

International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research Website: www.ijdacr.com (Volume 1, Issue 2, September 2012)

Low Complexity Sphere Decoding for V-BLAST Spatial Multiplexing MIMO

Abhishek jain abhishekjain0106@gmail.com Angita Hirwe Angita.hirwe@gmail.com Rupesh Dubey rupesh_dubey7@yahoo.co.in

Abstract— With the tremendous growth in the field of communication, wireless system requires significantly higher spectral efficiency. The solution of this problem is MIMO Spatial Multiplexing (SM). In this paper we compare performance of different methods for decoding multiple input-multiple output (MIMO) transmission System incorporating VBLAST-SM, which includes sphere decoding (SD), zero forcing (ZF), SVD-SD and maximum likelihood (ML) techniques.

Keywords:- MIMO SM, V-BLAST, ZF, ML, MMSE, SD.

I. INTRODUCTION

In present scenario with advancement in the field of communication, wireless system requires significantly higher spectral efficiency (i.e., higher transmission rate measured in bit/second/Hz) improved quality of service. The drawback is overcome by assigning additional bandwidth this can enhance capacity linearly. Due to assignment of spectral resources not only expensive also limited. So the best way to enhance the system capacity without requiring the need to additional spectral resources is MIMO Spatial Multiplexing (SM). In SM, multiple signals are transmitted instantaneously via enough spaced antennas. This result in linearly increase in the channel capacity proportional to the minimum number of receives and transmit antennas. However, MIMO SM-based system requires strong signal processing methodes at the receiver to efficiently recover the signal transmitted from the multiple antennas, and hence to explore the advantages of MIMO systems. At the receiver side, the main challenge resides in designing signal processing techniques, i.e., detection techniques, capable of separating those transmitted signals with acceptable complexity and achieved performance.

Over the last two decades diverse Multiple-Input Multiple-Output (MIMO) arrangements have been developed for achieving diversity, multiplexing and/or beam-forming gains [1]. For example, while Bell Lab's Layered Space-Time (BLAST) scheme [2] was designed for high-rate transmission, the class of Space-Time Block Codes (STBCs) [3] was developed for achieving a beneficial diversity gain.

A. MIMO system

A MIMO system typically consists of m transmit and n receive antennas (Figure-1).By using the same channel, every antenna receives not only the direct components intended for it, but also the indirect components intended for the other antennas. A time-independent, narrowband channel is assumed. The direct connection from antenna 1 to 1 is specified with h11, etc., while the indirect connection from antenna 1 to 2 is identified as cross component h21, etc. From this is obtained transmission matrix H with the dimensions n x m.

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{\dots} & h_{1m} \\ h_{21} & h_{22} & h_{\dots} & h_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ h_{n1} & h_{n2} & h_{\dots} & h_{nm} \end{bmatrix}$$



Figure .1 block diagram of MIMO



International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research Website: www.ijdacr.com (Volume 1, Issue 2, September 2012)

The following transmission formula results from receive vector y, transmit vector x, and noise n.

Y=Hx+n

Data to be transmitted is divided into independent data streams. The number of streams M is always less than or equal to the number of antennas; in the case of asymmetrical $(m \neq n)$ antenna constellations, it is always smaller or equal the minimum number of antennas. For example, a 4x4 system could be used to transmit four or fewer streams, while a 3x2 system could transmit two or fewer streams. Theoretically, the capacity C increases linearly with the number of streams M.

$$C = MBlog_2\left(1 + \frac{S}{N}\right)$$

In a MIMO system, a given total transmit power can be divided among multiple spatial paths (or modes), driving the capacity closer to the linear regime for each mode, thus increasing the aggregate spectral efficiency.

MIMO systems enable high spectral efficiency at much lower required energy per information bit. Spectral efficiency is observed to be improved with increase in no. of input, output elements of MIMO system.

The increasing demand for high data rates and, consequently, high spectral efficiencies has led to the development of spatial multiplexing systems.

B. MIMO spatial multiplexing

Spatial multiplexing techniques simultaneously transmit independent information sequences, often called layers, over multiple antennas. Using M transmit antennas, the overall bit rate compared to a single-antenna system is thus enhanced by a factor of M without requiring extra bandwidth or extra transmission power.

In any case for MIMO spatial multiplexing the number of receives antennas must be equal to or greater than the number of transmit antennas.

