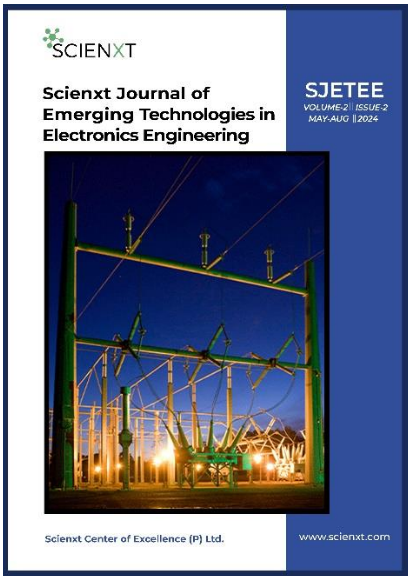


**Scienxt Journal of Emerging Technologies in Electronics Engineering**
**Volume-2 || Issue-2 || May-Aug || Year-2024 || pp. 1-11**

# *BER and MSE performance of MIMO-OFDM systems using channel estimation technique*

**[*1]Megha Dhote, [2]Vivek Kumar, [3]Sohan Yaduvanshi, [4]Prathiksha Pal**

[*1]Assistat Professor, Department of Electronics& Communication Engineering,Bhopal Institute of Technology, Bhopal (M.P) India

[2,3,4]Department of Electronics& Communication Engineering,Bhopal Institute of Technology, Bhopal (M.P) India

**Corresponding Author: Megha Dhote*
*Email: meghadhote76250@gmail.com*

## Abstract:

Next generation mobile systems will use multiple antennas at the transmitter and receiver to achieve higher capacity and diversity gain at high speeds. By transmitting through multiple transmitting and receiving antennas, multiple wireless data pipes are created. A transmitted signal while propagating through the wireless channel undergoes multipath fading effect accompanied by noise and interference. Mitigation of these effects and increase in throughput is only possible if the channel is accurately estimated at the receiver in order to perform channel estimation.

Depending on the rate of channel fading, whether gradual or rapid, various authors have proposed adaptive channel estimators utilizing LMS, RLS, and NLMS algorithms. These methods may necessitate statistical channel data or may exhibit suboptimal efficiency. In terms of performance or computations. In order to overcome the above effects, the work focuses on the QR-RLS based channel estimation method for MIMO-OFDM systems.

The algorithm proposed, employing the QR-RLS channel estimation technique, offers reduced mean square error (MSE) and bit error rate (BER) when contrasted with preceding channel estimation methods.

## Keywords:

Least Mean Square (LMS), Recursive Least Square (RLS), Normalized Least Mean Square (NLMS), Square Root-Recursive Least Square (QR-RLS)

## 1. Introduction:

In recent years, Internet usage has increased in leaps and bounds and has billions of users. Internet usages like VOD-Video on Demand, E-Mail, Browsing, Contacts etc. demand high speed Internet that leads to a need for broadband adoption. At the same time, cellular systems have made it possible for people to stay connected with the world from almost anywhere, resulting in a concept while On The Move. With the increase in users and their demands, the broadband market continues to grow, which in turn leads to development of new technologies like Wimax [1], LTE, LTE-advanced for broadband wireless. These technologies provide usage flexibility, high throughput and more coverage.

Wireless channel [2] is the main barrier for these new technologies. It causes impairments like noise addition, interference, multipath fading effects etc. in the transmitted signal. This demands very complex algorithms in the wireless receiver to overcome these impairments. Previous technologies like GSM [3] use FDM (Frequency Division Multiplexing), while CDMA uses orthogonal codes and spread spectrum to overcome channel impairments. These systems have their own limitations. For example, FDM requires guard band for separation to overcome interference between two consecutive users. Similarly, CDMA [4] needs to generate orthogonal sequences with zero correlation which is difficult to achieve if the number of users increases indefinitely. This leads to OFDM [5] (Orthogonal Frequency Division Multiplexing). The concept is equivalent to dividing the channel frequency response into smaller orthogonal sub bands. Since each adjacent frequency is orthogonal to each other, it eliminates the need of guard band for separation. Simultaneously,

OFDM divides high data rate signal into multiple small data rate signals. Moreover, it can be implemented by simple FFT/IFFT techniques, leading to ease in implementation.

