ISSN : 2231-0711

Performance Enhancement of K-Best MIMO Decoder

R.Ramya, V.Tamizhamuthu

Department of Electronics and Communication,Sri Manakula Vinayagar Engineering College, Puducherry, India-605107.

Abstract-**This work focuses on a modified K-Best algorithm for a multi input and multi output communication system. In MIMO systems, the maximum-likelihood (ML) decoder is known as the optimum scheme in the sense of minimizing the bit error rate (BER) which exponentially has increased computational complexity particularly in high-dimensional MIMO communication systems. The sphere decoding algorithm and its relevant K-Best decoding algorithm have been adopted, because of their ability to implement ML decoding with significantly reduced complexity. In this work, also a special type of code called gold code is used which boost ups the performances further. Also the combined benefits of radius reduction commonly associated with sphere decoding and the benefits associated with the K-Best decoding approaches are obtained. This modified algorithm needs much smaller value of K which holds the advantages of branch pruning algorithm and adaptively updates pruning threshold, on achieving near optimum performance. When compared to K-Best decoder this examines smaller number of points as much as possible. This K-Best decoder supports a 4X4 64-QAM system efficiently.**

Key words:-MIMO, sphere decoder, k-best, gold code

I. INTRODUCTION

The greatest current challenge for future wireless communication systems is to provide broadband mobile (or at least portable) data access with a quality of service (QoS) as high as possible.

The key role in mobile radio techniques is played by the effective bandwidth availability and only a limited bandwidth for data transmission is available to each wireless service. For years researchers around the world have been intently searching for these multiple-antenna systems, called MIMO systems i.e., Multi input and multi output system. It is now possible to achieve a major increase in spectral efficiency (bps/Hz) with a simultaneous increase in failure safety of connections through the use of MIMO technique.

Multi Input Multi Output systems have emerged as a major area of research in the field of Wireless Communications for many applications. It is defined as a wireless communication system consisting of multiple antennas at the transmitter and multiple antennas at the receiver.

II. SYSTEM MODEL

The number of antennas at the transmitter and receiver are denoted by M and N respectively. For the case, when the transmit antennas equal the receive antennas, we denote the number by N [1].The equation representation for this system is given by,

$$Y = Hs + n \tag{1}$$

where,

H matrix = N X M which is a channel matrix

S vector contains m=2M elements

Y vector contains n=2N elements

This both vectors can be represented as, H = n x m.

For this system model the estimated transmitted ML signal vector is given by

$$S_{ML} = \arg\min_{s\in\Omega^m} \|y - Hs\|^2 \tag{2}$$

where,

Ω is a set contains all possible modulation points.

III. SPACE-TIME BLOCK CODES

The STBCs are realized with the goal of finding a tradeoff between diversity and multiplexing. The data transmission rate can be increased by sending same symbols at different time instants [2]. This would save the redundancy of sending the same symbols, which in turn would increase the data rate. But, in a multipath environment, there is a possibility that the channel cannot support the data rate decided by the Space Time Block Code. The multipath fading characteristics most often results in lossy transmission, which would lead to incorrect decoding at the receiver. Apart from the most popular Alamouti code which has a code rate of 1, there are several other codes, which maintain the orthogonal structure of the code, but with lower code rates. The following is the half rate space-time block code for a 4-Tx system. In this case, four symbols are transmitted in eight time slots. The rate of this code is therefore 1/2.

$$G_4 = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2 & x_1 & -x_4 & x_3 \\ -x_3 & x_4 & x_1 & -x_2 \\ -x_4 & -x_3 & x_2 & x_1 \\ x_1^* & x_2^* & x_3^* & x_4^* \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & -x_2^* \\ -x_4^* & -x_3^* & x_2^* & x_1^* \end{bmatrix} \tag{3}$$

In above matrix the column specifies the antenna number and row specifies the time slot. The code rate can be increased by reducing the time slots in transmitting the same information. This can be clearly observed in the following code which has a higher code rate.

