

Channel equalization and impulsive noise reduction in OFDM using SAGE-Based Rayleigh Channel Estimation and an AW-ZFE

N P Sarada Devi

Asst. Professor, Dept of ECE, S K University, Anantapuramu.
Research Scholar, Dept of ECE, JNTUA, Anantapuramu.

Andhra Pradesh – 515 002, India.

Dr.M L Ravi Chandra

Professor and HOD

Dept. of ECE, Srinivasa Ramanujan Institute of Technology,
Anantapuramu, Andhra Pradesh – 515 701, India.

Abstract— In contemporary wireless communication systems, orthogonal frequency division multiplexing, or OFDM, is frequently used to split high-speed data streams into several low-speed streams. Impulse noise significantly impairs OFDM communication systems' performance. These days, a variety of techniques are used to improve the performance of OFDM systems by lowering impulse noise and implementing channel equalization. In the meanwhile, when estimating Channel State Information (CSI), these methods recorded minimum throughput and experienced performance degradation issues. This paper develops an adaptive weighted zero forcing equalizer (adaptive weighted ZFE) for impulsive noise reduction and channel estimation in OFDM systems. Initially, channel estimation is done using the Space-Alternating Generalized Expectation-Maximization (SAGE) algorithm. Adaptive weighted ZFE then does the impulsive noise reduction and channel equalization. Here, the weighted ZFE and the adaptive idea are combined to create the adaptive weighted ZFE. Furthermore, the superiority of adaptive weighted ZFE in impulsive noise reduction and channel estimation is examined. With a Bit Error Rate (BER) of 1.87×10^{-4} , Mean Square Error (MSE) of 0.0001, throughput of 94.976 Mbps, and Symbol Error Rate (SER) of 0.0013, the experimental results show that the Adaptive weighted ZFE achieved higher performance.

Keywords: Orthogonal Frequency Division Multiplexing, Impulse Noise, Adaptive weighted Zero Forcing Equalizer, Space-Alternating Generalized Expectation-Maximization, channel estimation.

I. INTRODUCTION

In recent years, significant changes in wireless networks have been underway due to the increasing advancement of diverse on-demand services [12]. OFDM is a multipath method with various communication standards because of its effects in mitigating multipath distortion in the wireless channel [9]. OFDM is a widely used method in wireless communication systems due to its ease of implementation and enabling the utilization of available bandwidth [14]. OFDM is considered a digital modulation method that divides the single wideband signal into smaller or narrower bands of parallel bit streams. In OFDM, each narrowband stream is separately modulated on various orthogonal subcarriers, and then, the frequency is multiplexed. Due to its high spectral efficiency and high data rate, OFDM is widely utilized in wireless applications [10][13]. Also, OFDM modulation has attained huge success in communications because of its advantages in mitigating inter-carrier and inter-symbol interferences, resistance to multi-path fading, and computational complexities. Various OFDM variations are developed over the years to address

the challenges in diverse communication environments. For instance, Cyclic Prefix (CP) OFDM, Time-Domain Synchronous OFDM, Zero Padding OFDM, and so on are designed for optimizing the performance under unique scenarios [11][12]. The channel estimation methods are commonly used to increase the performance of OFDM system, where the received signals of multipath channels are corrupted by co-antenna interferences and Inter-Symbol Interference (ISI) [9]. Usually, the CSI is estimated accurately to provide effective OFDM communication [9]. Ideally, OFDM-based communication systems are corrupted by impulsive noise, which is a man-made noise that exhibits adverse effects and non-Gaussian characteristics in communication systems with poor error rate performance and great capacity loss [10]. The impulsive noise is generated by various sources, namely various maritime operations, switches for electrical equipment, ignition noise in automobiles, and so on. The impulsive noise occurs randomly with high-power impulses under short duration compared to Additive White Gaussian Noise (AWGN) [8]. In general, various multicarrier modulations engaged in wireless communication systems are highly resistant to impulsive noise. However, the degradation of performance caused by impulse noise is becoming a challenging research area for communication engineers [15]. Thus, efficient impulsive noise suppression techniques are employed to increase the performance of OFDM communication systems in the presence of additive impulsive noise [8]. At present, various noise reduction algorithms are introduced into the communication systems are received considerable attention [6][7]. The accuracy of channel estimation is increased in two main ways under time-varying conditions. One is to utilize suitable denoising algorithmic techniques for reducing the available noises, and the other is the utilization of suitable deep-learning techniques to directly estimate the response of channels accurately [2]. A self-optimizing filter, called an adaptive filter, is used to estimate the characteristics of the input-output signal by adjusting its internal parameters, whereas adaptive algorithms help to significantly reduce noise presented in signals [10]. This paper presents an Adaptive weighted ZFE designed for channel estimation and reducing impulsive noise in OFDM communication systems. Here, the channel estimation is initially performed in the OFDM system by utilizing the SAGE algorithm. Following this, the channel equalization and reduction of impulsive noise is performed by utilizing the Adaptive weighted ZFE model.