## 2. Channel estimation:

Coherent demodulation acquires channel knowledge at the receiver to compensate for the channel induced distortions. The process of acquiring the channel knowledge is called channel estimation which is an integral part of most of the communication receivers nowadays. Apart from the knowledge of channel statistics, the channel estimator also requires knowledge of the instantaneous channel values to track the channel fading and compensate it. Available literature generally describes two types of channel estimation methods. One is based on pilot based estimation and the other is blind estimation [6]. Blind channel estimation methods avoid the use of pilots and have higher spectral efficiency. However they suffer from high computational complexity and low convergence speed required to derive statistical information from received data. On the other hand, pilot based estimation uses pilots in block/distributed manner, depending on channel slow/fast fading conditions. The transmitter transmits multiplexed pilot symbols along with data symbols to acquire channel knowledge at the receiver. Such a channel estimation scheme is called Pilot Symbol Aided Modulation (PSAM). The estimator then uses sophisticated signal processing algorithms like LSE and MMSE to acquire the channel knowledge using pilot symbols. Several authors have proposed channel estimation in frequency domain [7] for OFDM systems using MMSE and LSE methods. However MMSE methods require prior knowledge of channel statistics. Such information is not generally known which leads to modified LMMSE based method. Still this method requires higher computations. On the other hand, LSE based method requires just a scalar division to estimate the channel in frequency domain, but it leads to high channel estimation MSE error since the estimation error gets spread over the whole frequency band This results in time-domain channel estimation, enhancing robustness by effectively capturing the inherent frequency correlation among the taps.

Literature also addresses [8] time domain channel tracking methods like MMSE, LMS, RLS adaptive estimators for OFDM systems. These methods use training symbols for estimator coefficient updating. As mentioned earlier, MMSE requires prior knowledge, while LMS method only use currently received value for filter coefficient updating, resulting in slow convergence. Filter updating based on a block of received data is more accurate, fast converging and also averages out the noise effect. These approaches are referred to as RLS-based channel tracking. However, RLS-based updating is encumbered by considerable computational demands stemming from matrix inversion and singularity, particularly in scenarios with highly correlated channels. Consequently, the proposed solution introduces QR-RLS-based channel estimation tailored for MIMO OFDM systems, leveraging preamble symbols for initial channel estimation. This method yields superior outcomes in environments characterized by low to moderate channel fading. In instances of rapid fading channels, performance enhancement is attained by employing a time-domain QR-RLS channel estimator alongside scattered pilots in the frequency domain. The above method produces better results in low and moderate channel fading environments.

In fast fading channel conditions, performance enhancement is attained by utilizing a time-domain QR-RLS channel estimator in tandem with scattered pilots in the frequency domain.

## 3. MIMO-OFDM system:

The technique depends on the accompanying two methodologies: bit-square pre-scrambling of the OFDM image, and cutting of the OFDM motion before transmission. Two distinctive scrambling groupings are displayed. The first is an altered m-succession with the least peak factor, while the second one is a disordered twofold grouping created by Calculated guide and chosen by pinnacle factor least criteria. MATLAB PC reproduction of OFDM framework with 64 subcarriers with 4 pilot tones and recurrence area brush type pilot channel estimation and the AWGN multipath channel is performed. Additionally, the soundness of the pre-mixed and cut OFDM flag is inspected. Accordingly, a bit mistake rate (BER) execution for different cut-out dimensions gotten by the methods for a PC reproduction is introduced. In addition, the productivity of the joined pre-scrambling furthermore, cutting strategy is considered also. From that point forward, a few scholastics and architects have made noteworthy commitments in the field of MIMO. Presently MIMO innovation has stirred intrigue due to its conceivable applications in advanced TV, remote neighborhood, metropolitan zone systems and versatile correspondence

