

Channel Estimation Technique for High Speed Wireless Data Communication in Noisy Environment

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Abstract

In noisy environment, to increase the capacity of high speed data communication the orthogonal frequency division multiplexed (OFDM) channel estimation technique is used. In this paper a Modified Variable Step Size Leaky Least Mean Square Channel Estimation (MVSS-LLMS) algorithm is suggested to improve the data estimation accuracy of MIMO-OFDM system in non-line of sight (NLOS) path. The performance of proposed algorithm is compared with the existing channel estimation technique. The Bit Error Rate (BER) as well as signal to noise ratio is improved.

Keywords: MIMO, OFDM, MVSS-LLMS, BER, NLOS, SNR

1. Introduction

Multiple inputs multiple outputs (MIMO) is a multiple antenna technique widely used in 4G and 5G for enormous wireless data transmission in non-line of site (NLOS) noisy environmental communication system. It reduces the inter symbol inference (ISI) occurred by multipath in a time dispersive faded wireless channels. The channel capacity and the spectral efficiency of optimum receiver are also improved.

MIMO with OFDM (MIMO-OFDM) is more popular now a day for mobile wireless data communication system, where best features of OFDM and MIMO are used for data transmission. Various channel estimation techniques are used for improving the channel capacity, spectral efficiency and to minimize the effect of fading environment on the data received by optimum receiver. The probability of error and the signal to noise ratio (SNR) are the two parameters through which we can estimate the capacity of the algorithm. Some of the widely used algorithms are Least square (LS) [1], Least mean square (LMS)[2], normalized NLMS[3], variable step size LMS(VSS-LMS)[4,5] and Recursive least square (RLS)[6].

2. MIMO-OFDM System

A MIMO-OFDM system with frequency selective Rayleigh fading channels and two transceiver antennas system is shown in figure 1. The receiver output is given by

$$Y(n) = W(n) X(n) + N(n) \quad (1)$$

Where $Y(n)$ is the received signal vector, $X(n)$ is the transmitted signal vector, $W(n)$ is the weight which is multiplied at time instant t and $N(n)$ is the AWGN noise. The OFDM with 64 subcarriers and a guard interval of 8 is used to preserve the orthogonality.

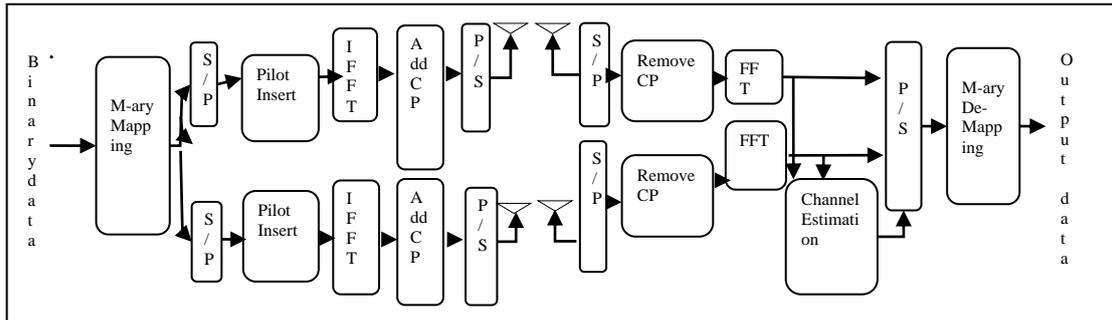


Figure 1. MIMO OFDM System Model

3. Adaptive Channel Estimation Techniques

Adaptive channel estimation is an estimator shown in figure 2, in which weights are updated recursively. A particular estimator is selected on the basis of complexity of the algorithm, system performance and practicality in application. The mean squared error is defined as

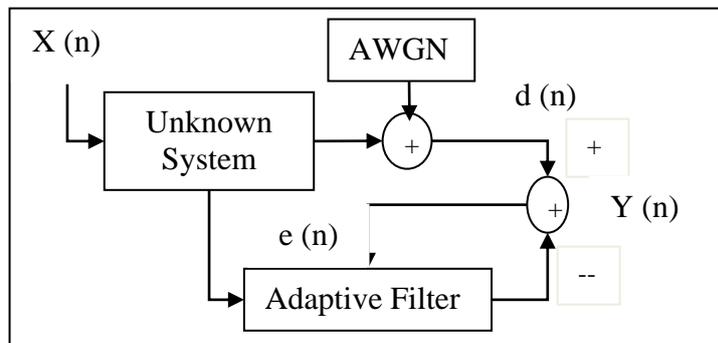


Figure 2. Adaptive Channel Estimation Model [10]

$$MSE = E \{ |W(n) - \hat{W}(n)|^2 \} \quad (2)$$

Where $\hat{W}(n)$ is the estimate of equivalent channel of n^{th} OFDM system. For performance evaluation of OFDM system the bit error is calculated.