IV. GOLD CODES

Gold codes are used efficiently when multiple data is transmitted where the codes have bounded small cross-correlations within a set of transmitted symbols. A set of Gold code sequences consists of $2^n - 1$ sequences each one with a period of $2^n - 1$.

This gold code can be generated using the following steps.

1. Pick two maximum length sequences of the same length $2^n - 1$ such that their absolute cross-correlation is less than or equal to $2^{(n+2)/2}$, where n is the size of the linear feedback

shift register used to generate the maximum length sequence [3].
2. The set of the $2^n - 1$ exclusive-ors of the two sequences in their various phases (i.e. translated into all relative positions) is a set of Gold codes. The highest absolute cross-correlation in this set of codes is $2^{(n+2)/2} + 1$ for even n and $2^{(n+1)/2} + 1$ for odd n. The code is given below.

$$C = \frac{1}{\sqrt{1+p^2}} \begin{bmatrix} S_i + jp.S_{i+3} & p.S_{i+1} + S_{i+2} \\ S_{i+1} - p.S_{i+2} & jp.S_i + S_{i+3} \end{bmatrix}, \quad (4)$$

$$p = \frac{-1+\sqrt{5}}{2}$$

The matrix given above is the transmission format where row indicates the number of antenna and column indicates the time slots required to transmit the symbols $\{S_i, S_{i+1}, S_{i+2}, S_{i+3}\}$. p is the constant which is given by above value used to transmit 4 symbols in just 2 time slots. This achieves full diversity and full rate and the code is called golden code. It is introduced in the transmitter side which encodes the symbols efficiently and obtains the full code rate.

V. SPHERE DECODER

A sphere decoder searches for the closest lattice point within a certain search radius [4]. The search radius leads to tradeoff between performance and complexity which is given in [5]. In this, we focus on analyzing the performance of sphere decoding with golden codes.

The SDA traverses through the tree and computes the path metric for each node in the tree, where any branch that delivers a path metric exceeding the predefined pruning constraint R will be discarded. Thus, only the remaining subset of the tree is visited, and thus the complexity can be reduced. This algorithm usually performs a depth-first search and selects child node by following Schnorr-Euchner (SE) strategy where the K-Best algorithm traverses the tree in a breadth-first level-by-level fashion with only K best nodes kept at each level. It requires a sufficient large K to maintain a performance level that is close to ML, which results in an increased complexity. Furthermore, due to its level-by-level tree Search fashion, this algorithm does not update R adaptively for discarding unpromising nodes. Therefore, the K-Best decoder usually searches more nodes and contains higher hardware complexity compared to the sphere decoder [6].

In order to reduce the complexity, winner path extension (WPE) K-Best decoding approach is used here where there is no need of sorted list of the K nodes chosen at each level. The step by step process of this approach is as follows.

Step:1 For the K survivors from a previous level, compute the search center.

Step:2 Extend each of the centers to its best child node.

Step:3 Among these extended points, select the one with the smallest path Metric as the winner path, and put it into a "winner list."

Step:4 Replace the winner path by the next best node.

Step:5 Repeat 4) until candidate list contains K nodes.

However, this effort has been made to reduce the K nodes required to achieve a certain BER. These approaches are typically tied to a complex preprocessing algorithm such as column vector reordering and matrix inversions which increases the complexity of the preprocessor. In the given work, we provide a means of both reducing K by using a special encoding technique and maintaining performance with only a typical QR preprocessing stage; thus, the overall complexity of the decoder is reduced [7].

VI. COMBINED MODEL OF K-BEST AND GOLD CODE

This work presents a modified K-Best decoding algorithm that can achieve high average decoding throughput with low complexity. The key contributions in this work are the following,

1) This algorithm requires a smaller K. Furthermore, the only required preprocessing operation is a standard QR matrix decomposition.
2) The tree pruning thresholds are updated by this approach and any non-promising tree nodes beyond this threshold will be discarded in the early stages of tree searching. Hence, the search space is reduced and also the complexity.
3) In this paper a sorter-free WPE structure has been studied that can decrease the implementation complexity.