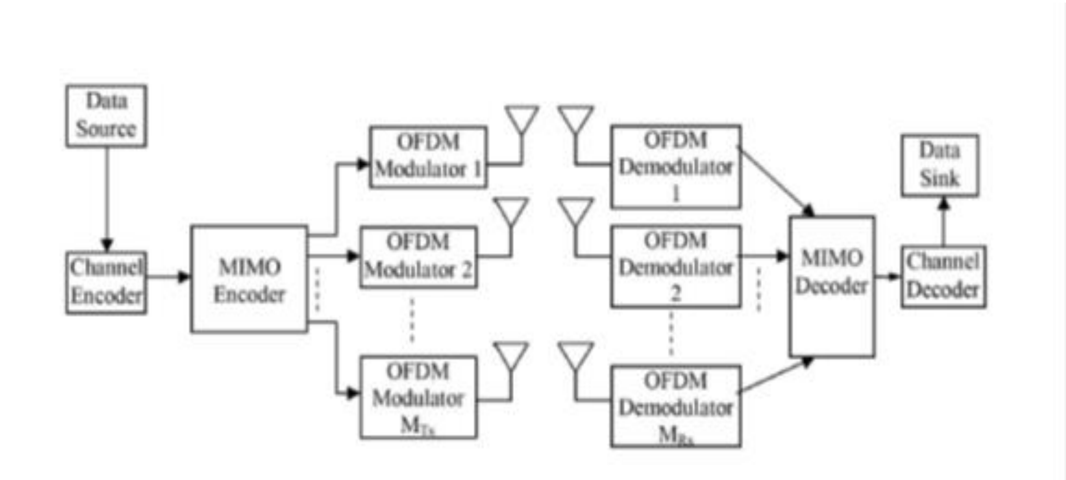


*Figure. 1: Block Diagram of MIMO-OFDM Communication System*

## 4. Proposed methodology:

The MIMO-OFDM system is implemented using MATLAB/SIMULINK. The input to the system comprises binary data, modulated using QAM and mapped into constellation points.

Fig. 2 illustrates the MIMO-OFDM system models incorporating a channel estimation technique.

The digital modulation scheme transmits data in parallel by assigning symbols to each subchannel. A complex I-Q mapping vector, depicted in Figure 2, determines the phase mapping of subchannels. The parallel digital data stream is converted into an analog signal suitable for transmission through the addition of a cyclic prefix to the baseband modulation signal, ensuring non-overlapping signals. Subsequently, the signal is split into two or more parts as required.

Square Root Recursive Least Squares (QR-RLS) Algorithm

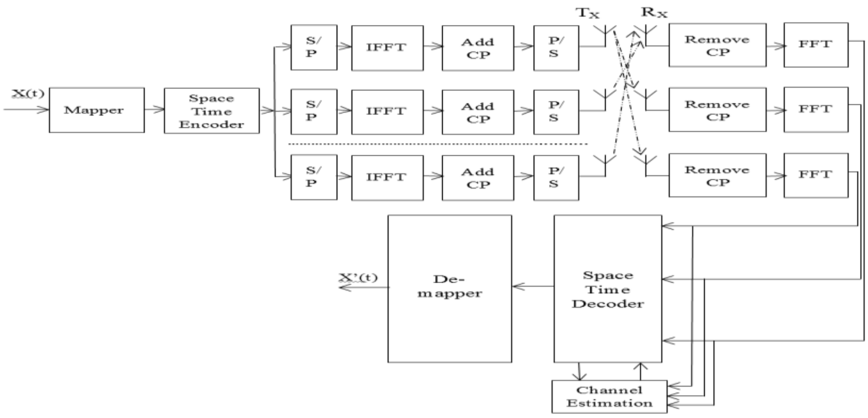


***Figure. 2: MIMO-OFDM System Models with Channel Estimation Technique***

| Parameter | |
|---|---|
| Antenna | 2×2, 4×4 |
| Users | Single, Four, Eight and Sixteen |
| Carrier Frequency | 5 GHz |
| Number of Subcarriers | 128 |
| Modulation | 16-QAM |
| Channel | Rayleigh Fading Channel |
| Signal to Noise Ratio | 15 dB |
| Number of OFDM Block | 100 |

