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A Heuristic Approach to Achieve Optimal Capacity and Reduction in Bit Error Rate for MIMO based Land Mobile Satellite System

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Abstract: ***The proposed technique is a heuristic approach to transmit beamforming, an improved BER performance is achieved in the absence of channel statistics. The heuristic beamforming approach based on signal processing technique enables the realization of an alternative to ensure a relatively high degree of satellite coverage directionality without increasing the complexity of satellite payload capability. This paper proposes transmit beamforming in the absence of channel statistical measures. Based on this, system parameters such as Capacity and BER are analyzed. The results obtained are in line with the theoretical values .It is observed that a SNR of 10 dB results in a BER of $10^{-3.8}$ for 16 QAM which is a significant improvement over the conventional technique which has a BER of $10^{-0.5}$ for the same signal to noise ratio value.***

Index Terms: Transmit beamforming, interference reduction, CSI, MIMO.

I. INTRODUCTION

The successful implementation of terrestrial based multiple input multiple output techniques has pioneered extensive research in land mobile satellite MIMO. The wide spread popularity of multi input multi output technology has substantially made the possibility of realizing next generation gigabit wireless a reality [1]. Prior to the use of MIMO based LMS system, single input single output LMS system was used .But the advantages of high multiplexing gain, array and coding gain, multi-user and space diversity gain and also the enhancement of capacity with increase in the number of antennas at the transmitter and receiver end points, thereby resulting in efficient utilization of usable frequency spectrum in comparison to LMS SISO systems has led to the widespread use of MIMO based LMS systems [2], [3], [4]. The earth station component of this system provides urban and sub urban coverage and the satellite component is used to provide high quality of service with improved data reliability [5] and better bandwidth efficiency to rural environments and sparsely populated regions [6].

In LMS MIMO systems, multiple antennas at the satellite and earth station send and receive more than one data signal over the same channel by exploiting the multipath propagation. Theoretical studies and analysis, conducted in this field reveal that there is an increase in capacity when using multiple antennas. Beamforming is a technique widely used in MIMO configurations to reduce co-channel interference hence, enables the usage of higher order modulations such as 64 QAM. Beamforming transmits a null in the direction of interference thereby cancelling the effect of interference upon the signal. Link budget can be improved by directional transmission provided by beamforming. Transmit beamforming technique ensures an improvement in instantaneous signal to noise ratio which in turn reduces the probability of error of received signal. But the practical applicability of transmit beamforming technique in satellite based MIMO system is uncertain as it requires channel state information. The separation between the satellite and ground station increases the complexity of transmission from the earth station and reception of CSI at the satellite. To overcome this issue, a heuristic approach to transmit beamforming is proposed in this paper which requires no CSIT. This technique makes use of information signal being transmitted to provide directionality to the signal transmission reducing the interference and also providing an orthogonality to the data sent from satellite antenna elements to earth station. A substantial improvement in BER, received SNR and data reliability is achieved by the application of this proposed heuristic transmit beamforming technique. The implementation of the proposed techniques is a key step towards attaining an improvement over the previous approaches in the field of satellite based MIMO systems. The paper is divided into following sections: Section II: The methodology is explained with mathematical formulations. Section III: Presents analysis of results and Section IV: The paper is concluded.

II. SYSTEM MODEL

The proposed method addresses the challenges of obtaining a high received SNR by the adoption of heuristic transmit beamforming . The system model overview discusses the mathematical and system design formulation of heuristic transmit beam forming technique with no CSIT .

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2.1) Mathematical and system design formulation of heuristic transmit beamforming technique with no CSIT .

Signal prior to its transmission from the satellite antenna is convolution encoded and QAM modulated. The signal then undergoes heuristic transmit beamforming to further improve the system performance which is mathematically derived as follows:

The discrete time varying MIMO system model is depicted by the following expression [7]:

$$y=Hx+n \qquad (1)$$

where x represents the signal vector being transmitted from satellite station of n_t x 1 dimension and y is the signal vector of n_r x 1dimension, received at the earth station.

n represents the noise vector of n_r x 1 dimension

H represents the channel transfer matrix of n_r x n_t dimension.

n_r and n_t represents the number of receiver and transmitter antenna elements.

In this 2 x 2 MIMO system model, there is uniform power allocation [8] at the transmitter in absence of the CSI at the transmitter .

The transmitted vector is represented as follows:

$$\vec{x}=(x_1,x_2) \qquad (2)$$

It is observed that in most of the transmit beamforming techniques, the input signal components are multiplied with transmit beamforming vectors in order to provide directionality to the signal component so as to prevent interference. It serves as an interference management technique providing assurance to the fact that signal received by the receiver antenna is actually the intended signal oriented towards it . In this proposed methodology, the signal components are used to compute the beamforming weight vectors which distinguish it from the existing beamforming techniques.

