International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Adaptive Estimation with Varying Position Updation in MIMO-OFDM System

G. Rajender*[1], P. Sree Sudha[2]

Submitted: 10/01/2024 **Revised**: 16/02/2024 **Accepted**: 24/02/2024

Abstract: Estimation of channel Interference in wireless communication has remain a topic of research from many decades. With rapidly evolving new communication system and randomly varying channels, the existing estimation approaches need a finer updation in mitigating the interference issue. For signal estimation Kalman filtration has been used for its simpler computation and faster processing. Kalman filter are state based estimation which update the estimates based on a priori estimates. Existing Kalman estimation show lower estimation performance under a dynamic varying channel condition. The random deviation in user position with dynamic varying channel results into estimation error. To improve the estimation performance, in this paper an updation to the existing Kalman filtration is proposed. Two adaptively varying monitoring factors were presented to incorporate the varying position in estimation process. Proposed update observes an improvement in system throughput and estimation accuracy with less data loss under dynamic varying interferences.

Keywords: *Adaptive channel estimation, Kalman Filter, MIMO-OFDM system, time variant channel condition*

1. Introduction

Resource allocation for interference monitoring is presented in [1]. This approach is developed based on load balancing, where the interfacing base stations are provided with the information of streaming packets and allocated bandwidth for communication. Similar allocation approach for interference management based on packet loss monitoring is outlined in [2]. The developed method monitors the retransmission phase in reducing interferences. Power allocation in cross layer coding was developed in [3,4] using a scalable approach of power and data rate allocation. The presented method controls the power allocation for interference monitoring in accordance to the data rate usage. Channel interference was governed using temporal and spatial coding in [5]. This method improved the accuracy in estimation for varying channel interferences.

Estimation of signal was developed in [6,7] under imperfect channel condition. The presented method developed a pilot assisted estimation approach for a multi path scenario. The estimation was developed for a MIMO system in [8], where the interference is tracked based on the accumulated channel gains and operation phase in communication system. Extended filtration for channel estimation was outlined in [9, 10], where a semi blind estimator is used in tracking of noise for interference mitigation. The filtration is developed using feedback logic processing on multiple data bits. Approach of estimation in MIMO-OFDM communication system is outlined in [11-13] under diverse channel conditions. [14] Outlined the estimation approach using Kalman based filtration approach for a MIMO-OFDM system, where jakes training was used to improve estimation performance with minimum computation complexity. In [15], joint frequency and time offset approach for channel estimation for a MIMO-OFDM communication system is presented. Pilot based approaches were presented in [16] defining the estimation process in a MIMO-OFDM communication system. The proposed approach controls the Doppler Effect and computes the impulse response for estimation.

Multi antenna interface for Kalman based estimation is developed in [17], where the channel fading and Doppler Effect is monitored for interfacing channel. The presented method uses a correlation method in developing estimates. Estimation using basic expansion model (BEM) is outlined in [18]. The presented approach operates on complex amplitude (CA) and develops an auto regression model for channel estimation using Kalman filter. QR equalization is developed in the process of estimation. Pilot assisted estimation used in Kalman filter is outlined in [19,20] which operated on the minimization of fading effect in a MIMO-OFDM communication system. Pilot assisted channel estimation using a least mean approach for Kalman filtration is outlined in [21]. This approach defines the usage of Kalman filter for varying channel condition based on the recursive feedback logic. Kalman filtration using noise tracking is developed termed extended Kalman filter (EKF) for phase noise in MMO-

[1] *CMR Institute of Technology, Hyderabad, Telangana, India-501401*
https://orcid.org/0000-0003-1012-2979
[2] *G Narayanamma Institute of Technology and science (Women), Hyderabad, Telangana, India-500104*
https://orcid.org/0000-0002-9355-2829
** Corresponding Author Email: rajender427@gmail.com*

OFDM communication system. Online tracking of channel parameter for MIMO-OFDM communication system using state-space modeling is outlined in [22]. The estimation using Kalman filtration is used in system for lower computation complexity. The decision in a Kalman filter is developed using thresholding logic. The defined threshold limit is derived from multiple testing under varying channel conditions. However, the rapid change in the channel parameters and varying position of user in the network in a random manner constraint the existing thresholding operation of Kalman filter resulting in lower estimation performance. To outline the presented work, the rest of this paper outlines the MIMO-OFDM system model in section 2. The dynamic estimation approach is outlined in section 3 with simulation result of the developed approaches in section 4. Section 5 outlines the conclusion of the presented work.