The modified K-Best decoding algorithm can achieve close-to-ML performance with a much smaller value of K and significant reduction in the number of search nodes. The severity of the problem is reduced and the required K value of algorithm is decreased here. In K-Best approach, K nodes are kept at each level of the tree branches [5]. Another method is the tree is decomposed into A individual sub-branches which are also called as A stages. A new K is obtained to search these sub-branches. A represents the number of possible values in the constellation and the nodes at the top tree level are considered as the new root points of each stage. The updating of the pruning constraint reduces the search space.

The total number of nodes will not decrease by merely decomposing the tree into A sub-branches, since a straightforward decomposition sequentially distributes the search nodes into different stages [8]. This should be taken into account and a method to reduce the number of nodes should be used. This reduction is achieved by updating the pruning constraint at the completion of each stage. On updating this constraint, two major effects are obtained.

i. Unpromising nodes are neglected similar to the sphere decoder.
ii. Further the complexity to search the tree is reduced by terminating the search early without the need to process the entire stages.

With is the efficient code called gold code which is explained in subdivision V is combined with this modified algorithm. This results in the performance enhancement which is analyzed in simulation results in terms of bit error rate.

VII. SIMULATION RESULTS

The Modified K-Best decoding algorithm have been presented through tree decomposition and early termination, the proposed algorithm searches less modulation points and results in lower complexity. Gold codes have been introduced which enhances the performances for various k values is presented in below figures. Fig. 1 presents the simulation that verifies the BER performance of gold code with space time block code whereas 5 antennas are used. From this it is clearly known gold code has better performance when compared to STBC G4. Because of 4 antennas and 8 time slots the bit error rate is poor for G4 code whereas for gold code only 2 antennas and 2 time slots are used to send two symbols. So this achieves better bit error rate performance when compared to G4 which is depicted in below fig.1.

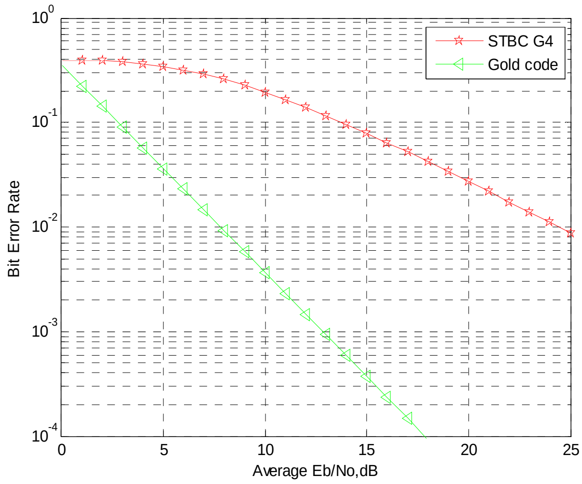

Fig. 1: BER of gold code

Fig. 2 shows the performance of the 16 and 64 QAM systems when combined with gold code as an encoding technique.

1. For 64 QAM system the SNR ranges up to 25 dB where in modified k-best can achieve the same solution with k=7.
2. If k is reduced to 5 there will be deviation from performance that becomes dominant for high SNRs i.e., SNR>20 dB.
3. 16 QAM system with k=5 is compared with proposed algorithm with k=5 gives a better BER performance.

