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Performance Analysis of Efficient Power Allocation Techniques with Different Modulation for 4X4 V-BLAST MIMO-OFDM System

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Abstract

Objectives: To propose an optimal power allocation method for high-speed V-BLAST MIMO-OFDM system for better performance in terms of SNR and BER than the traditional methods. **Materials and Methods:** To study and evaluate the performance of two linear channel estimators, the Least Square Error (LS) and Linear Minimum Mean Square Error (LMMSE) are used for 4 × 4 VBLAST Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) system with different modulation-4 QAM,16QAM and 64 QAM. For power allocation, optimal power is determined by the Greedy Power Allocation and the Cuckoo Search algorithm depending on the condition of the carriers measured from the channel estimation. **Findings:** Based on the detection method, Vertical Bell Labs Layered Space-Time (V-BLAST) MIMO-OFDM is found to be the high-speed system. Here, the proposed optimal power allocation method for high-speed V-BLAST MIMO-OFDM system showed a better performance in terms of Signal to Noise Ratio (SNR) and BER than the traditional methods. This thesis work has been evaluated based on different channel estimation with different modulation techniques for V-BLAST MMSE MIMO-OFDM System. The test program has been implemented in the latest technology system in Matlab R2013a. The experimental results show that our proposed method achieves better performance in terms of Bit Error Rate (BER) and SNR compared with the existing methods used for improving the performance of the MIMO-OFDM. Linear MMSE proved efficient channel estimation technique over LS. MMSE -OSIC achieves very good performance with respect to other detectors in VBLAST MIMO-OFDM environment for 4×4 MIMO-OFDM systems. **Application:** This result would be useful to make efficient Adaptive MIMO-OFDM system. It would be also useful in adaptive modulation and power allocation concept for making better wireless communication system. This performance analysis can perform for different channel models.

Keywords: Cuckoo Search (CS) Algorithm, Frequency Division Multiplexing, Greedy Power Allocation, Multiple Input Multiple Output Orthogonal, (MIMO-OFDM), Optimal Power Allocation, Vertical Bell Labs Layered Space-Time (V-BLAST) Detection

1. Introduction

Now a days lots of applications require wireless communications. To broadcast a large amount of data rate, additional bandwidth is required which is very costly. So there is a need for us to move to the efficient concept of MIMO. In wireless communications, reliability can be accomplished with the help of Space-Time Code (STC) because here multiple redundant copies of data will be transmitted. Therefore, as a result, the high probability is accomplished. Using STC maximum amount of data can be fetched. Classifications of STC mainly two type, Space-Time Block Code (STBC) and other Space-Time Trellis Code (STTC). To achieve diversity gain using STTC multiple antennas, multiple copies of data are issued. While in STBC to accomplished diversity gain block of data is

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transmitted at a time. So it is the very straightforward technique than STTC. Combining both the techniques MIMO and OFDM Wireless communication becomes more profitable[1-4].

MIMO provides peer-to-peer communication at the transmitter as well as at receiver side. Using the concept of MIMO the High rate of data can be achieved without extra bandwidth. Three main components of MIMO are Transmitter, receiver, and channel. To achieve diversity gain in MIMO the important classification of coding algorithms are pre-coding, spatial multiplexing and diversity based scheme. Pre-coding mainly depends on the design of the antennas. While in spatial multiplexing data streams are broadcasted to multiple antennas individually and in diversity based scheme, structured codes are broadcasted to space and time domain. MIMO consists of two types of equalization techniques mainly linear and non-linear. In the linear method of equalization, Zero-Forcing and Minimum Mean Square Error are the standard linear detection technique. Though the linear technique is easy to execute, it will be affected from noise enhancement so they are not used in wireless communications. Although it suffers from noise, it requires only low complexity for implementing the hardware. In this case, we can increase the performance by utilizing Ordered Successive Interference Cancellation (OSIC). But in the case of non-linear, it does not suffer from noise enhancement[5,6].