The major research contribution is summarized below,

- **Designed Adaptive weighted ZFE for channel equalization and impulse noise reduction:** In this research, the Adaptive weighted ZFE is designed for channel equalization and for reducing impulsive noise in OFDM communication systems. Here, the Adaptive concept is integrated with the weighted ZFE to design the Adaptive weighted ZFE.

The remnant portion of the paper are structured as, section 2 elucidates the existing models employed for channel estimation and impulsive noise reduction in OFDM systems. In section 3, the Adaptive weighted ZFE model designed in this research is demonstrated. Section 4 portrays the results and discussion performed, and the article is concluded with future research findings in Section 5.

II. MOTIVATION

In modern wireless systems, OFDM is used to provide high bandwidth utilization and data rate. OFDM was more robust against multi-path delays. OFDM has attained huge success in communication because of its advantages in mitigating inter-carrier and ISI, resistance to multi-path fading, and complexities. In recent years, OFDM-based communication systems have mainly been degraded by impulsive noise. Thus, various efficient impulsive noise reduction methods were employed to increase the performance of OFDM communication systems. Meanwhile, these methods recorded minimum throughput and suffered from performance degradation issues during the estimation of CSI in OFDM systems. Thus, it encourages designing a novel technique for channel equalization and impulsive noise reduction in OFDM systems.

III. LITERATURE REVIEW

Xing, C., *et al.* [1] developed Joint estimation of Channel and Impulse noise-Temporally Multiple Sparse Bayesian Learning (JCI-TMSBL) to mitigate impulse noise and estimate channel state in OFDM systems. The JCI-TMSBL significantly minimized the computational complexities during channel estimation and impulse noise reduction in a cyclic prefix-based OFDM system. Meanwhile, this model was not successful in balancing the errors that occurred during channel estimation. Li, Y., *et al.* [2] introduced NDR-Net to reduce impulsive noise and channel estimation in OFDM systems. This approach computed the noise level of OFDM communication systems under high convergence speed from real-time varying multipath channels. However, this scheme was not successful in minimizing the complexities by performing deep research and analysis, and it failed to reduce the noise introduced by pilot and channel estimation under high-order modulation. Mirsalari, S.H., *et al.* [3] designed a Least Squares Support Vector Regression (LSSVR) for reducing impulsive noise and channel estimation in OFDM systems. The LSSVR model attained minimum simulation and processing time while estimating multipath channels in the presence of impulse noise. Nevertheless, due to the unpredictable impulses and their high energy level, this scheme obtained poor estimation accuracy. Zhao, Y., *et al.* [4] established Sparse Bayesian Learning (SBL) and Forward-Backward Kalman filter (FB-Kalman) algorithm to reduce impulsive noise and perform

channel estimation in OFDM systems. This model captured the time correlation of sparse time-varying channels and effectively improved the signal channel estimation performance by exhibiting rapid convergence and recording less computational cost. However, this approach was not successful in utilizing advanced algorithmic models for increasing the robustness in detecting the presence of noise. Tseng, D.F., *et al.* [5] devised a Deep Neural Network (DNN) for the reduction of impulsive noise and performing channel estimation in an OFDM system. The DNN was more significant in reducing the computational complexities and was robust against impulse noise. Although this model was not successful in preventing the performance degradation arising from the unknowing occurrence of impulse noise. Also, this model suffered from high frequency of anomalous occurrences during the estimation of CSI.

A. Challenges

The limitations of previous works utilized for channel equalization and impulsive noise reduction in OFDM systems are depicted below,

- The JCI-TMSBL algorithm introduced in [1] reduced the computational complexity and improved the accuracy of channel estimation by utilizing a high-precision method under impulse noise environment for channel estimation in OFDM systems. However, this model failed to perform well in sparse channel scenarios, being outperformed by tradition Minimum Mean Square Error (MMSE) or Least Squares (LS) estimators.
- The NDR-Net approach designed in [2] was robust to channel estimation after signal clipping and performed well under minimum local oscillation offset condition. Meanwhile, this scheme failed to consider a threshold mechanism or weighting function to suppress and detect impulsive components.
- The SBL and FB-Kalman algorithm designed in [4] improved the estimation performance in an impulsive noise background. Meanwhile, this model recorded high algorithm complexities and was not successful in avoiding excessive amplification of both impulsive noise and AWGN.

