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Selective Spanning With Fast Enumeration Algorithm for MIMO

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Abstract-

Multiple input multiple output system have been emerged technology to increase channel capacity and a technical breakthrough for high data rate wireless transmission. The main objective of MIMO system is to obtain low Symbol Error Rate (SER) and acceptable computational complexity. The MIMO system cannot be implemented due to complexity problem. The complexity of MIMO system can be reduced by using different detector algorithms. In this paper, the performance of MIMO system over AWGN (Additive White Gaussian Noise) with ZF, MMSE, SD, K best algorithm and SSFE are analyzed using different antenna configuration. The Bit Error Rate performance of all detectors are studied for 16QAM modulation technique using AWGN channel for the analysis purpose and their effect on BER (Bit Error Rate) have been presented.

Keywords- Complexity, detector, MIMO system, ML, SER, SD, SSFE.

I. INTRODUCTION

Multi Input Multi Output (MIMO) system has multiple antennas at transmitter and receiver side to improve channel capacity under limited bandwidth and transmit power. In MIMO system, fading can be effectively mitigated and link reliability is significantly improved[5]. The MIMO system is mainly used for high data rate by means of spatial diversity. So MIMO system is efficient solution for wireless communication system and the capacity of MIMO system is depends on the number of transmit and receive antennas. MIMO systems are implemented to obtain diversity gain or capacity gain to avoid fading[1]. The transmitter and receiver of MIMO system are essential to have an accurate estimation of the Channel State Information (CSI)[5]. If the number of antenna is increases in MIMO system to estimate CSI is challenging task in practical. So it is not implemented in practical due to complexity of receiver design [13]. The receiver has a problem to separate transmitted information symbol.

This is the reason for complexity. For this complexity problem MIMO system are used detectors to detect accurate transmitted symbols. The performance of some detector is complicated and degrades performance of MIMO system again it increases complexity. So we have to choose detectors carefully. The optimum MIMO detector is Maximum Likelihood detector gives good performance when compare with other detectors[8]. The solution involves an exhaustive search through all possible transmitted signal vectors; this search has exponential complexity, which is undesirable in practical systems. The detector increase complexity exponentially when the number of transmit and receive antennas are increases. Other sub-optimal algorithms such as ZF and MMSE are practically considered with some disadvantage e. So the suboptimal MIMO detectors have been developed to reduce computational complexity. The searching process viewed as tree structure only path with small distances are kept. The tree traversal algorithms are classified into depth first algorithm such as SD and breadth first algorithm such as K best. Sphere detector gives near ML performance with reduced computational complexity. The searching process is reduced in sphere detector to limiting the search by drawing a circle around the received signal just small enough to the closest lattice point within a sphere radius and eliminates the search of all points outside the circle [5]. The depth-first tree search algorithm is used in SD leads inconvenient for implementation because the computational complexity varies for different signals and channels and [17] the number of tree node visited is large in low SNR and visited node is small in the high SNR range.

This algorithm typically have variable throughput which is undesirable in system with strict latency requirement [10]. The alternative algorithm K best algorithm is fixed throughput and it visit constant number of nodes independent of SNR. In K best large K value is required to achieve performance close to exhaustive search [11]and sorting is required to find the K best path at each step of algorithm. The K best algorithm has sorting complexity. So we forward into modified algorithm to find fast approximation to sort. In SSFE M update vector is used to find K smallest path without sorting each step of algorithm. In the simulation result, we prove the performance of SSFE algorithm is good compared with other suboptimum detectors for different antenna configuration.

In this paper we discuss about detector which are used in MIMO receiver system and compare the performance of detectors BER with SNR .Our simulation result show SSFE gives good bit error rate. Section II describes the background information about detectors of MIMO system. Section III discuss about the new proposed method. Finally simulation and results are discussed in Section IV.

II. RELATED WORKS

In this section, we discuss about the background information of detectors used in MIMO receiver. The goal of this topic has been to provide an overview of all detector used in MIMO receiver [16]. We are going to discuss which method is the best in practice. In signal detection method, the transmitted signals are assumed as interference signal except for desired data stream from the target transmit antenna. Here we minimized or nullified interference signal from other transmit antenna for detecting desired signal from target transmit antenna. Many signal detectors are used in MIMO system [4].