The mathematical representation of beamforming vector and the computation of individual beamforming weight vector components are represented as follows:

$$\vec{w}=(w_1,w_2) \qquad (3)$$

$$w_1 = x_1 / \| \vec{x} \| \qquad (4)$$

$$w_2 = x_2 / \| \vec{x} \| \qquad (5)$$

where $\vec{w}$ is the beamforming weight vector and w_1 , w_2 are beamforming weight vector components. $\vec{x}$ is the L2 norm of $\vec{x}$.

$$\vec{z}=(w_1x_1,w_2x_2) \qquad (6)$$

The weight vector computed in (4) and (5) is multiplied with the corresponding signal vector components . Signal beam $\vec{z}$ is directed normal to the antenna.

The resultant signal vector $\vec{z}$ is transmitted from the satellite antenna and it propagates along the channel which is a statistical channel model called Loo model. It is based on the assumption that LOS component is log normally distributed and the multipath effect is Rayleigh distributed. The mathematical interpretation of the model is defined in [9] as:

$$p(r)=r/(b_0\sqrt{2\pi d_0})\int 1/z \;\exp[-(\ln z-\mu)^2/2d_0-(r^2+z^2)/2b_0]I_0(rz/b_0)dz \qquad (7)$$

Where d_o is the variance and μ is the average value of pdf of Loo propagation model .b_0 is the mean scattered power due to multipath fading. I_0 is the zeroth order Bessel function .

The capacity of a channel depends on the allocated spectrum , characteristics of the path as well as the knowledge of channel state information at the transmitter and receiver [10],[11],[12]. Channel Capacity is found to increase with increase in SNR [13] as well. Capacity [14] of time invariant flat fading spectrally efficient optimized channel model in the absence of CSI at transmitter end point by the application of heuristic transmit beam forming is computed.

During the transmission of signal from the satellite to earth station , some transmitted bits would be in error due to the presence of noise ,distortions or bit synchronization redundancy[15]. Hence, a new variant approach to improve the capacity, BER with better reception at the receiver is designed and formulated.

III. RESULTS AND DISCUSSIONS

The performance of proposed method is evaluated by simulations with respect to capacity versus received SNR, BER versus received SNR for 16 QAM , 8 QAM and 4 QAM modulation schemes and the results are tabulated. This section is broadly categorized as 3.1) Analysis of the system performance with respect to capacity, BER of received SNR and also a performance comparison is done.

3.1) Analysis of the system performance with respect to capacity, BER and performance comparison.

The input parameters considered for the proposed system performance analysis is tabulated below:

Table I. Input parameters for the performance analysis of Heuristic system

Input Parameters	Value
Antenna spacing between co-located antenna elements of 2x2 MIMO LMS system	λ/2
Modulation scheme	16 QAM ,8 QAM and 4 QAM
SNR	0-10 dB

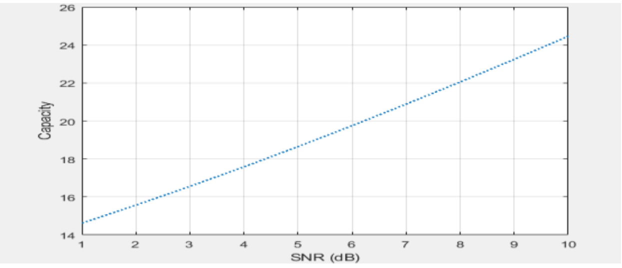

Figure 1. Illustrating the relation between capacity and received SNR for the Heuristic method

For different values of received SNR, capacity is tabulated for the proposed approach.

Table II. Performance Measures based on the Heuristic Method

SNR in dB	Capacity (bits/sec/Hz)
1	14.5
5	18.5
10	24.5

It is inferred that by the implementation of heuristic transmit beamforming ,an enhanced capacity is being achieved in comparison to the conventional technique. A capacity of 18.5 bits / second / Hz is achieved for a SNR of 5 dB and for 10 dB SNR, capacity of 24.5 bits/sec/Hz is observed as illustrated in Figure 1.