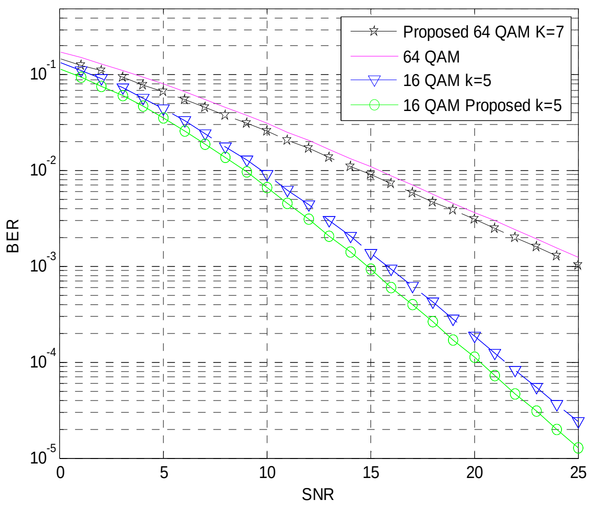

Fig. 2: Performance of 16 & 64 QAM

Fig. 3 shows the performance of the 16 and 64 QAM after standard QR decomposition is applied.

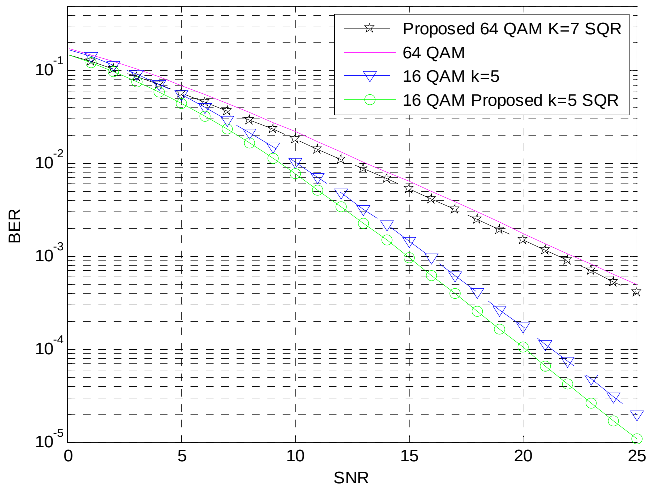

Fig. 3: BER with different k with SQR

After SQR applied, the 16 QAM shows no difference whereas higher order gives better performance.

VIII. CONCLUSION

Of all the available decoding algorithms, this work studies the k-Best algorithm. This reduces the complexity of the existing algorithm by searching less number of nodes. The performance was enhanced by combining a new code which is called as golden code with the modified algorithm even for higher order constellation.

REFERENCES

[1] Hochwald and S. Brink, "Achieving near-capacity on a multiple-antenna channel," IEEE Trans. Commun., vol. 51, no. 3, pp. 389–399Mar. 2003.

[2] X.-B. Liang, "A High-Rate Orthogonal Space-Time Block Code", IEEE Communications Letters, vol. 7, pp. 222-223, May 2003.

[3] Ouertani, R.; Saadani, A.; Othman, G.R.-B.; Belfiore, J.-C.; "On the Golden Code Performance for MIMO-HSDPA System", Vehicular Technology Conference- IEEE 64th , 1-5, Sept. 2006.

[4] A. M. Chan and I. Lee, "A New Reduced Complexity Sphere Decoder for Multiple Antenna Systems," IEEE International Conference on Communications, vol. 1, pp. 460-464,2002.

[5] Babak Hassibi and Haris Vikalo, "On the sphere-decoding algorithm I.Expected complexity", IEEE Transactions on Signal Processing, 53(8), 2806–2818, 2005.

[6] Z. Guo and P. Nilsson, "Algorithm and implementation of the K-Best sphere decoding for MIMO detection," IEEE J. Sel. Areas Commun. vol. 24, no. 3, pp. 491–503, Mar. 2006.

[7] Chung-An Shen and Ahmed M. Eltawil, "Radius Adapative K – Best Decoder With Early Termination Algorithm and VLSI Architecture", IEEE Trans. On Circuits And Systems—I: Regular Papers, pp. 1-11, March 2010.

[8] A. D. Murugan, H. El Gamal, M. O. Damen, and G. Caire, "A unified framework for tree search decoding: Rediscovering the sequential decoder," IEEE Trans. Inf. Theory, vol. 52, no. 3, pp. 933–953, Mar2006.