3.1. LMS [2]

The Instantiation cost function of LMS algorithm is

$$J_n = (e)^2 \quad (3)$$

By using the steepest decent rule, the updated weights as

$$W(n+1) = W(n) - \mu \partial J_n / \partial W(n) \quad (4)$$

Then the modified weights becomes,

$$W(n+1) = W(n) - 2\mu e(n) x(n) \quad (5)$$

3.2. RLS [6]

In RLS channel estimation algorithm, weights are updated recursively as

$$k = \lambda^{-1} p \cdot u / (1 + \lambda^{-1} p^T x(n) x^T(n)) \quad (6)$$

$$W = W + k \cdot \text{conj}(e(n)) \quad (7)$$

$$p = (\lambda - 1)p - (\lambda - 1) p k^T x(n) \quad (8)$$

4. Proposed MVSS-LLMS algorithm

For MVSS-LLMS the cost function is calculated as,

$$J_n = e^2(n) + \gamma(n) w^T(n) w(n) \quad (9)$$

Then the modified weights [9] becomes

$$w(n+1) = e^2(n) - \mu(n) \partial J_n / \partial w(n) \quad (10)$$

And $\mu(n)$ updated as

$$\mu(n+1) = \gamma \mu(n) + \gamma(n) e^2(n) \quad (11)$$

For updating of $\mu(n)$ autocorrelation of the error is required

$$\mu(n+1) = \gamma \mu(n) + \gamma(n) P^2(n) \quad (12)$$

The autocorrelation of $e(n)$ is represented by $P(n)$

$$P(n+1) = \beta P(n) + (1 - \beta) e(n) e(n-1) \quad (13)$$

And variable β becomes,

$$\beta(n+1) = 1 - \log \beta(n) \quad (14)$$

So equation (13) modified as

$$P(n+1) = \beta(n) P(n) + (1 - \beta(n)) e(n) e(n-1) \quad (15)$$

Updated weight becomes, [7]

$$W(n+1) = (1 - 2\mu(n)\lambda(n)) w(n) + 2\mu(n) e(n) x(n) \quad (16)$$

5. Performance Analysis

5.1. Computational Complexity

The computational complexity depends on the number of multiplication, division and addition performed by the algorithm. The following table 1 shows the computational complexity.

Table 1. Computational Complexity [8]

Algorithms	Multiplication	Addition	Division
LMS	$2N+1$	$2N$	-
RLS	N^2+5N+1	N^2+3N	1
MVSS-LLMS	$5N$	$4N+3$	-

5.2 Bit Error Rate (BER)

$$\text{BER} = (\text{Number of bits in error}) / \text{Number of Bits Transmitted} \quad (17)$$

Table 2. BER Comparison of algorithms for SNR 10 and 20

Iteration	SNR-10		SNR-20	
	LMS	MVSS-LLMS	LMS	MVSS-LLMS
5	0.000350	0.000075	0.000200	0.000030
10	0.000160	0.000035	0.000100	0.000025
15	0.000106	0.000025	0.000067	0.000015
20	0.00008	0.000021	0.000050	0.000010
25	0.000062	0.000016	0.000039	0.000010
50	0.000075	0.000010	0.0000470	0.000006
100	0.000046	0.000011	0.000030	0.000007
200	0.000047	0.000010	0.000030	0.000007
500	0.000045	0.000009	0.000028	0.000007
1000	0.000045	0.000016	0.000028	0.000010
2000	0.000052	0.000012	0.000032	0.000008
5000	0.000046	0.000010	0.000029	0.000005
10000	0.000040	0.000011	0.000026	0.000007

