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Implementation Of V-BLAST Detector In MIMO For High Data Rate SDR

Prof. Madki M. R. Miss Mane S. S.
Department of Electronics,
Walchand Institute of Technology, Solapur.413006

Abstracts

The demand for ever higher speed mobile communication is one of the main drivers of the telecommunication industry. A promising method capable of achieving high data rates is Multiple Input – Multiple Output (MIMO) technology, which has the potential to increase capacity linearly with the number of antennas. Orthogonal Frequency Division Multiplexing (OFDM) employed in conjunction with MIMO architecture constitutes an attractive solution for modern wireless communication systems as it has the ability to deal with multipath propagation. While designing a receiver structure for this MIMO system, two main considerations that should be taken into account are the error performance and the implementation complexity. One such receiver is the V-BLAST (Vertical Bell-Laboratories Layered Space-Time) which utilizes a layered architecture and applies successive cancellation by splitting the channel vertically, and at every stage the stream with the highest signal to noise ratio (SNR) is decoded.

1. Introduction

Multiple Input Multiple Output (MIMO) wireless systems use multiple antenna elements at transmit and receive to improve capacity over single antenna topologies in multipath channel characteristics play key role in determining communication performance.

OFDM can be used in conjunction with a MIMO transceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems.

A key part of the system is the receiver (Rx) signal processing algorithm. The first proposed algorithms were the Diagonal Bell Laboratories Layered Space-Time (D-BLAST) and VBLAST. While the D-BLAST achieves the full MIMO capacity, it is more complex as compared to the VBLAST, which, despite its simplicity, achieves a significant portion of the full MIMO capacity. V-BLAST is a detection algorithm to the receipt of multi-antenna MIMO systems.

Previous studies have shown that, the comparative study presents various MIMO VBLAST detection algorithms with respect to signal to noise ratio (SNR) and bit error rate (BER) performance. As the comparison results show, Minimum Mean Square Error (MMSE) algorithm is the best solution for 2X2 MIMO system targeting at Giga-bit wireless transmission. So we are implementing this detection technique, which is utilized by the high data rate Software Defined Radio (SDR). The term software radio implies radio functionalities defined by software. SDR enables a single terminal to handle various kinds of wireless systems through a simple software change and it reconfigures the terminal function.

2. Multiple Input Multiple Output (MIMO):

To achieve a high system capacity for multimedia applications in wireless communications, various methods have been proposed in recent years. Among them, the MIMO system using multiple antennas at both the transmitter and the receiver has attracted a lot of research interest due to its potential to increase the system capacity without extra bandwidth, and providing spatial diversity not available to single antenna systems. Thus, information can be sent and received over multiple channels.

In recent years, MIMO based wireless communications has received widespread attention in the communication community. To date, a majority of the work in this area has been of a theoretical nature and little attention has been paid to the implementation requirements of MIMO system.

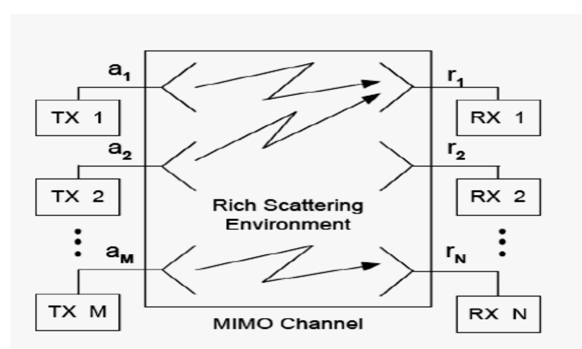

Figure 1. MIMO Channel

They transmit independent data (say x1, x2, …,xM) on different transmit antennas simultaneously and in the same frequency band. At the receiver, a MIMO decoder users M>N or M=N antennas. Assuming N receive antennas, and representing the signal received by each antenna as rj we have:

r1= h11X1 + h12X2 +...+ h1NXN
r2= h21X1 + h22X2 +...+ h2NXN
.
.
.

$r_N = h_{N1}X_1 + h_{N2}X_2 + \ldots + h_{Nn}X_N$

As can be seen from the above set of equations, in making their way from the transmitter to the receiver, the independent signals {x1, x2, …, xN} are all combined. Traditionally this "combination" has been treated as interference. However, by treating the channel as a matrix, we can in fact recover the independent transmitted streams {xi}. To recover the transmitted data stream {xi} from the {rj} we must estimate the individual channel weights hij, construct the channel matrix H. Having estimated H, multiplication of the vector r with the inverse of H produces the estimate of the transmitted vector x. This is equivalent to solving a set of N linear equations in N unknowns.