2. System Outline

The proposed work is developed for a MIMO-OFDM communication system. MIMO-OFDM system is suitable for high data rate services which are developed as a set of multi-input-multi-output antenna interfacing. A MIMO system with multiple input-output interfacing is illustrated in figure 1.

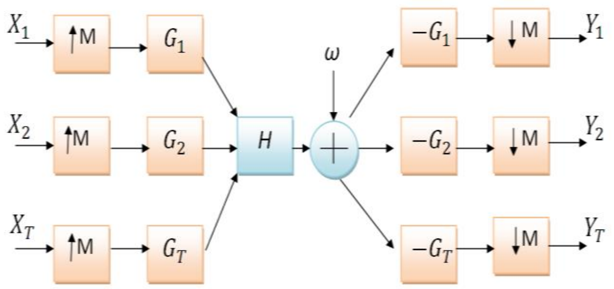


Fig 1: MIMO communication interface

The MIMO system reads multiple user input data in parallel and modulate with multiple carriers transmitting over multiple channels. In accessing multiple data simultaneously there is a severe interference been observed in the channel due to simultaneous transmission. In minimizing the interference in the channel orthogonal frequency division modulation (OFDM) system is proposed. Communication system architecture for a OFDM communication system is presented in figure 2.

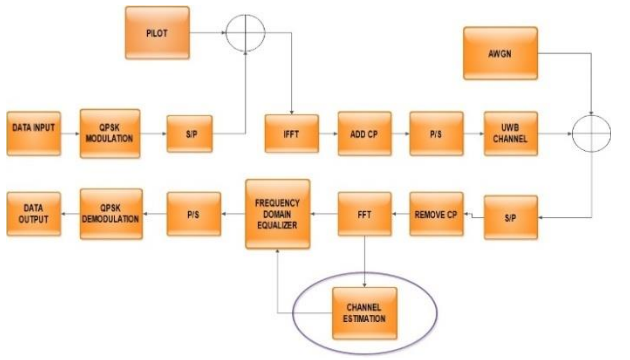


Fig 2: OFDM communication system with channel interface

The MIMO-OFDM communication system process on P simultaneous information's symbols (I) which are modulated with n sub carriers. The information symbols are processed as a group of data represented as,

$$I = [I_1, I_2, \dots I_P]^T \tag{1}$$

Where the information symbols are modulated with a set of subcarriers $XC_I = [C_I(0) \cdots C_I(k) \cdots C_I(N-1)]^T$ .The modulated information is processed for invert transformation using IFFT. Then this information is cyclic prefixed to include information of the transmission in the transmitting packets. The appended CP information data is represented as,

$$I' = [\{I_1(m)\}\{I_2(m+1)\} \cdots \mathrm{I}_\mathrm{p}^\mathrm{T}]^T \tag{2}$$

Where m cyclic prefix bits are inserted with each information symbol. The transmitting information is then modulated with transmitting power and carrier signal and mapped to different transmitting antennas. The received signal at the receiver end is given as,

$$Rx = \mathbb{H}I' + \xi \tag{3}$$

Where, I' is the modulated transmitted information mapped to different transmitting antennas and ξ is the additive noise observed in the channel. H defined the channel matrix for K multipaths given as,

$$\mathbb{H} = \begin{bmatrix} \mathbb{H}_{1,1} & \mathbb{H}_{2,1} \cdots\cdots\cdots & \mathbb{H}_{m_T}, 1 \\ \mathbb{H}_{1,2} & \mathbb{H}_{2,2} \cdots\cdots\cdots & \mathbb{H}_{m_T}, 2 \\ \mathbb{H}_{1,K} & \mathbb{H}_{2,K} \cdots\cdots\cdots & \mathbb{H}_{m_{T,K}} \end{bmatrix} \tag{4}$$

The effect of each channel has a varying impact on the transmitting data. Due to high varying interferences estimation approach has a constraint of slow convergence or lower estimation accuracy. The channel estimation unit in the receiver module is developed in estimation of the equalizer for interference mitigation. It is required to enhance the estimation process to adapt to the dynamic channel variations.