A. Zero Forcing

Zero Forcing is the linear detector algorithm used in MIMO system which applies the inverse of the frequency response of the channel[15]. It applies the inverse of the channel frequency response of received signal, to restore the signal after the channel. In MIMO system it knowing the channel allows recovery of the two or more streams which will be received on the top of each other on each antenna. The name Zero Forcing corresponds to bring down the inter symbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise.

x is the transmitted data over H channel now we get y received data

$$y=H x \quad (1)$$

Using zero forcing detector in the MIMO receiver part we get the estimated transmitted data is

$$X\hat{}= Hx(1/H) \quad (1)$$

H^{-1} or (1/H) is the channel inverse. The simplest way of calculating inverse is by means of QR factorization, H=QR. It can also be calculated in a more stable way and it avoids inverting the upper triangular matrix R[10]. Here zero forcing detectors are used to find the transmitted data from the received signal. It is simplest and reasonably easy to implement.

B. Minimum Mean Square Error Detector (MMSE)

MMSE does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI component in the output[14]. The MMSE is used to minimize E (X^2). It is used to reduce error signal. MMSE estimator is a method in which it minimizes the mean square error (MSE), which is a universal measure of estimator quality [10]. The same problem they are discussed above in zero forcing is addressed in MMSE because MMSE detector is small modification in the ZF denominator of the channel frequency.

Let us assume that x be an unknown random variable and R be a known random variable, then

$$R=HX+n \quad (3)$$

An estimator X(R) is any function of the measurement y, and its mean square error is given by

$$MSE = E \{(X\hat{}- X)2 \} \quad (4)$$

Here the expectation is taken over both X and R. The MMSE always performs better than the ZF equalizer and is of the same complications of implementation[10]. The linear detectors are suffering in performance loss in fading channel especially spatial correlation between antenna elements.

C. Maximum Likelihood

The maximum likelihood detector for a MIMO receiver operates, by comparing the received signal vector with all possible noiseless received signals in the receiver side searches across all possible combinations, and tries to solve the inter channel interference (ICI) caused by transmitting from all antennas simultaneously, on the same frequency[5]. Under certain assumptions, this receiver achieves optimal performance in the sense of maximizing the probability of correct data detection[9]. Maximum-likelihood (ML) detection for high order MIMO systems face a major challenge in computational complexity that grows exponentially with the number of transmitted and received antennas and depends only on the spectral efficiency [5]. This limits the practicality of these systems from an implementation point of view, because it's impossible to implement for large array sizes and high order digital modulation schemes particularly for mobile battery-operated devices. This reality motivated researchers to consider other suboptimal approaches for MIMO decoding, such as Zero Forcing (ZF), Minimum Mean Square Error (MMSE). The computational complexity of ML is equal to the complexity of single–input multiple–output (SIMO) systems[9]. The model for the generic multiple-input multiple-output (MIMO) system can be written as

$$y = Hx + n \qquad (5)$$

where **x** denotes the transmitted signal vector of dimension $N\times 1$ and **y** denotes the noisy received signal vector of dimension $P \times 1$; **H** is the channel matrix of dimension $P\times N$ represents a vector of independent Gaussian noise When the transmitted symbols are uniformly distributed, the optimum detector (in the sense of minimizing SER) is the maximum likelihood (ML) detector[9]. The ML detector calculates the squared distance **d** between the received vector **y** and every possible signal constellation **X**:

$$d = \|y- Hx\|^2 \qquad (6)$$

At a receiver, a detector forms an estimate of the ransmitted symbol. The optimal detector minimizes the average probability of error, i.e., it minimizes P(x^ ~=x).

$$\min \|y-Hx\|^2 \qquad (7)$$

Here the minimization over all the points in the constellation. Given the "skewed" lattice **Hx**, find the "closest" lattice point to a given dimensional vector **x**. The closest lattice point search problem in is known to be, in general, of exponential complexity[5]. The basic idea is to specify in advance the number of constellation points to be considered when calculating Euclidean distance metrics for each transmit antenna [12]. The ML decoding technique is the optimal decoding technique achieving the best performance in terms of Symbol Error Rate (SER)[8] ML detector uses an exhaustive search algorithm where all possible codeword are checked, and the one with minimum distance is selected as the final codeword.