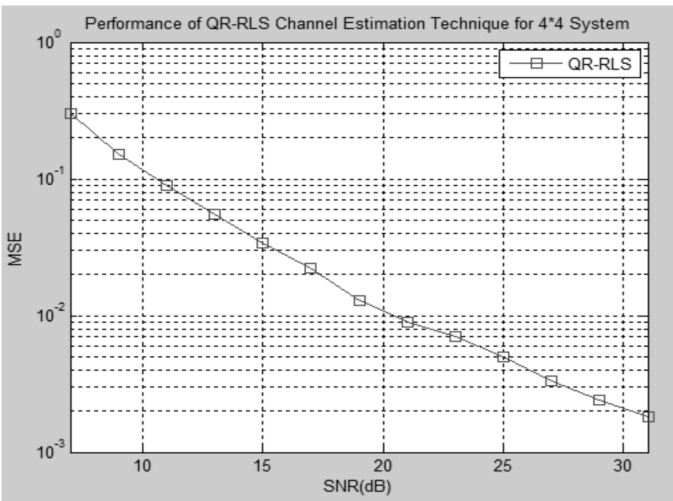


***Figure. 3: Performance MSE for 4×4 MIMO-OFDM Systems***

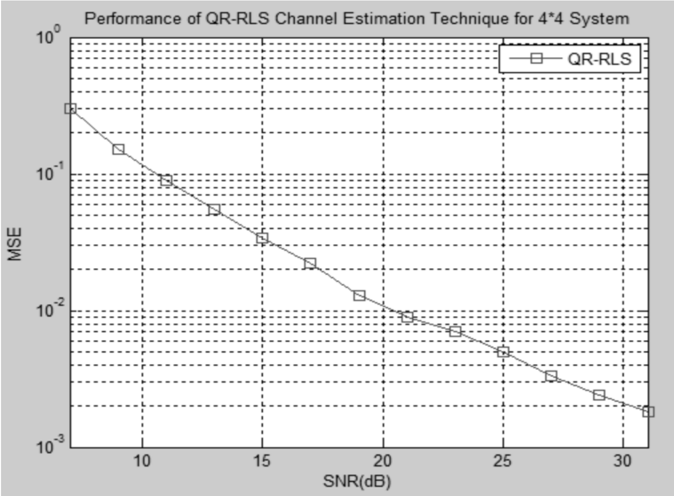


*Figure. 4: Performance BER for 4×4 MIMO-OFDM Systems*

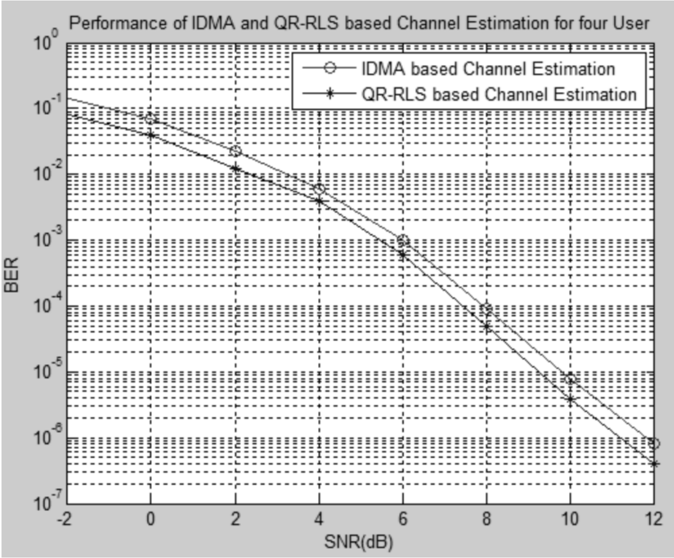


*Figure. 5: Performance of IDMA and QR-RLS based Channel Estimation for Four User System*

*Table. 1: Comparison Result for SNR*

| SNR | Previous Technique [1] | Proposed Technique |
|---|---|---|
| | IDMA based Channel Estimation Technique | QR-RLS based Channel Estimation Technique |
| -2 | 0.14 | 0.08 |
| 0 | 0.07 | 0.04 |
| 2 | 0.022 | 0.012 |
| 4 | 0.006 | 0.004 |
| 6 | 0.001 | 0.0006 |
| 8 | 0.0009 | 0.000049 |
| 10 | 0.000008 | 0.0000038 |
| 12 | 0.0000008 | 0.0000004 |

A QR-RLS-based MIMO-OFDM channel estimation method is proposed, utilizing Givens rotation-based QR factorization for estimator updating. Channel estimation is crucial for receiver design in wireless communication systems. Given the impracticality of measuring every wireless channel directly, training sequences are utilized to estimate channel parameters such as attenuations and delays. Since most Ultra-Wideband (UWB) receivers correlate the received signal with a predetermined template signal, prior knowledge of the wireless channel parameters is essential to predict the condition of the template signal matching the received signal.

### Mathematical Equations

Due to the wide bandwidth and reduced signal energy, UWB pulses suffer from severe pulse distortion. Consider the received signal at the qth receive antenna represented in matrix form as

$$Y(n)=(U(n).H(n))+V(n)$$

The posteriori error is given by the difference between the received preamble symbol and its corresponding estimate at time n on the qth receiving antenna

$$e(q,n)=y(q,n)-\tilde{y}(q,n)$$

Where H has the same dimensionality as H. The weighted square-root error at time n is given by

Where λ is a weighting factor, its value ranging between (0, 1) depending on the presence of channel fading conditions. The solution to the above equation yields the optimum value for the estimated channel coefficients H at time n. The optimal solution is

$$e(q,n)=y(q,n)-X_{pre}(n)\tilde{H}_q$$

Where R_preamble is the autocorrelation matrix of the preamble signal, and P_rx_preamble is the cross-correlation matrix between the received signal and the preamble signal at time n.

$$e(q,n)=\sum_{i=0}^{n}\lambda^{n-i}(|e(q,i)|)^2$$

$$H_q(n)=R^{-1}{}_X(n)\times R_{Yqx}(n)$$

### Simulation Results

In simulations, perfect system synchronization is assumed. Different values of Signal-to-Noise Ratio (SNR) are considered, and performance is evaluated.