3. Estimation Approach

Various estimation approaches were developed in past. Due to low computation complexity and faster convergence, Kalman filters were adapted in different communication system. Kalman is a recursive estimation filter which process on the feedback error derived by the estimate correlated with the input information. Kalman filter process on two stages of operation, namely update and measurement. The recursive process of update and measurement is illustrated in figure 3 below.

Kalman filter perform the estimation using state transition model where the state information at n^th iteration given as,

$$I_n = AI_{n-1} + Br_n + \mu_n \quad (5)$$

Where, A&B are the state transition and the control matrix respectively, I_{n-1} and I_n are the information symbol at *n-1* iteration and r_n is the current input data. The observation vector O_n is given as,

$$O_n = F_n H + \beta_n \quad (6)$$

Vector F_n is the transmitting n^{th} symbols in frequency domain μ_n and, β_n are the zero mean gaussian noise. The prediction is perofrmced based on the estimated error e_n is given as,

$$e_{n-1} = A_n E_n A_n^H + Q_\mu \quad (7)$$

The estimation is performed based on the past error e_{n-1} current eror is computed given as,

$$E_n = (E_{n-1} - G_n I_n E_{n-1}) \quad (8)$$

Where, G_n is the Kalman gain and given as,

$$G_n = E_{n-1} X_n^H \left(I_n E_{n-1} I_n^H + Q_\beta\right)^{-1} \quad (9)$$

The estimate is given as,

$$Cr_n = Cr_{n-1} G_n (O_n - I_n Cr_{n-1}) \quad (10)$$

The estimation is developed based on the thresholding conditions given by,

$$K\_Est = \begin{cases} Cr_n, & Cr_n \geq R\sigma_n^2 \\ 0, & Cr_n \leq R\sigma_n^2 \end{cases} \quad (11)$$

Where K_{Est} the kamana estimate and R is is the relative channel parameter based on prior knowledge and ck is the estimated channel response. The Kalman estimation is developed with the assumption of prior knowledge of channel data. However, in current communication system, with the varying user's position the interference randomly varies. The position variation of active communicating users has varying interference with the movement, hence a new estimation process using two monitoring parameters is proposed. The proposed estimation defines a forwarding movement (*fr*) or backward movement (*d*) in deriving the channel response. Figure 3 illustrate the variation in interference under the two cases.

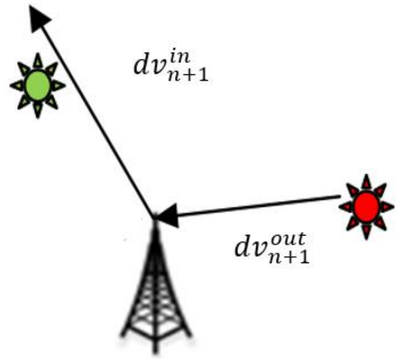


Fig 3: Varying interference observed with varying user position

The estimates are computed using Least Mean Square Error (LMSE) approach, where the two monitoring parameters are defined as,

$$p_{n+1}^{\wedge fr} = p_n^{\wedge fr} + 2\mu^{fr} e_n^{fr} a_n \quad (12)$$

$$p_{n-1}^{\wedge d} = p_n^{\wedge d} + 2\mu^{d} e_n^{d} a_n \quad (13)$$

The updation of the forwarding or descending movement is updated by $\mu^{fr} and \mu^d$ paramters respectively. The error $e_n^{fr} and e_n^d$ observed for the forwarding a desceneding condition is given by,