D. Sphere Detector

Sphere Detector is a suboptimum detector technique which aims to reduce the computational complexity of the ML detector technique[1]. In case of a sphere detector the searching process can be view as tree structure like small path distance only kept. The received signal is compared to the closest lattice point, since each codeword is represented by a lattice point[4]. The number of lattice points scanned in a sphere detector depends on the initial radius of the sphere. The correctness of the codeword is dependent on the SNR of the system[4].

The search can easily be restricted by drawing a circle around the received signal. So the search allows only those codeword to be checked that happen to fall within the sphere radius. All the remaining codeword are not taken into consideration for decoding. The radius must be chosen in such a way that the value should cover the lattice. The initial radius selected plays a critical role in identifying the correct point in the lattice. Ideally, the noise variance of the system is found and the initial radius of the sphere is adjusted according to the Signal to Noise Ratio. This entails the sphere detector to find at least a single point inside the sphere. [2] The main idea of the Sphere Detector is to reduce the computational complexity of the maximum likelihood detector by only searching over only the noiseless received signals that lie within a sphere of radius R around the received signal[3]. The depth-first tree search algorithm is used in SD leads inconvenient for implementation because the computational complexity varies for different signals and channels. The main problem with depth-first sphere detection is that the number of tree nodes visited is large in the low signal to noise ratio (SNR) range, while the number of tree nodes visited is small in the high SNR range[4]. As a result, depth-first sphere detection algorithms typically have variable throughput which is undesirable in systems with strict latency requirements.

$X^{\wedge}= \text{argmin } X€x^{M} \; ly^{\wedge}\text{-}Hxl^{2} <= R^{2}$ (8)

E. K Best algorithm

The K best algorithm approach reduce MIMO detection problem as a breadth first tree search operation[6]. This algorithm proceed spanning sorting and deleting process repeating level by level till to reach leaf node. After the final level, K best candidate are sorted and output as a final candidate list. The idea of the K-Best algorithm is to select only the smallest k distances in each level in the tree[17]. It is simpler than the sphere decoder (depth-first) because in the K Best the number of calculations is fixed for any received data vector which approximately equals $k \times N \times 2M$, where $2M$ is the modulation order (constellation size) in each level and N is the number of levels[11]. The number of levels is twice the number of transmit antennas in our implementation whereas in the sphere decoder this may reach the full $2MN$ complexity order of the ML decoder. The K best nodes are expanded to the next level to maintain a constant throughput [16] and the best K candidates based on PED are sorted at each level of tree. To achieve ML performance we require large K value, which result in an increased complexity and memory requirement. So K best algorithm contains higher hardware complexity compared to the sphere decoder. The smaller K value not only helps to reduce the number of the sorting stages[11]. The complexity is occurring due to calculation of PED and sorting K best distance.

F. Selective Spanning With Fast Enumeration (SSFE) Algorithm

In the SSFE algorithm, we do not perform sorting among the branches originating from different branches in the previous level. We only sort the branches emerging from the same node at any level; this will cause the SSFE tree search to be more structured and allow for some parallelism in the implementation. Therefore, the number of operations in SSFE decoder is potentially less than that of the K-Best decoder[12] because the K-Best uses a sorting unit to reduce the branches after each stage. The SSFE decoder allows for parallel processing of the branches and that makes the SSFE potentially faster than the K-Best at the expense of more hardware. The level update vector is used to structure number of spans for each node in tree traversal. No nodes are deleted in this algorithm. Based on the update vector the length of candidates in the final list is selected.