To take advantage of the additional throughput offered, MIMO wireless systems utilise a matrix mathematical approach. Data streams t1, t2... tn can be transmitted from antennas 1, 2... n. Then there are a variety of paths that can be used with each path having different channel properties. To enable the receiver to be able to differentiate between the different data streams it is necessary to use. These can be represented by the properties h12, travelling from transmit antenna one to receive antenna 2 and so forth. In this way for a three transmit, three receive antenna system a matrix can be set up: r1 = h11t1 + h21t2 + h31t3r2 = h12t1 + h22t2 + h32t3

$$r3 = h13t1 + h23t2 + h33t3$$

Where r1 = signal received at antenna 1, r2 is the signal received at antenna 2 and so forth. In matrix format this can be represented as:

$$[R] = [H] \times [T]$$

To recover the transmitted data-stream at the receiver it is necessary to perform a considerable amount of signal processing. First the MIMO system decoder must estimate the individual channel transfer characteristic hij to determine the channel transfer matrix. Once all of this has been estimated, then the matrix [H] has been produced and the transmitted data streams can be reconstructed by multiplying the received vector with the inverse of the transfer matrix.

$$[T] = [H] - 1 \times [R]$$

C. V-BLAST Technique

Bell-labs Layered Space-Time (BLAST) architecture belong to the class of Layered Space-Time Coding.

A data stream is de-multiplexed into M sub-streams termed layers in BLAST architecture. The layers are arranged horizontally across space and time for V-BLAST and the cycling operation is removed before transmission as shown in Fig.2. At the receiver, as mentioned previously, the received signals at each receive antenna is a superposition of M faded symbols plus additive white Gaussian noise (AWGN).

The detection process consists of two main operations:

I) Interference suppression (nulling):

The suppression operation nulls out interference by projecting the received vector onto the null subspace (perpendicular subspace) of the subspace spanned by the interfering signals. After that, normal detection of the first symbol is performed.

II) Interference cancellation (subtraction):

The contribution of the detected symbol is subtracted from the received vector.

O IJDACR International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research Website: www.ijdacr.com (Volume 1, Issue 2, September 2012)



Figure .2 Block diagram of V-BLAST Architecture

II. DETECTION TECHNIQUES

A. Zero Forcing Equalizer

Zero Forcing Equalizer refers to a form of linear equalization algorithm used in communication systems which applies the inverse of the frequency response of the channel. The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel The name Zero Forcing corresponds to bringing down the inter-symbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. For a channel with frequency response F(f) the zero forcing equalizer C(f) is constructed by C(f) = 1/F(f) Thus the combination of channel and equalizer gives a flat frequency response and linear phaseC(f)F(f) = 1.

Zero-Forcing (ZF) technique is the simplest MIMO detection technique, where filtering matrix is constructed using the ZF performance based criterion. The drawback of ZF scheme is the susceptible noise enhancement and loss of diversity order due to linear filtering.

To alleviate for the noise enhancement introduced by the ZF detector, the MMSE detector was proposed.

B. Minimum mean square error (MMSE)

In statistics and signal processing, a minimum mean square error (MMSE) estimator describes the approach which minimizes the mean square error (MSE), which is a common measure of estimator quality. The term MMSE specifically refers to estimation in a Bayesian setting with quadratic cost function. Let x be an unknown random vector variable, and let y be a known random vector variable (the measurement or observation). An estimator $\hat{x}(y)$ of x is any function of the measurement y. The estimation error vector is given by $e = \hat{x} - x$ and its mean squared error (MSE) is given by the trace of error covariance matrix

$$MSE = tr \left\{ E\{(\hat{x} - x)(\hat{x} - x)^{T}\} \right\}$$

Where the expectation is taken over both x and y. When x is a scalar variable, then MSE expression simplifies to E { $(\hat{x} - x)^2$ }. The MMSE estimator is then defined as the estimator achieving minimal MSE.

C. Maximum Likelihood



A simplified linear MIMO communication system

In MIMO system main task is detecting a set of M transmitted symbols from a set of N observed (received) signals. To assist us in achieving our goal, we draw the transmitted symbols from a known finite alphabet $X = \{x_1 \dots x_B\}$ of size B.