$$e_n^f = y_n - p_n^{\wedge f} a_n \quad (14)$$

$$e_n^d = y_n - p_n^{\wedge d} a_n \quad (15)$$

Where, the gain factor a_n is given as,

$$a_n = (p_n^{\wedge fr} + p_n^{\wedge d})/2 \quad (16)$$

The error is computed as a gradient deviation of error value given as,

$$dv_{n+1} = dv_n - \zeta \nabla(dv_n), \; for\; n = 0,1 \ldots k \quad (17)$$

Where, $\nabla(dv_n)$ is the gradeient deviation of the comoauted error. The updation factor ζ defiens the error updation rate and hence an optimal factor is computed given by,

$$\zeta_{opt} = \arg\min (\zeta \nabla(dv - \zeta G_k)) \quad (18)$$

In the case of location varying, the two errors observed were updated as,

$$dv_{n+1}^{in} = dv_n^{in} + 2\zeta_{opt} dv_n^{fr} a_n \quad (19)$$

$$dv_{n+1}^{out} = dv_n^{out} + 2\zeta_{opt} dv_n^{d} a_n \quad (20)$$

The estimation error for the minimal estimate obtained as,

$$er\_min = \min\left(E\{|X - dv|^2\}\right) \qquad (21)$$

Where the estimate function (E) computes the variation of computed error with the updated data for minimal error. The minimal estimated is used in the Kalman filter for resulting the final estimate which is defined as a threshold function given as,

$$K\_Est = \frac{\|er\_min_{n+1} - er\_min_n\|}{\|er\_min_n\|} < \frac{T}{K} \qquad (22)$$

The estimate is repeated for n iteration and Kalman estimate with minimum error is computed. The estimate is iterated for correlating the obtained errors of previous error with the current measurement. The estimation threshold ($T \in \{T_{low}, T_{max}\}$)is dynamic of the interference monitored an defined as two bounding variable given as,

$$T_{low} = \min\left(\frac{1}{2}£^{-1}\left(\frac{\left(\sum_{n=1}^{k}\sqrt{Cr_n^T\,\varepsilon\,Cr_n}\right)}{n}\right)\right) \qquad (23)$$

and

$$T_{max} = \max\left(£^{-1}\left(\frac{\left(\sum_{n=1}^{k}\mu_n\right)}{n}\right) + \left(\frac{\left(\sum_{n=1}^{k}\beta_n\right)}{n}\right)\right) \qquad (24)$$

Where, ek is the estimated error under varying user position and μ_n and β_n are the estimated interfernces. The two limitrs are weight optimized using the parameter($£ > 0$) which defines the interference level in the channel given as a prior information to Kalman filter.

4. Simulation Result

The simulation of the developed communication system is carried out using a 2x2 antenna system. 128-bit block size is considered for transmission having 16 bot cyclic prefix bits. A FFT of 256 size is considered and the modulation was performed for 50 sub carrier signals. The system is developed with following communication parameter values for a MIMO-OFDM system using Matlab tool.

Table 1: Parameters for simulation of communication system

Parameter of the communication system	Types and values used
Modulation	QPSK
Operating Frequency	5GHz
Transmission Rate	7.2Mbps
Sampling time period	0.16µs
Sampling Frequency	7.68 MHz
Number of Sub-carriers	512
Sub-carrier for Data	240
Sub-Carrier for pilot	48

For the analysis of the proposed system, Delay, system throughput and packet loss ratio parameter were evaluated for varying SNR conditions. Observed metrics for simulated system is shown in following figures.