SSFE decoder with $\mathbf{m}$ = [2 2 1 1], where $\mathbf{m}(i)$ is the number of surviving paths at level i emerging from any of the $\mathbf{m}(i-1)$ surviving paths at level $(i-1)$. The distance equation is also the metric of the SSFE algorithm. The SSFE operation may be explained as follows. Starting from first level (the equation of $\hat{}y4$), we search to get the best $\mathbf{m}(1)$ symbols nearest to y (received vector) based on the distances calculated from equation (7). In the second level, for each one of $\mathbf{m}(1)$ surviving branches from the previous step, search for the best $\mathbf{m}(2)$symbols nearest to received symbol by computing the incremental distances from equation and adding them to the distance from the previous branch, which will be one of the surviving $\mathbf{m}(1)$ branches from the previous step. Repeat the previous steps until reaching the last level (note that in the SSFE, we do not do any sorting across the different surviving paths from the previous level, we only sort within the branches emerging from the same surviving path in the previous level). Finally, we have $\mathbf{m}(1)\times\mathbf{m}(2)\times\mathbf{m}(3)\times\mathbf{m}(4)$ surviving branches. The advantage of SSFE is memory rearrangement and non-deterministic dynamism is all eliminated.

III. PROPOSED WORK

SYSTEM MODEL

Based on the performance of MIMO system we construct the above block diagram. In this transmitter part of the block diagram bits are send and using modulation techniques the bits are converted into symbols. Then the transmitted symbols are sending via multiple antennas at the transmitter. This symbol through over the wireless channel and reaches the receiver via receiving antenna. The output of the receiver having noise with input signal. Using detector we find the transmitted signal. Here we are choosing K best and SSFE algorithm. Both are modified of sphere detector. The searching problem is taken as tree structure format which path with small distance only kept. [13]In K best sorting and deleting process are repeated to reach leaf node. In SSFE greedy algorithm is used without sorting process so the performance of SSFE is when we compare with K best and other suboptimal detectors. The K best algorithm first we declare K value for sorting process[17] and then SSFE tree structure is declare as M vector. After the receiver the performance is based on the detectors. Finally we get the transmitted bit.

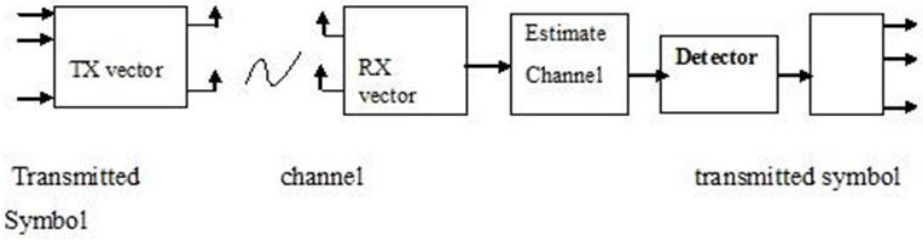

Fig.1: 2×2 MIMO transceiver architecture with detector

SIMULATION SYSTEM

The following figure explains about the process of our project. Here the bits are sending from the transmitter part to receiver part via wireless channel. Consider the bits are X. It may be X_1,X_2,……X_n are sending to the Modulated symbol block. In this block the bits are converted into the symbols. Each symbol consist of few bits presented it based on the Modulation technique. After that the symbols transmitted via multiple antennas present at the transmitted side. This antenna sends the symbols to the next block channel. Now we get the output form Hs. Here some noises are added with the output so we get Hs+n. here n is the Gaussian noise. This reaches the receiver side of the multiple antennas. Then this antenna sends the received symbols to the next section. Here the transmitted symbols are estimated with the help of the Euclidean distance of received symbols, channel and transmitted symbols.