O IJDACR International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research Website: www.ijdacr.com (Volume 1, Issue 2, September 2012)

The detector's role is then to choose one of the B^M Possible transmitted symbol vectors based on the available data. An optimal detector should return, $\hat{s} = s_*$, the symbol vector whose (posterior) probability of having been sent, given the observed signal vector v, is the largest:

$$s_* \triangleq_{s \in X^M}^{\operatorname{arg} max} P(s \text{ was sent } | v \text{ is observed})$$

$$s_* \triangleq_{s \in X^M}^{\operatorname{arg} max} \frac{P(v \text{ is observed} | s \text{ was sent })P(s \text{ was sent})}{P(v \text{ is observed})}$$
Above equation is known as the Maximum A

Above equation is known as the Maximum A posteriori Probability (MAP) detection rule. Making the standard assumption that the symbol vectors $s \in X^M$ is equiprobable, i.e. that P(s was sent) is constant, the optimal MAP detection rule can be written as:

 $s_* \triangleq_{s \in X^M}^{\arg max} P(v \text{ is observed} | s \text{ was sent })$

A detector that always returns an optimal solution satisfying above equation is called a Maximum Likelihood (ML) detector.

D. Sphere Decoding (SD)

Sphere Decoding (SD) approach was inspired from the mathematical problem of computing the shortest non-zero vector in a lattice. The principle of SD is to search for the closet constellation point to the received signal within a sphere with predetermined radius 'd', where each transmit candidate is represented by a lattice point in a lattice field {Hs}. Figure 3 depicts a geometrical representation of the idea behind SD algorithm, the search can be restricted to be in a circle around the received signal just small enough to enclose at least one lattice point or ML solution, thus search time can be significantly reduced by eliminating the search of those lattice points lie outside the circle.



Figure .3 model of Sphere Decoding

Techniques like Maximum likelihood decoding require an exhaustive search over all possible code words used. The computational complexity of these techniques is exponential in the length of the codeword. A promising approach called the sphere decoding algorithm was proposed to lower the computational complexity.







International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research Website: www.ijdacr.com (Volume 1, Issue 2, September 2012)



IV. Conclusion

Spatial Multiplexing with VBLAST decoder has been analyzed for Zero Forcing, Sphere Decoding, SVD-SD and Maximum Likelihood Equalizers. Above mentioned figure depicted is a modulation of QASK and constellation value of 2.different detector has been implemented and ML give better performance then SD, ZF, V-blast .when SD is modified the SVD-SD perform better then SD hence SVD-SD is less complex then ML, SD respectively. So over all SVD-SD is better.

V. References

[1] L. Hanzo, O. Alamri, M. El-Hajjar, and N. Wu, Near-Capacity Multi-Functional MIMO Systems: Sphere-Packing, Iterative Detection and Cooperation. John Wiley and IEEE Press, 2009, 714 pages.

[2] P. Wolniansky, G. Foschini, G. Golden, and R. Valenzuela, "V-BLAST: An architecture for realizing very high data rates over the rich-scattering wireless channel," in Proceedings of the International Symposium on Signals, Systems, and Electronics (ISSSE'98), Pisa, Italy, 1998, pp. 295–300.

[3] V. Tarokh, N. Seshadri, and A. Calderbank, "Space-time codes for high data rate wireless communication: performance criterion and code construction," IEEE Transactions on Information Theory, vol. 44, no. 2, pp. 744–765, 1998.

[4] Foschini, G.J.: "Layered space-time architecture for wireless communication in a fading environment when using multiple antennas', Bell Lab. Tech. J., 1996, 1, (2), pp. 41–59

[5] M. Grotschel, L. Lov´asz, A. Schriver, "Geometric Algorithms and Combinatorial Optimization", Springer Verlag, 2nd ed., 1993

[6] U. Fincke, M. Pohst, "Improved methods for calculating vectors of short length in a lattice, including a complexity

analysis". Mathematics of Computation, vol. 44, pp. 463–471, 1985

[7] T. Kailath, H. Vikalo, B. Hassibi, "MIMO Receive Algorithms" in Space-Time Wireless Systems: From Array Processing to MIMO Communications, (editors H. Bolcskei, D. Gesbert, C. Papadias, and A. J. van der Veen), Cambridge University Press, 2005

[8] Kwan-wai Wong, Chi-Ying Tsui, R. S.-K. Cheng, Wai Ho Mow, "A VLSI architecture of a K-best lattice decoding algorithm for MIMO channels", ISCAS (3) 2002: 273-276