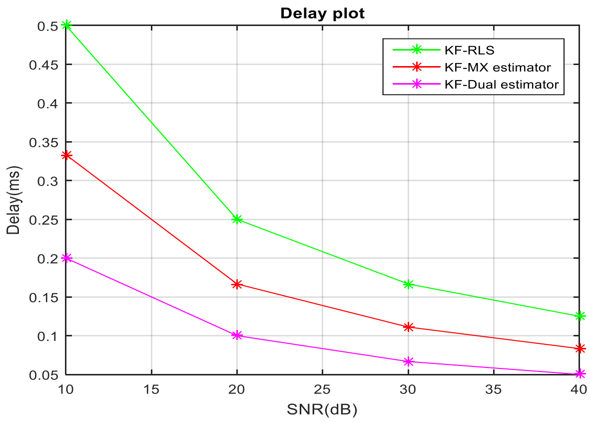


Fig 4: Delay performance for the developed system

Table 2: observation of delay parameter for varying SNR

SNR (dB)	Kalman filter-RLS method	Kalman filter - min-max method	Proposed Estimator with dual parameter
10	0.51	0.33	0.3
20	0.26	0.16	0.2
30	0.23	0.12	0.06
40	0.14	0.08	0.04

Delay parameter is defined as the time taken in processing the signal estimation. The efficiency of the estimation is evaluated by the time taken in detection of the noised parameter from the received signal. The signal strength for a given signal is measured in terms of signal to noise ratio (SNR) is given by,

$$\text{Singal\_SNR} = \frac{|I(t)|}{\upsilon} \qquad (25)$$

Where, *I(t)* is the information data and |I(t)| define the energy in the signal at a noise variance of υ. The simulation derives that the variant in the signal strength due to multiple path channel interference is more effectively estimated for the proposed dual metric monitoring. As the proposed approach process the estimation for both forwarding and descending probability, the convergence is achieved faster which reduces the processing delay. The proposed method observed to minimize the processing delay by 1.2 msec compared to existing approaches of signal estimation.

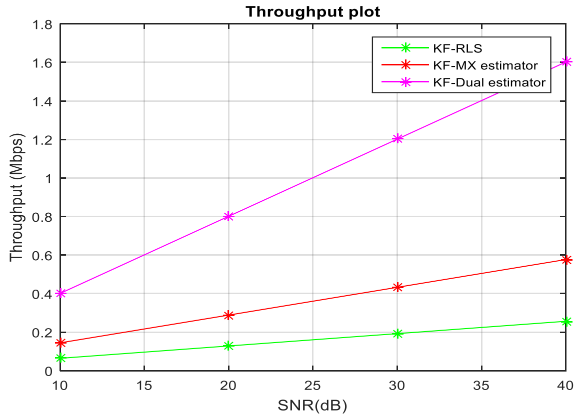


Fig 5: System throughput metric for the developed system

Table 3: observation of System throughput parameter for varying SNR

SNR(dB)	Kalman filter-RLS method	Kalman filter min-max	Proposed Estimator with dual
10	0.14	0.18	0.3
20	0.18	0.29	0.7
30	0.21	0.43	1.1
40	0.24	0.58	1.5

System throughput of the proposed system is compared with the existing approaches to observe the offering data service combability under the varying noise level. System throughput is defined as the volume of data transmitted over volume of data retrieved for an observing time period as given by,

$$sys\_Th = \frac{Vol.\ Tx}{Vol.\ Rx} \quad (26)$$

Where, $Vol.Tx$ defiens the volume of transmitted data and $Vol.\ Rx$ defines the Volume of retrieved data at the receiver for a given time interval.

The proposed estimation approach attains a higher throughput to the system, as the processing time is observed to reduce. The decreased time period increases the data processing volume which resulted into increase in system throughput. The proposed system attains about 1.5Mbps increase in throughput as compared to the existing Kalman based filtration.In addition to the delay and system throughput, observation to the accuracy of the estimation is also evaluated. The packet loss ratio (PLR) is defined as a ratio of packets been correctly retrieved over total transmitted packets, given as,

$$PLR = \frac{correlated\ information\ correctly\ retrieved}{Total\ information\ generated} \quad (27)$$

PLR for the simulated system is shown in figure 7.

