation algorithm is also suitable for the design of this system with moderate SNR. Further scopes in advancements are researching and are implementing in nearby years.

## References

[1] J Tang, Daniel K C, et.al "Energy Efficient Optimization with Interference Alignment In Multi Cell MIMO Interfering Broadcast Channel". IEEE Trans., vol.63, pp 2486-2499, July, 2015.
[2] Gaurav Gupta, A K Chaturvedi "User Selection in MIMO Interfering Broadcast Channel", IEEE, vol 40, June 2014.
[3] M.J Kim, Y.C Ko, H.H.Lee "Channel Selection Algorithms Based on Interference Alignment in MIMO Interfering Broadcast Channel" IEEE, pp 1067-1071 Oct 2013.
[4] O. El Ayash, S.W Peters et.al "The Practical Challenges of Interfering Alignment". IEEE, vol.20, pp 35-42, Feb 2013. 3571
[5] J Tang, S Lambotharan "Interference Alignment for MIMO Multi Cell Interfering Broadcast Channel", IEEE, vol. 61, pp 164-175, Oct 2012.
[6] Kuldeep Kumar, Manwinder Singth, "Proposed Waterfilling Model in a MIMO System", IJETAE, vol 1, pp 127-132, Dec 2011. 3571O. El Ayash, S.W Peters et.al "The Practical Challenges of Interfering Alignment". IEEE, vol.20, pp 35-42, Feb 2013.
[7] Y.J Ma, J.L.O, et.al. "Group Based Interference Alignment", IEEE vol 15, pp 383-385, April 2011.
[8] V.R Cadambe, S.A Jafar, "Interference Alignment and Degrees of Freedom of the K User Interference Channel", IEEE Trans, vol 54, pp 3425-3441, August 2008.
[9] Nihar Jindal, Sriram Viswanath, et.al, "On The Duality of Gaussian Multiple Access and Broadcast Channels", IEEE vol. 50, pp 768-783, May 2004.
[10] A.B.Carleial, "Interference Channels", IEEE Trans., vol 24, pp 60-70, 1978.

 