In OFDM, data streams are broadcasted to a various number of subcarriers by splitting the high rate stream of data into many low-rate streams of data. To avoid Inter Symbol Interference, the guard time is introduced and to bypass Inter-Carrier Interference, OFDM symbol is expanded cyclically. To avoid the problem of interference, the OFDM transmits data using closely spaced narrowband orthogonal subcarriers. To acquire diversity gain OFDM is integrated with multiple antennas at transmitter and receiver. In OFDM, the channel is divided into various sub-channels to achieve diversity gain. To maintain orthogonality with minimum frequency division to each other, the frequency of various subcarriers is overlapped. Here the available bandwidth is utilized powerfully. To achieve efficient communication in OFDM system a standard detection technique known as VBLAST is introduced. Here the detection process utilizes techniques like zero-forcing and minimum mean square error. In this algorithm, at first, the most powerful signal is detected first and then the received signal is regenerated. After that this regenerated signal is subtracted from the received signal and the same process is repeated. To enhance performance, the data stream is decoded with high Signal to Noise Ratio (SNR) at the receiver side. There are two operations in the detection process at receiver. First is the elimination of interference after that the process of detecting the first symbol is done. In Second step the detected symbol is subtracted from the received symbol then it utilizes various receivers to perform the detection technique[7-13].

Several recent research papers with different approaches for improving the spectral efficiency of MIMO-OFDM Systems are reported in the literature. It has been proposed the fractional water filling algorithm for the coded Zero Forcing V-BLAST system which implemented joint power and rate allocation that simultaneously maximized instantaneous system capacity and minimized the outage probability of the MIMO-OFDM system[14]. The Fractional Water Filling (FWF) algorithm significantly outperformed other strategies. By analyzing the performance and simulation results, the full MIMO diversity is achieved by the FWF algorithm. For outage performance of the algorithms, precise approximations and a number of closed-form bounds were given. Many outcomes also applied to generic multi-stream transmission systems or the systems depending on successive interference cancellation. It has been proposed a speedy algorithm for inverse Cholesky factorization to calculate a triangular square-root of the estimation error covariance matrix for Vertical Bell Laboratories Layered Space-Time architecture (V-BLAST).Then It was applied to intend an improved square root algorithm for V-BLAST, which speeded up several steps compare to the previous one and can offer additional calculation savings in MIMO-OFDM systems. Compared to the conventional inverse Cholesky factorization, the proposed method has kept away the back substitution of the Cholesky factor and required only half divisions. Compared to existing V-BLAST algorithms, this kind of V-BLAST algorithm was speedy.

It has been proposed baseband processor which is efficient for MIMO-OFDM system specifically in uplink mobile communications[15]. They have also proposed an Inter-carrier Interference-based (ICI-cancellation-based) Carrier Frequency Offset (CFO) estimator to solve the CFO problem in the multiuser transmission. For minimum Signal-to-Interference-Noise (SINR) ratio, it was executed based on an iterative search criterion. The efficient maximum likelihood Bit-Error-Rate (BER) result was achieved by using two MIMO detectors-vertical Bell Laboratory layered space-time (V-BLAST) and V-BLAST

with maximum likelihood. Additionally, integration and verification of the complete transceiver were done by a System-on-Chip (SoC) platform to denote its efficiency. It has been proposed a superposition-based adaptive modulated STBC (SPAM-STBC) for improvement of adaptive modulation optimization of Space-Time Block Coding (STBC) in MIMO-OFDM systems. For the different channel conditions in transmit antennas, the prior adaptive modulated STBC chosen the same modulation based on averaging of the multiple channel gains. When different modulation was preferred to every transmit antenna, the STBC decoding problem arose. In this method, they selected the best possible modulation corresponding to each channel circumstance by the super positioned space-time encoding and decoding. From simulation performances, it is clear that SPAM-STBC scheme gave better result compare to both the fixed and adaptive modulated STBC schemes by the maximum 0.407 bits/sec/Hz in terms of spectral efficiency. It has been developed an efficient process for error estimation of MIMO-OFDM system[16]. They have analyzed estimation in several applications. With increased complexity, while performing loading, the proposed algorithm gave the best performance. They have shown system dependent performance for the algorithm of bit loading in coded OFDM. The proposed method of Adaptive interleaving has come out to be a good option and accumulation in bit loading for coded OFDM. Finally, with targeting error rate to a certain limit, the application of the resulting expressions to an adaptive coded modulation algorithm gives an efficient result. From Signal to Interference plus Noise Ratio (SINR) and Bit Error Rate (BER), the proposed efficient power allocation algorithm is efficient for Cuckoo Search algorithm as well as Greedy power allocation and also to achieve better BER, the corresponding modulation is also adapted. For channel estimation, the Linear Minimum Mean Square Error (LMMSE) and Least Square Error (LS) are used for 2x2 VBLAST MIMO-OFDM[16]. The presented work in this research paper is extended work of that.