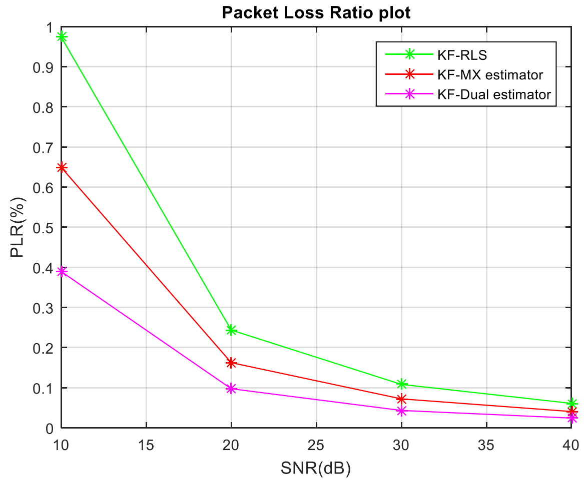
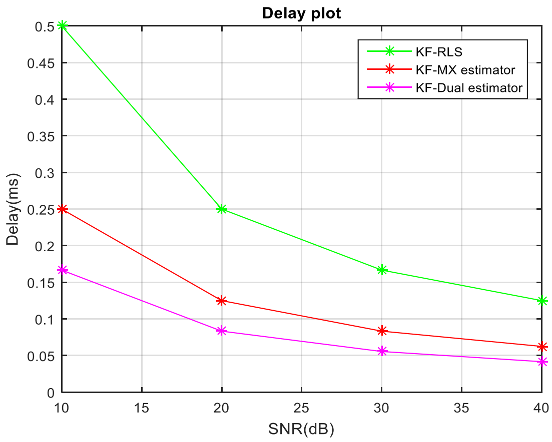


Fig 6: Packet loss ratio observed the developed system

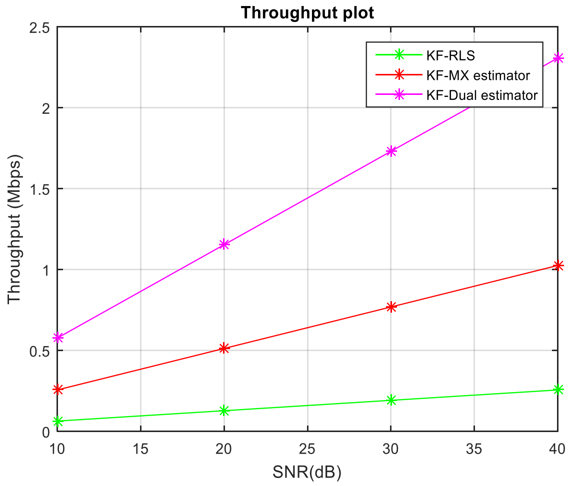
Table 4: Observation of Packet loss ratio parameter for varying SNR

SNR(dB)	Kalman filter-RLS method	Kalman filter - min-max method	Proposed Estimator with dual parameter
10	0.98	0.66	0.38
20	0.25	0.18	0.11
30	0.11	0.09	0.03
40	0.08	0.07	0.03

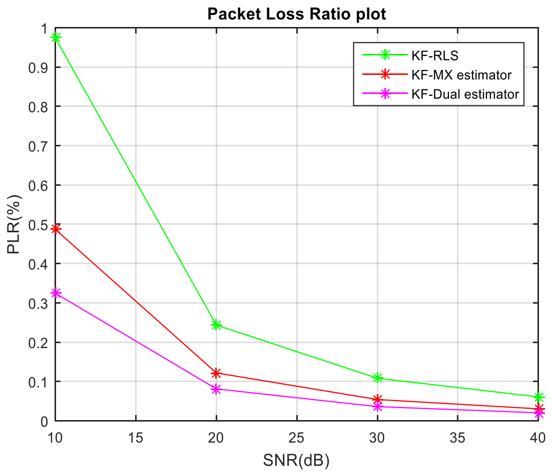
With varying interference level, the performance of estimation varies. The estimation with higher robustness and accuracy of estimation result into lower data loss. In the proposed approach the estimation due to dual bound limits the observation limits are increased, this resulted into a wider range of estimation probability. The observation of the simulated model illustrates 5% improvement in retaining of data accuracy when compared to existing Kalman based estimation approach. The validation of varying channel is performed with a fading value of 150dB and Doppler shift of 15KHz. Observation of the simulated system for processing delay, system throughput, and packet loss ratio at a Doppler shift of 15KHz and fading of 150dB is shown in figure 8 (a-c) respectively.