Channel estimation and impulsive noise reduction in OFDM systems aim to accurately recover transmitted signals by mitigating the effects of multipath fading and bursty noise, where the performance of the system is severely degraded by non-Gaussian noise. Real-time challenges, such as low-latency demands, high noise unpredictability, and dynamic channel variations, require adaptive and innovative models to ensure reliable, efficient, and robust communication.

B. Maintaining the Integrity of the Specifications

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications

that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

IV. DESIGNED ADAPTIVE WEIGHTED ZERO-FORCING EQUALIZER MODEL FOR CHANNEL ESTIMATION AND IMPULSIVE NOISE REDUCTION IN OFDM

In this research, the Adaptive weighted ZFE is designed for channel estimation and impulsive noise reduction in OFDM systems. Initially, the channel estimation in the Multiple-Input Multiple-Output (MIMO)-OFDM system is performed using the SAGE algorithm [14]. After that, the channel equalization and impulsive noise reduction are executed using the proposed Adaptive weighted ZFE model. Here, the Adaptive weighted ZFE is designed by incorporating the Adaptive concept and the weighted ZFE [15]. The block diagram of the proposed Adaptive weighted ZFE for channel estimation and impulsive noise reduction in OFDM is given in Fig 1.

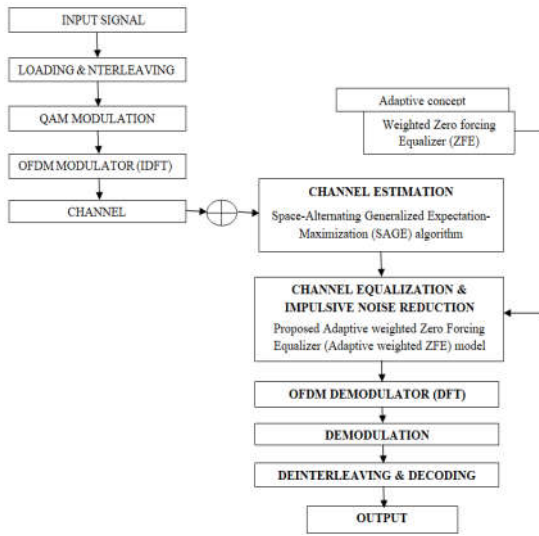


Fig 1. Illustration of Adaptive weighted ZFE for channel estimation and impulsive noise reduction in OFDM

A. MIMO-OFDM Model

MIMO-OFDM [15] communication systems are equipped with various reception and transmission antennas. Let us consider, X_r be the number of reception antennas, and X_t be the number of transmission antennas. In OFDM systems, the total receiving antennas is greater than or equal to the total transmitting antennas, i.e. $X_r \geq X_t$. Then, the input data is demultiplexed by the transmitter for the generation of data streams using serial-parallel conversion followed by data coding. After that, the modulation is performed using a Discrete Fourier Transform (DFT) modulator, then the symbol streams are passed for constellation mapping and perform cyclic prefix. The transmission of transmitted signals X_t of OFDM signals via transmitter antennas is finally performed. On the receiver side, the parallelization process is executed, and the removal of the added cyclic prefix is performed. Then, the signals are dem

odulated in order to permit signal reception on the receiver antenna by using an Inverse DFT (IDFT) modulator.

The data symbols of the individual transmitter are transmitted in a data vector form, designated as,

$$Q^{a_g} = [Q_1^{a_g}, Q_2^{a_g}, Q_3^{a_g}, \dots, Q_n^{a_g}]^T, \quad a_g = 1, 2, 3, \dots, P_g \quad (1)$$

In the expression, the number of data symbols is signified as n . Following this, the transmission of OFDM symbols over the transmit antennas is performed, and model the received signal for all sub-carriers. Thus, the signal received by the a^{th} sub-carrier is given by,

$$K_w^{a_u} = \sum_{a_g=1}^{P_g} H_{w,w}^{(a_u, a_g)} Q_w^{a_g} + V_w^{a_u} \quad (2)$$

Here, the diagonal channel matrix is signified as $H^{(a_u, a_g)}$, the diagonal element is represented as w , the receiver and transmitter antenna is symbolized as a_r and a_g . The expression of the transmitted symbol vector of dimension $(w \times 1)$ is given in equation (2), where the number of transmit antennas is represented as w . Likewise, the acknowledged symbol vector by the receiving antenna is signified as $K(a)$, and the symbol vector at the receiver side is given by $(i \times 1)$. The impulse noise vector of dimension $(i \times 1)$ is given by $V(a)$, and $H(a)$ represents the channel matrix of dimension $(i \times w)$.