2. Materials and Methods

2.1 Cuckoo Search (CS) Algorithm in V-BLAST MIMO-OFDM

The objective of Cuckoo Search (CS) algorithmis to propose a new solution instead of the weaker fitness solution: The first step in this algorithm is to introduce a random population of n host nests with the power of the subcarriers Pi. The second step is to gain a cuckoo randomly by Levy flight behaviour, i which is defined by

$$Xi\ (t + 1) = Xi\ (t) + á \oplus Levy\ (ë),\ á > 0 \quad (2.1)$$

$$Where\ \ Levy\ (ë) = t\ (-ë),\ 1 < ë < 3 \quad (2.2)$$

Then calculate its fitness function, Fi by subtracting last best solution from present best solution. Now randomly choose nest (say j) among host nests and find its fitness function, Fj. The key point in this algorithm is to replace j by new solution, if Fj>Fi and at new locations build new ones using Levy flights. In finding the optimum solution, it is essential to keep current optimum nest and again randomly find a cuckoo if Maximum Iteration is more than Current Iteration.Based on the results computed from the cuckoo search algorithm, the power allotted optimally to the subcarriers. Next, pivoting on the power allotted to the subcarriers modulation can be selected adaptively for modulating the symbols. The fundamental idea in adaptive modulation is to transfer at high data rate when the subcarrier power is valid and at lower data rate when the same is not at the good level. If the symbol cancellation is perfect, The *BER*, E_{kn} of the ith transmitted symbol in terms of the post- detection SINR can be calculated by

$$BER_{kn} = E_{kn} = f(SINR) \quad (2.3)$$

The Signal to Noise Ratio (SNR) for the M-ary QAM can be calculated on knowing BER by

$$SNR = \frac{1}{3}\left[Q^{-1}\left(\frac{BER}{4}\right)\right]^2\left(2^C - 1\right) \quad (2.4)$$

Where $Q^{-1}(x)$ = Inverse Q function

$$c = \text{Coding rate} = \frac{k}{n} = \frac{\text{Number of information bits}}{\text{Number of encoded bits}}$$

From the values calculated from the equations (2.3) and (2.4), the modulation can be chosen adaptively as given by the Table 1[17].

2.2 Greedy Power Allocation in V-BLAST MIMO-OFDM

The greedy power allocation algorithm for allocating the optimal power to the subcarriers contains two stages. They are Initial stage and Data transmission stage.

2.2.1 Initial Stage

In the introductory stage, the bit and power allocation are resolved using a greedy algorithm. The steps concerned

Table 1. Adaptive Modulation based on given SNR and BER

Modulation	SNR BER=10^{-2}	SNR BER=10^{-3}	SNR BER=10^{-4}
8QAM 1/2	8 < SNR < 10.5	10 < SNR < 12.5	11.5 < SNR < 14
8QAM 3/4	11 < SNR < 13.5	13.5 < SNR < 15.5	15 < SNR < 17
16QAM 1/2	10.5 < SNR < 11	12.5 < SNR < 13.5	14 < SNR < 15
16QAM 3/4	13.5 < SNR < 16.5	15.5 < SNR < 18.5	17 < SNR < 20
32QAM 1/2	13.5 < SNR < 16.5	15.5 < SNR < 18.5	17 < SNR < 20
32QAM 3/4	16.5 < SNR < 19.5	18.5 < SNR < 22	20 < SNR < 23
64QAM 1/2	16.5 < SNR < 19.5	18.5 < SNR < 22	20 < SNR < 23
64QAM 3/4	SNR > 19.5	SNR > 22	SNR > 23

in the greedy power allocation algorithm are as accompanies: Let the total power constraint is *Pt* and the transmit power for the *k*th subcarrier *Pk* is given by

$$P_{m,k} = f(b_{m,k})\, G_{m,k}(H) \tag{2.5}$$

Where $b_{m,k}$ = Number of bits transmitted with the carrier *k* from the mth transmitting antenna