(a)



(b)



(c)

Fig 7: Observation for (a) processing delay, (b) system throughput, and (c) packet loss ratio at a fading factor of 150dB and Doppler shift of 15 KHz

Observations for the monitored parameters at fading factor of 150dB and Doppler shift of 15 KHz is presented in table 5.

Table 5: Observation for simulated model at fading factor of 150dB and Doppler shift of 15 KHz

	SNR (dB)	Kalman filter-RLS method	Kalman filter-min-max	Proposed Estimator with dual parameter
Delay (ms)	10	0.51	0.24	0.16
	20	0.26	0.14	0.07
	30	0.18	0.07	0.05
	40	0.14	0.05	0.04
Throughput (Mbps)	10	0.12	0.31	0.5
	20	0.15	0.52	1.3
	30	0.32	0.71	1.8
	40	0.46	1.13	2.4
PLR	10	0.96	0.42	0.3
	20	0.23	0.15	0.08
	30	0.13	0.05	0.03
	40	0.03	0.03	0.01

The observation at fading factor of 150dB and Doppler shift of 15 KHz shows a lower delay metric, increase in throughput and lesser PLR. These observation inferences the robustness of the proposed approach at different channel effects in the MIMO-OFDM communication system.

5. Conclusion

The performance of estimation in a MIMO communication system is improved by developing a new estimation parameter in consideration with varying potion and channel interference. Two observing factor of user varying position were defined in updating the monitoring parameter using an adaptive threshold value, the presented approach evaluated for varying channel interference illustrated an increase of throughput and decrease in estimation convergence due to distinct varying parameters. The proposed approach observes an increase of 12% in throughput in comparison to existing Kalman filtration approach. The packet loss is observed to decrease by 8% and the convergence delay is decreased by 13% as compared to the existing estimation approach using Kalman filter. The proposed approach shows a significant enhancement in the estimation under dynamic channel interference conditions.

References

[1] Venkatraman, Ganesh, Antti Tölli, Markku Juntti, and Le-Nam Tran. "Traffic aware resource allocation schemes for multi-cell MIMO-OFDM systems." IEEE Transactions on Signal Processing 64, no. 11 (2016): 2730-2745.

[2] Karabulut, Muhammet Ali, AFM Shahen Shah, and HacIIlhan. "A Novel MIMO-OFDM Based MAC