In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter symbol-interference (ISI) in case of frequency selective channel. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrowband sub channels experiences almost flat fading. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments.

3. Vertical Bell-Laboratories Layered Space-Time (V-BLAST):

The V-BLAST is an ordered successive cancellation method applied to receiver and at every stage the stream with the highest SNR is decoded.

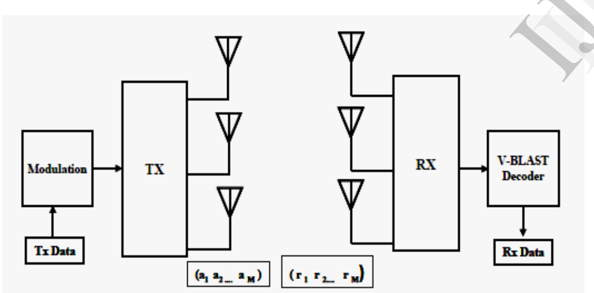

Figure 2. V-BLAST System Model

Main Steps for V-BLAST detection:

1. Ordering: choosing the best channel.
2. Nulling: using ZF, MMSE, ML.
3. Slicing: making a symbol decision
4. Canceling: subtracting the detected symbol
5. Iteration: going to the first step to detect the next symbol.

The detection process consists of two main operations:

1. 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.

2. Interference cancellation (subtraction):
The contribution of the detected symbol is subtracted from the received vector.

Its principle is quite simple, first it detects the most powerful signal (Highest SNR), and then it regenerates the received signal from this user from available decision. Then, the signal regenerated is subtracted from the received signal and with this new sign; it proceeds to the detection of the second user's most powerful signal, since it has already cleared the first signal and so forth. This gives less interference to a vector received. In V-BLAST , however, the vector encoding process is simply a demultiplex operation followed by independent bit-to-symbol mapping of each sub stream.

As the received signal at each antenna for each subcarrier is a signal that consists of a combination of multiple data streams from multiple transmit antennas, a higher complexity detector is required to recover the transmitted vector compared to single antenna systems. Therefore the V-BLAST detector is used here.

3.1 V-BLAST with Minimum Mean Square Error (MMSE):

V-BLAST detection uses linear nulling techniques such as Minimum Mean Square Error (MMSE) and Zero Forcing (ZF). The MMSE receiver suppresses both the interference and noise components, whereas the ZF receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence, MMSE is superior to ZF in the presence of noise. The MMSE receiver gives the solution of,

$$\hat{x} = D \cdot x = \left(\frac{1}{SNR} I_{N_R} + H^H H\right)^{-1} \cdot H^H x$$

This technique targets to enhance the performance of V-Blast detector by improving the SNR, which in run utilize by high data rate Software Defined Radio.

4. Software Defined Radio (SDR):

Nowadays interests of MIMO researchers are shifting from theoretical analysis to experimental verification of developed algorithms & systems. Equipment for experiment are desired to be flexible to implement a variety of MIMO system, e.g. spatial multiplexing & space time coding, open loop & closed loop, single user & multiuser. One of the solution for such an equipment is software defined radio (SDR) technology.

In recent years, much attention has been paid to software-defined radio (SDR) technologies for multimode wireless systems. SDR can be defined as a radio communication system that uses software to modulate and demodulate radio signals.

Software Defined Radio (SDR) technology makes use of highly flexible radios i.e. SDR changes its function by rewriting software on reconfigurable

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devices such as FPGA and DSP. This technology is extremely valuable to the research community, since an SDR platform can be used for experiments on multiple communication schemes inexpensively compared to traditional approaches.

The demand for mobile communication systems with global coverage, interfacing with various standards and protocols, high data rates and improved link quality for a variety of applications has dramatically increased in recent years. The Software-Defined Radio (SDR) is the recent proposal to achieve these. In SDR, new concepts and methods, which can optimally exploit the limited resources, are necessary. Smart antenna system is one of those, which combats the co-channel interference and maximizes the user capacity of mobile communication system

5. Conclusion:

The MMSE V-BLAST detection algorithm will gives the better SNR and BER performances with 2X2 MIMO system employing OFDM, that can be used for high data rate SDR. And which will appear to be a better solution for MIMO system targeting at GHz wireless transmission. However, the system can be used in the area where there is need of high data rate transfer.

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