$G_{m,k}(H)$ = Pseudo inverse of the kth carrier

$f(b_{m,k})$ = transmit power for transmitting bits with targeted BER and it is given by

$$f(b_{m,l}) \cong \left\{ Q^{-1}\left(\frac{p_r(e)}{K} \right) \right\}^2 \frac{(2^b - 1)N_0}{3} \tag{2.6}$$

Where $P_r(e)$is the symbol error probability for $2 \le K \le 4$ and N_0 is noise power

Step 1: Initialization

$b_{m,k}$=0 and $G_{m,k} = 0$

Step 2: Bit and power assignment iterations

The optimal bit and power allocation iterations continued until the following constraint is satisfied

$$\sum_{m=1}^{M}\sum_{k=1}^{K} P_{m,k} \le P_{total} \text{ (For maximum bit rate,}$$

$$R = \max \sum_{m=1}^{M}\sum_{k=1}^{K} b_{m,k} \text{)} \tag{2.7}$$

Then calculate the residual power for the transmission of one more bit as in the given equation

$$\Delta P_{m,k}(b_{m,k}+1) = G_{m,k}(H)\left[f(b_{m,k}+1) - f(b_{m,k}) \right] \tag{2.8}$$

Find the subcarrier and the transmitting antenna which causes minimum value of $\Delta P_{m,k}$ by

$$\{\hat{m}, \hat{k}\} = \arg \min_{m,k} \Delta P_{m,k} \tag{2.9}$$

The number of bits for the next iteration is calculated by

$$b_{\hat{m},\hat{k}} = b_{\hat{m},\hat{k}} + 1 \tag{2.10}$$

Then calculate

$$P_{\hat{m},\hat{k}} = P_{\hat{m},\hat{k}} + \Delta P_{\hat{m},\hat{k}} \tag{2.11}$$

Equation (2.8) can also be written as

$$\Delta P_{m,k}(b_{m,k}+1) = G_{m,k}(H)\left[2^{b_{m,k}+1} - 2^{b_{m,k}} \right] \tag{2.12}$$

Step 3: Optimal bit and power allocation values

After the iterations are completed by meeting the constraints in equation (2.7) the set of power,

$P = \{P_{m,k}\}_{m=1,k=1}^{M,K}$ and number of bits, $b = \{b_{m,k}\}_{m=1,k=1}^{M,K}$

to be allocated for the subcarriers will be obtained. Thus in the initial stage the optimal bit and power values are calculated and in the data transmission stage, the subcarriers will be allocated with these bit and power values.

2.2.2 Data Transmission Stage

In the transmission stage, the carriers will be allocated with optimal power and bits, found from the initial stage. The main aim of greedy power allocation is to allocate the maximum power to the subcarrier through strongest sub channel and lower power to the weaker one. For achieving this condition of the channel is estimated from channel estimation through SNR value and then the channels are sorted in the ascending order of their strength. After that the power and bit will be allocated optimally to the carriers as determined from the initial stage[18,19].

Hence from the estimated channel information the technique of adaptive modulation and optimal power allocation can be done in the V-BLAST MIMO-OFDM with the use of Cuckoo search algorithm as well as greedy

power allocation algorithm. The capacity of the system will be also improved and it yields good BER performance. The results obtained with the proposed system are discussed in the following section.

3. Results and Discussion

The proposed system is employed in the MATLAB platform with the system configurations of Intel core i3 processor, 4GB RAM and Windows 8 Operating systems. We are analysing the execution of the proposed representation using 4x4 V-BLAST MIMO-OFDM. The records used for communication through the system are produced by the Pseudo Random series creators with the data rate of 64 kbps. The complete power constraint on the system to the transmission of signals is 1W, which is allotted to the subcarriers. The whole channel bandwidth is 20 MHz and is segmented into 64 subcarriers every with the random amount of assigned power. The signals to be transferred are encoded with convolution encoding, and they are plotted into symbols by M-ary QAM. Next, they are changed into the time domain through IFFT with the size of 64, and the sampling rate is 20MHz. After that, the cyclic prefix is supplemented to the symbols with the length of 16 that is 16 bits from the extremity of the series is bound previously the beginning of the bit series. Then, they are inherited by the transmitting antennas to the recipient side through the Rayleigh fading channel. At the recipient side, the signals are demodulated by ejecting the cyclic prefix and changing it back to the frequency domain. Consequently, the similar signals are used for channel computation and V-BLAST decoding to recover the communicated signal. In the Channel estimation stage, the cuckoo search algorithm is implemented for optimal power allotment and adaptive modulation. The results demonstrate that the proposed system attains higher BER and SNR performance before an optimal power allocation.