$$X\wedge = \text{l}Y\text{-}Hs\text{l}^2 \qquad (9)$$

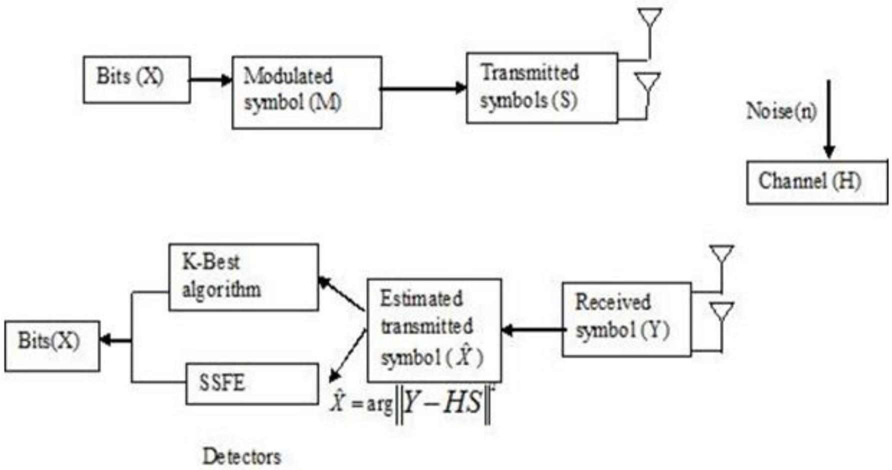

Fig 2: Flow Diagram

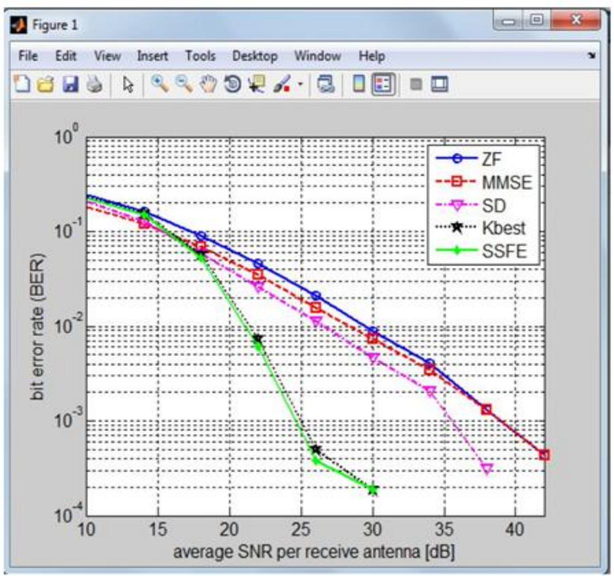

Fig.3: performance comparison of 4×4 MIMO detector

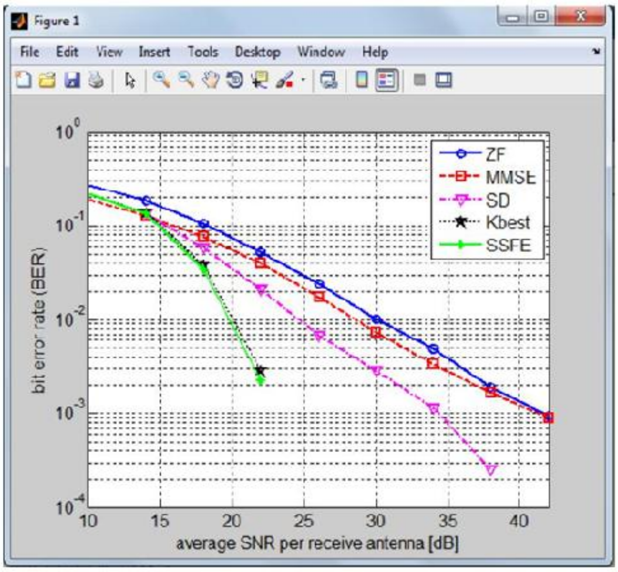

Fig.4: performance comparison of 5×5 MIMO detector

IV. RESULT AND DISCUSSION

In this section, the BER analyses of MIMO detectors are done for 16 QAM modulation techniques over AWGN channel. The BER analysis of MIMO detectors are done for 16 QAM modulations for different values on M and N. Here the antenna configuration is 4×4, 5×5, 6×6, 7×7. From the simulation result we understand performance of SSFE[5] and K best detectors are best when compared with other detectors. At the SNR range of 35 to 40 dB we get BER is for ZF, MMSE and SD but the same BER rate is occurred by K best and SSFE detector at SNR 25 dB and 24dB for 4×4 antenna configuration. So performance of SSFE is good. For different antenna configuration the performance of all detectors are varying and gave better performance.

V. CONCLUSION

In this paper, SNR vs. BER plot for 16 QAM over AWGN channel for MIMO system employing different antenna configurations are presented. We considered receiver design of MIMO systems with Gaussian channel estimation errors. In this paper we analyzed performance and comparison of the MIMO detectors with K best and SSFE .Our K best and SSFE is robust to CSI errors and is near optimal in the sense of minimizing the probability of symbol error. We demonstrated, via simulations, that our SSFE detector incurs very small performance loss (when compared to the exact ML solution) with significantly lower computational complexity.

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