B. Channel Estimation

In order to accurately estimate the channel coefficients, the CSI under mobile fading and multipath conditions is estimated during channel estimation. Here, the channel estimation in the OFDM communication system is performed using the SAGE [14] algorithm. Generally, the time domain SAGE algorithm helps to neglect the inversion of the matrix required with non-constant envelope modulations in the channel estimator, whereas decisions for an iterative solution of the LS estimator are provided by the frequency domain SAGE algorithm. In the time domain, the signal received is viewed in the form of complete data " A " and incomplete data " F " that is modified with the channel estimate $\hat{m}_{X_t, X_r, b}(l)$. Thus, the channel estimate with c^{th} iterations of the b^{th} path at time l computed by time domain SAGE is expressed as follows,

$$\hat{A}_{X_t, X_r, b}^{(c)} = \hat{A}_{X_t, X_r, b}^{(c)} + \left[F_{X_r} - \sum_{X'_t=1}^{X_t} \sum_{b'=0}^{B-1} \hat{A}_{X'_t, X_r, b'}^{(c)} \right] \quad (3)$$

$$\hat{m}_{X_t, X_r, b}^{(c+1)}(l) = \frac{\bar{S}_{X_t, b}^r \hat{A}_{X_t, X_r}^{(c)}(l)}{\bar{S}_{X_t, b}^r \bar{S}_{X_t, b}} \quad (4)$$

$$\hat{A}_{X_t, X_r, b}^{(c+1)} = \bar{S}_{X_t, b}^r \hat{m}_{X_t, X_r, b}^{(c+1)} \quad (5)$$

$$\hat{A}_{X_t, X_r, b''}^{(c+1)} = \hat{A}_{X_t, X_r, b''}^{(c)} \quad (6)$$

Here, the length of channel impulse response is signified as B , the distorted transmitted signals is indicated as x_t , and the column vector is denoted by $\bar{S}_{X_t,b}$. Following this, the initialization of the channel estimator with the channel estimate $\hat{m}_{X_t,X_r,b}^{(0)}$ is performed from the prevailing OFDM symbol, and is given by,

$$\hat{A}_{X_t,X_r,b}^{(0)}(l) = \bar{S}_{X_t,b} \hat{m}_{X_t,X_r,b}^{(0)} \quad (7)$$

C. Channel Equalization And Impulsive Noise Reduction

In OFDM communication systems, channel equalization and impulsive noise reduction are performed in order to ensure the reliability of recovered data in the presence of impulsive noise and distortions. In this research, the Adaptive weighted ZFE is used to reduce impulsive noise and perform channel equalization. Here, the Adaptive weighted ZFE is designed by incorporating the Adaptive concept with the ZFE [15]. The process carried out is briefly exemplified as follows,

(i). Zero Forcing Equalizer

The ZFE [15] is a linear equalization algorithm used in communication systems for reversing the frequency responses of the channels. In zero forcing, the multiplication of the signal vector of the receiver K with the filter matrix f is performed at the receiver end. Here, the filter matrix is given by,

$$f = H^+ = (H^H H)^{-1} H^H \quad (8)$$

In the expression, the Hermitian transpose function is signified as $(\cdot)^H$, and the generalized inverse matrix based on the matrix f is given by H^+ . Then, the transmit signal vector received by the channels undergoes a linear processing mechanism in order to recover the signals. Thus, the process performed during linear processing is expressed as,

$$\hat{N}^d = L^d (H)^d \quad (9)$$

Here, the output of the equalizer is signified as N^d , and L^d represents a selection matrix. The quantification of entity output is based on the adjacent symbols. Thus, the selection matrix L^d of the ZFE is designated as,

$$L_o = \psi \quad (10)$$

Let us consider, the ZFE never operates perfectly in the presence of impulsive noise. Thus, effective equalization strategies are followed to operate the equalizer under Minimal Mean Output-Energy (MMOE) conditions and impulsive noise. The MMOE is minimized by the equalizer based on the condition $X_r \geq X_t$ for the e^{th} data symbol stream. The MMOE is expressed by,

$$MMOE_e = \phi \left[\|N\|^2 H \right] \quad (11)$$

where, the constraint of zero forcing is given by,

$$L_{ZF} - MMOE = \arg \min \phi \left[\|K\|^2 H \right] \quad (12)$$

By substituting $L\psi = T_{X_t}$ and the solution is given by,

$$L_{ZF} - MMOE = (\psi^H \eta_{vv}^{-1} H)^{-1} \psi^H \eta_{vv}^{-1} \quad (13)$$

$$\eta_{vv} = \phi \left[\psi \psi^H \right] = \psi \psi^H + \eta_{vv}^G \in \psi^{X_r \times X_r} \quad (14)$$

Thus, the correlation matrix is determined from the received data by using the equation (14).