Protocol for VANETs." IEEE Transactions on Intelligent Transportation Systems (2022).
[3] Kuo, Li-Chung, and Tommaso Melodia. "Cross-layer routing on MIMO-OFDM underwater acoustic links." In 2012 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON), pp. 227-235. IEEE, 2012.
[4] Tseng, Shu-Ming, and Yung-Fang Chen. "Average PSNR optimized cross layer user grouping and resource allocation for uplink MU-MIMO OFDMA video communications." IEEE Access 6 (2018): 50559-50571.
[5] Fedosov, V. P., A. A. Legin, and A. V. Lomakina. "Adaptive algorithm for data transmission in wireless channels based on MIMO—OFDM technique." In 2017 Radiation and Scattering of Electromagnetic Waves (RSEMW), pp. 218-221. IEEE, 2017.
[6] Ro, Jae-Hyun, Seung-Jun Yu, Young-Hwan You, Sung Kyung Hong, and Hyoung-Kyu Song. "An adaptive QR-based energy efficient signal detection scheme in MIMO-OFDM systems." Computer Communications 149 (2020): 225-231.
[7] Yuan, Chaoying, Xiaofeng Tao, Wei Ni, Na Li, Abbas Jamalipour, and Ren Ping Liu. "Joint power allocation and beamforming for overlaid secrecy transmissions in MIMO-OFDM channels." IEEE Transactions on Vehicular Technology 69, no. 9 (2020): 10019-10032.
[8] Tang, Ruiguang, Xiao Zhou, and Chengyou Wang. "Kalman filter channel estimation in 2× 2 and 4× 4 STBC MIMO-OFDM systems." IEEE Access 8 (2020): 189089-189105.
[9] De, Parthapratim. "Reduced-Rank Filtering-Based Semiblind MIMO-OFDM Sparse Channel Estimation." IEEE Systems Journal 15, no. 1 (2020): 1036-1047.
[10] Joy, Asif Alam, Mohammed Nasim Faruq, and Mohammad Abdul Matin. "Channel Estimation Techniques in the MIMO-OFDM System." In Enabling Technologies for Next Generation Wireless Communications, pp. 101-117. CRC Press, 2020.
[11] Omri, A., and R. Bouallegue. "New transmission scheme for MIMO-OFDM." International Journal of Next Generation Network 3, no. 1 (2011): 11-19.
[12] Sharma, Vishal, and Harleen Kaur. "On BER evaluation of MIMO-OFDM incorporated wireless system." Optik 127, no. 1 (2016): 203-205.
[13] Yang, Ruo-Nan, Wei-Tao Zhang, and Shun-Tian Lou. "Adaptive Blind Channel Estimation for MIMO-OFDM Systems Based on PARAFAC." Wireless Communications and Mobile Computing 2020 (2020).
[14] Gupta, Ashish Kr, Mukesh Pathela, and Arun Kumar. "Kalman filtering based channel estimation for mimo-ofdm." international journal of computer applications 53, no. 15 (2012).
[15] Simon, Eric Pierre, Laurent Ros, Hussein Hijazi, Jin Fang, Davy Paul Gaillot, and Marion Berbineau. "Joint carrier frequency offset and fast time-varying channel estimation for MIMO-OFDM systems." IEEE Transactions on Vehicular Technology 60, no. 3 (2011): 955-965.
[16] Chakraborty, Sucharita, and Debarati Sen. "Joint frequency offset and channel estimation in distributed MIMO-OFDM systems." Wireless Personal Communications 92, no. 4 (2017): 1829-1847.
[17] Baek, Myung-Sun, Mi-Jeong Kim, Young-Hwan You, and Hyoung-Kyu Song. "Semi-blind channel estimation and PAR reduction for MIMO-OFDM system with multiple antennas." IEEE Transactions on Broadcasting 50, no. 4 (2004): 414-424.
[18] Sun, Sumei, Ingo Wiemer, Chin Keong Ho, and TjengThiangTjhung. "Training sequence assisted channel estimation for MIMO OFDM." In 2003 IEEE Wireless Communications and Networking, 2003. WCNC 2003., vol. 1, pp. 38-43. IEEE, 2003.
[19] Uwaechia, Anthony Ngozichukwuka, Nor MuzlifahMahyuddin, MohdFadzil Ain, Nurul Muazzah Abdul Latiff, and Nor FarahidahZa'bah. "Compressed channel estimation for massive MIMO-OFDM systems over doubly selective channels." Physical Communication 36 (2019): 100771.
[20] Chang, Yu-Kuan, Fang-BiauUeng, Ye-Shun Shen, and Chih-Yuan Liao. "Joint kalman channel estimation and turbo equalization for MIMO OFDM systems over fast fading channels." KSII Transactions on Internet and Information Systems (TIIS) 13, no. 11 (2019): 5394-5409.
[21] Raviteja, Patchava, Khoa T. Phan, and Yi Hong. "Embedded pilot-aided channel estimation for OTFS in delay–Doppler channels." IEEE transactions on vehicular technology 68, no. 5 (2019): 4906-4917.
[22] Karthickmanoj, R., J. Padmapriya, T. Sasilatha, and G. Aagash. "Evaluation of Filtering Techniques in Channel Estimation for MIMO-OFDM Systems." In Journal of Physics: Conference Series, vol. 1979, no. 1, p. 012025. IOP Publishing, 2021.