Table. 1 presents simulation parameters.

The proposed algorithm is applied for channel estimation in a MIMO-OFDM system using QAM modulation. The channel employed is a Gaussian channel. Figure 5 illustrates the MSE versus Eb/No plot for the QR-RLS, NLMS algorithm, RLMS algorithm, and LMS algorithm. The curve for QR-RLS demonstrates a decrease in Bit Error Rate (BER) compared to the LMS algorithm. Initially, the overall BER performance isn't significantly improved, but as the Eb/No value increases, the BER performance also increases.

Figures 3, 4, and 5 showcase the performance metrics for a 4×4 MIMO-OFDM system and the comparison of the proposed algorithm with other existing algorithms.

Table. 1 compares the Bit Error Rate (BER) values between the previous and proposed algorithms. It's evident that increasing the energy per bit (SNR) leads to a decrease in BER in these algorithms. Notably, the NLMS algorithm demonstrates the best performance compared to other algorithms.

Conclusion

As the demand for high-rate data transmission increases, there is a growing need for wideband wireless communication systems supporting high-rate transmission over wireless channels. The combination of MIMO and OFDM techniques (MIMO-OFDM) presents an attractive solution for wireless cellular systems.

Accurate channel state information is essential for coherent detection and decoding in a MIMO-OFDM system, necessitating efficient channel estimation methods. Bit Error Rate (BER) remains a critical metric in wireless systems. This paper focuses on maintaining BER, Mean Squared Error (MSE), and Signal-to-Noise Ratio (SNR). The proposed QR-RLS algorithm maintains all these parameters in a MIMO-OFDM system. Implemented using MATLAB software, the proposed algorithm achieves favorable results compared to existing algorithms.

## References:

(1) Akhilesh Venkatasubramanian, Krithika.V and Partibane. B, “Channel Estimation For A Multi-User MIMOOFDM- IDMA System”, International Conference on Communication and Signal Processing, April 6-8, 2017, India.

(2) Mel Li, Xiang Wang and Kun Zhang, "Comparative Study of Adaptive Filter Channel Estimation Technique in MIMO-OFDM System Based on STBC", Proceedings of the 2014 International Conference on Machine Learning and Cybernetics, Lanzhou, 13-16 July, 2014.

(3) Biswajit Sahoo, Ravi Ranjan Prasad, and P. Samundiswary, "BER Analysis of Mobile WiMAX System using LDPC Coding and MIMO System under Rayleigh Channel", International conference on Communication and Signal Processing, April 3-5, 2013, India.

(4) Mukesh Patidar, Rupeshdubey, Nitinkumar Jain and Saritakul Pariya, "Performance Analysis of WiMAX 802.16e Physical Layer Model", 978-1-4673-1989-8/12/$31.00 ©2012 IEEE.

(5) B. Sklar, "Digital Communications Fundamentals and Applications," Prentice Hall, Upper Saddle River, NJ, 2000.

(6) Wei Jiang and Daoben Li, "Convolutional Multi-code Multiplexing for OFDM Systems", Beijing University of Posts and Telecommunications Beijing 100876, China (2007).

(7) Ke Chen and Xiaojing Huang, "A Novel Approach for Interference Suppression in Multi-Subband Convolutional Coded OFDM System", School of Electrical, Computer & Telecommunications University of Wollongong, Australia (2010).

(8) Chin-Liang Wang and Shun-Sheng Wang† and Hsiao-Ling Chang, "A Low-Complexity SLM Based PAPR Reduction Scheme for SFBC MIMO-OFDM Systems", 978-1-61284-254-7/11/$26.00 ©2011 IEEE.

(9) Sen-Hung Wang, Student Member, IEEE, and Chih-Peng Li, Member, IEEE, "A Low-Complexity PAPR Reduction Scheme for SFBC MIMO-OFDM Systems", IEEE SIGNAL PROCESSING LETTERS, VOL. 16, NO. 11, NOVEMBER 2009.

(10) Yang Zhou and Tao Jiang, "A Novel Multi-Points Square Mapping Combined With PTS to Reduce PAPR of OFDM Signals Without Side Information", IEEE TRANSACTIONS ON BROADCASTING, VOL. 55, NO. 4, DECEMBER 2009.

(11) Yuan Jinsha, and Shi Hongmei, "A Modified Symbol Timing Synchronization Algorithm for WiMAX OFDM Systems", 2008 IEEE Pacific-Asia Workshop on Computational Intelligence and Industrial Application.

(12) J. Stott, "The DVB terrestial (DVB-T) specification and its implementation in a practical modem," International Broadcasting Convention