The power dispensed to the subcarriers in the 4x4 V-BLAST MIMO-OFDM utilizing both the greedy power allocation and the Cuckoo Search algorithm are analysed in the accompanying Figure 1. In Figure 1, utilizing greedy power allocation least power is designated to the initial eight carriers and after that power allocation increment step by step. However, utilizing cuckoo search the power assigned to the second carrier is minimized and it is evident that the algorithm gives an optimum power allocation to the majority of the 16 carriers. Henceforth, from the figure 1it is clear that both the algorithms, giving the best possible power allocation to the carriers concerning the aggregate power requirement in the framework.

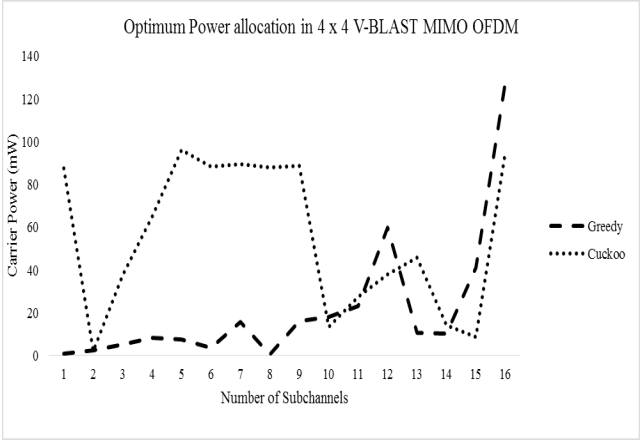

Figure 1. Greedy Power Allocation and Cuckoo Search based Power Allocation in 4 x 4 V-BLAST MIMO-OFDM.

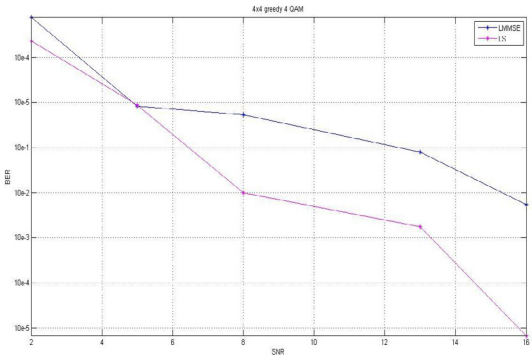

Figure 2. BER vs. SNR for Greedy Power Allocation in 4 x 4 V-BLAST MIMO-OFDM for 4 QAM with LS and LMMSE Channel Estimation.

In the accompanying Figures 2 to 7 indicated the BER versus SNR execution plot with diverse channel estimation and distinctive power allocation algorithms. From these graphs, we might comprehend that as the aggregate of constellations in the modulation rises, the BER and SNR performance also going in a superior way.The proposed optimal power allocation method for high-speed V-BLAST MIMO-OFDM system showed a better performance in terms of SNR and BER than the traditional methods. This work has been evaluated based on different channel estimation with different modulation techniques for VBLAST MMSE MIMO-OFDM System. The test program has been implemented in the latest technology

system in Matlab R2013a. The experimental results show that our proposed method achieves better performance in terms of BER and SNR compared with the existing methods used for improving the performance of the MIMO-OFDM. Linear MMSE proved efficient channel estimation technique over LS.