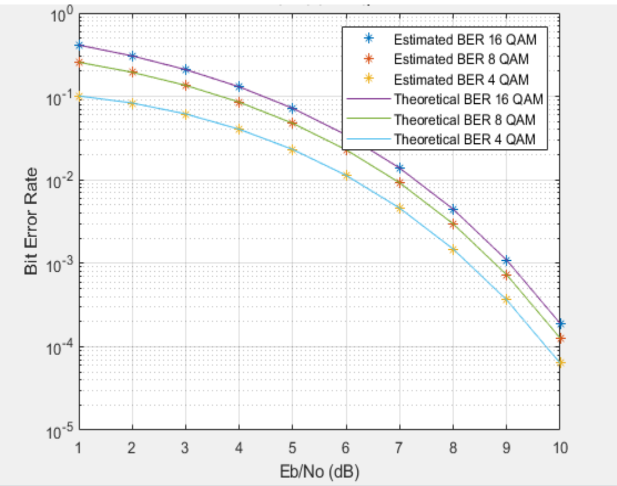

Figure 2. Illustrating the relation between BER and received SNR for the proposed method with respect to 16 QAM , 8 QAM and 4 QAM modulation schemes.

Table III :Performance Measures for Proposed Heuristic Method incorporating 16 QAM modulation scheme.

SNR in dB	BER
1	0.5
5	$10^{-1.2}$
10	$10^{-3.8}$

Table IV: Performance Measures for Proposed Heuristic Method incorporating 8 QAM modulation scheme.

SNR in dB	BER
1	0.35
5	$10^{-1.5}$
10	$10^{-3.95}$

Table V :Performance Measures for Proposed Heuristic Method incorporating 4 QAM modulation scheme.

SNR in dB	BER
1	10^{-1}
5	$10^{-1.9}$
10	$10^{-4.2}$

A received SNR of 5dB results in a BER of $10^{-1.2}$, $10^{-1.5}$ and $10^{-1.9}$, and a BER of $10^{-3.8}$,$10^{-3.95}$ and $10^{-4.2}$ is obtained for a SNR of 10 dB for 16 QAM ,8 QAM and 4 QAM modulation schemes respectively as depicted in Figure 2. BER performance achieved by this heuristic technique for 16 QAM, 8 QAM and 4 QAM is in line with theoretical observations.

Table VI : Performance Measure Comparison between Heuristic and Conventional technique[16]

SNRin dB	BER	
	Heuristic Approach (16 QAM)	**Conventional technique[16]**
10	$10^{-3.9}$	$10^{-0.5}$

A SNR of 10 dB results in a BER of $10^{-0.5}$in conventional technique [16] as illustrated in Table III. By comparing the system performance parameters of proposed approach with the scheme [16], a reduced BER performance is achieved with the heuristic approach.

IV. CONCLUSION AND FUTURE SCOPE

In this experimental work, the analysis was done for a 2 x 2 LMS MIMO system due to practical limitation of having only 2 antennas in the satellite system. An approach was presented which enables beamforming at the transmitter endpoint without requiring CSIT/CSIR providing interference reduction and directionality to the signal. BER of system for 16 QAM, 8 QAM and 4 QAM is analyzed which indicates a better performance in comparison to conventional technique and is in line with theoretical BER performance. A BER of $10^{-3.8}$, $10^{-3.95}$ and $10^{-4.2}$is obtained for a SNR of 10 dB for 16 QAM,8 QAM and 4 QAM modulation schemes ,respectively which is a significant improvement over the conventional technique. An efficient system model with minimum complexity and reduced overhead improving the received SNR, capacity, data rate and reliability is devised. The future scope of this work lies in the implementation of massive MIMO in future gigabit LMS communication systems, as it seems promising and competent enough to increase the data rate without any extra bandwidth. Also, the multi-user massive MIMO technique with multiple carrier systems and signal detection schemes with precoding and equalization techniques would provide better performance measures in comparison with the prevalent technology. It is a step towards the next generation communication system.

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Rachana B.Nair. received her B.E degree in Electronics and Communication Engineering from Tamil Nadu College of Engineering, India in the year 2006. She is a M.Tech post graduate in Cyber Security from Amrita University, India .Also, worked as an Assistant Professor in Ammini College of Engineering from 2011-2016. Currently, pursuing Ph.D in MIMO based LMS system in Amrita University. Her area of interest include digital/analog /optical/wireless/satellite communication systems and cryptography.

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Currently, pursuing research in compact conformal antennas for air-borne vehicle communication links, soft computing based antenna design for wireless systems like MIMO, MIMO satellites, Millimeter wave MIMO and Miniaturization of antenna and RF subsystems. He is having more than 50 research publications in Journals and conferences and a co-author in two book chapters.Currently, he is a Professor and Chairperson of the Department of Electronics and Communication Engineering, Amrita School of Engineering, Coimbatore campus since 2013. Fellow of Institution of Electronics and Telecommunication Engineers (FIETE) and Hon. Vice Chairman of IETE Coimbatore Center.

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