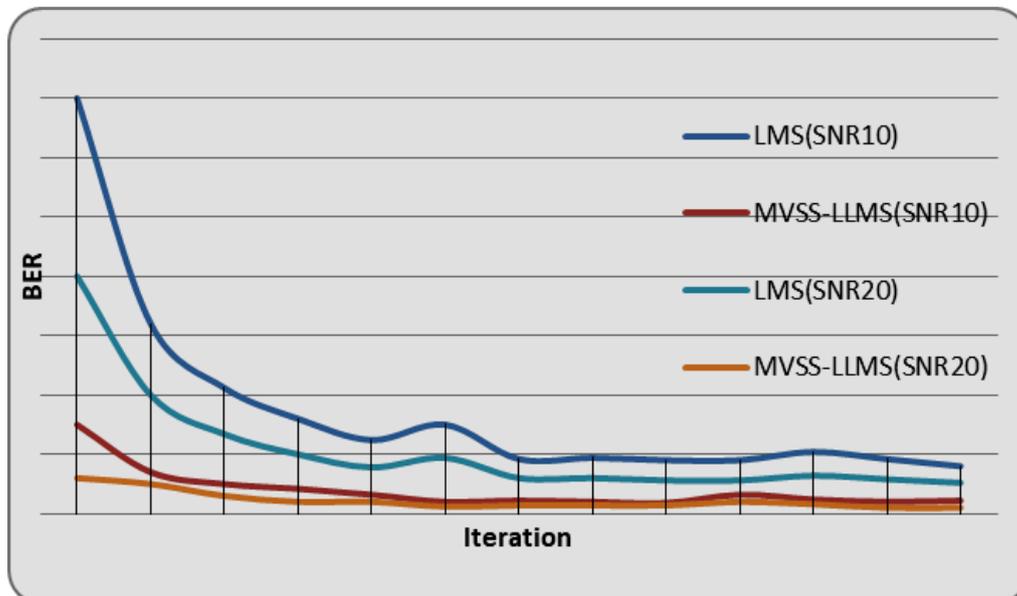
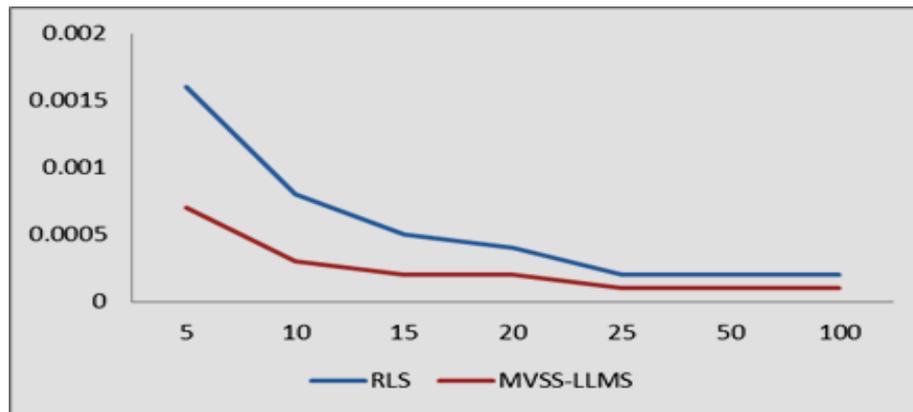


Figure 3. BER Comparison of LMS, and MVSS-LLMS for SNR-10 and SNR-20

Table 3. BER Comparison of Proposed algorithms with RLS for SNR 10

Iteration	RLS	MVSS-LLMS
5	0.0016	0.0007
10	0.0008	0.0003
15	0.0005	0.0002
20	0.0004	0.0002
25	0.0002	0.0001
50	0.0002	0.0001
100	0.0002	0.0001



FiFigure 4. BER Comparison of LMS, and MVSS-LLMS for SNR-10

6. Results

The bit error rate comparison of proposed MVSS-LLMS algorithm with LMS algorithm, for SNR 10 and 20 is shown in table 2. The curves are obtained with iterations of 10000. For the low SNR the and the 100 iteration the BER performance is improved whereas for high iteration and the high SNR the BER performance is almost constant as shown in fig. 3. The proposed algorithm performed well for 0-10 dB SNR. The plot also shows that the BER of MVSS-LLMS algorithm is almost reduced by 50% and it convergence rapidly.

Also table 3 and the fig.4 shows the BER comparison of the proposed algorithm with standard RLS algorithm, which is mostly used in fading wireless environment for the high speed data transmitted over the noisy channel. A curve is obtained with iterations of 100 and the SNR of 10 dB. The proposed algorithm is do better for low SNR and less iteration. Also the convergence speed of proposed algorithm is better than the RLS.

7. Conclusion

The BER performance of proposed MVSS-LLMS algorithm is improved. The computational complexity of the proposed algorithm is slightly more than the LMS. The proposed algorithm is faster in convergence, more accurate and more consistent compare to other mostly used channel estimation algorithms. For higher data rate and low SNR noisy wireless environment the proposed MVSS-LLMS channel estimation is more useful in data communication.

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