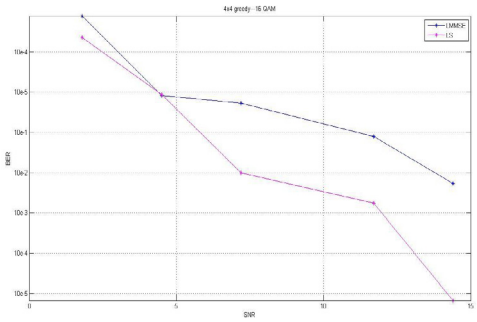

Figure 3. BER vs. SNR for Greedy Power Allocation in 4 x 4 V-BLAST MIMO-OFDM for 16 QAM with LS and LMMSE Channel Estimation.

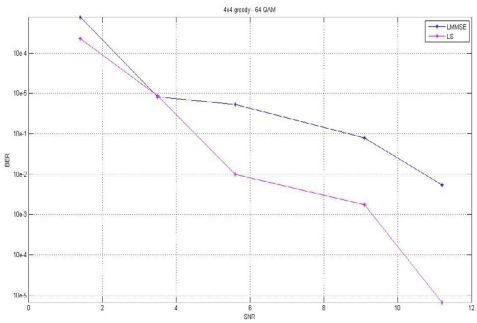

Figure 4. BER vs. SNR for Greedy Power Allocation in 4 x 4 V-BLAST MIMO-OFDM for 64 QAM with LS and LMMSE Channel Estimation.

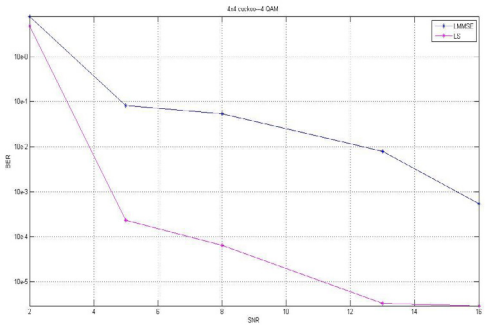

Figure 5. BER vs. SNR For Cuckoo Search Based Power Allocation In 4 x 4 V-BLAST MIMO-OFDM for 4 QAM with LS and LMMSE Channel Estimation.

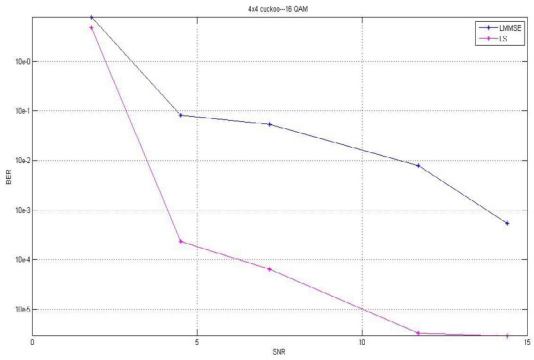

Figure 6. BER vs. SNR for Cuckoo Search Based Power Allocation in 4 x 4 V-BLAST MIMO-OFDM for 16 QAM with LS and LMMSE Channel Estimation.

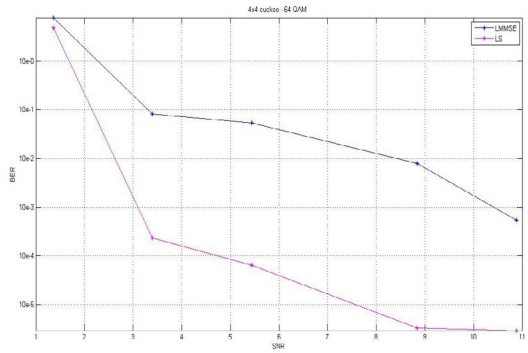

Figure 7. BER vs. SNR for Cuckoo Search Based Power Allocation in 4 x 4 V-BLAST MIMO- OFDM for 64 QAM with LS and LMMSE Channel Estimation.

4. Conclusion

The proposed optimal power allocation method for high-speed V-BLAST MIMO-OFDM system showed a better performance in terms of SNR and BER than the traditional methods. This work has been evaluated based on different channel estimation with different modulation techniques for VBLAST MIMO-OFDM System. The experimental results show that our proposed method achieves better performance in terms of BER and SNR compared with the existing methods used for improving the performance of the MIMO-OFDM. Linear MMSE proved efficient channel estimation technique over LS. This result would be useful to make efficient Adaptive MIMO-OFDM system. It would be also useful in adaptive modulation and power allocation concept for making better wireless communication system.

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