(ii). Channel equalization using designed Adaptive weighted Zero Forcing Equalizer

The channel equation is executed using the Adaptive weighted ZFE model, where the Adaptive weighted ZFE is designed by incorporating the Adaptive concept with the weighted ZFE [15]. The adaptive concept is integrated with weighted ZFE to significantly generate the noise correlation matrix by interpreting the previous instance values. The mathematical modelling of the Adaptive weighted ZFE model is given by,

Initially, the mitigation of noise effect is performed at the equalizer output, and the modelling of noise correlation is performed, and is designated as,

$$\eta_{ss} = \gamma_s^2 T_{X_r} \quad (15)$$

Here, the identity matrix is represented as T_{X_r} , and the variance is symbolized as γ_s^2 . Further, the noise correlation matrix is rewritten for increasing SNR, and is given by,

$$\eta_{ss} = \frac{1}{2} \gamma_s^2 T_{X_r} + \frac{1}{2} \gamma_s^2 T_{X_r} \quad (16)$$

Then, the smoothing factor is used to redefine the second term in the noise correlation matrix. Here, the smoothing factor is designed based on the DFT of the received signal at the receiver. Thus, the generated noise correlation matrix is designated as,

$$\eta_{ss}^T = \kappa \gamma_s^2 T_{X_r} + \delta \gamma_s^2 T_{X_r} \quad (17)$$

In the expression, the kernel impulse noise interpolator is represented as κ , and the smoothing term is given by δ . Further, the smoothing factor is articulated as,

$$\delta = [DFT(z) * P(z)] \quad (18)$$

$$P(z) = \begin{cases} 1, & \text{if } z < z_0 \\ 0, & \text{if } z > z_0 \end{cases} \quad (19)$$

In the expression, the pilot signal is expressed as z_0 , and the DFT of the received signal z is given by $DFT(z)$.

By substituting equation (18) in equation (17), we get

$$\eta_{ss}^T = [DFT(K) * P(K)] \gamma_s^2 T_{X_r} + \kappa \gamma_s^2 T_{X_r} \quad (20)$$

The resultant output of smoothing term based on noise correlation matrix is given by,

$$\eta_{ss} = \psi \psi^H + ([DFT(K) * P(K)] \gamma_s^2 T_{X_r} + \kappa \gamma_s^2 T_{X_r}) \quad (21)$$

Thus, the equalization output is expressed as,

$$L_{ZF} = (\psi^H \eta_{vv}^{-1} H)^{-1} \psi^H \left[\psi \psi^H + ([DFT(K) * P(K)] \gamma_s^2 T_{X_r} + \kappa \gamma_s^2 T_{X_r}) \right]^{-1} \quad (22)$$

Since the channel is time varying, the output of equalization is articulated as,

$$L_{ZF} = \left(\psi^H(t) \eta_{kv}^{-1}(t) H(t) \right)^{-1} \psi^H \left[\psi \psi^H + \left([DFT(K) * P(K)] \gamma_{S,T_x}^2 + \kappa \gamma_{S,T_x}^2 \right)^{-1} \right] \quad (23)$$

Let us consider ' κ ' is adaptive and varies from [0,3], where κ is given by,

$$\kappa = \left[\cos^2 \left(\frac{\mathcal{G}^2}{4} - \mathcal{G} \right) + \frac{\mathcal{G}^4}{\mathcal{G}^4 + 4} \right] \cdot \frac{3}{2} \quad (24)$$

In the expression, $\cos^2(\cdot) \in [0,1]$, $\frac{\mathcal{G}^4}{\mathcal{G}^4 + 4} \in [0,1]$, and $\mathcal{G}$ is any real number.

V. RESULTS AND DISCUSSION

The analysis executed for the validation of the efficacy of Adaptive weighted ZFE while estimating CSI and reducing impulsive noise in OFDM communication systems is demonstrated in this section.

A. Authors Experimental Set-Up

The Adaptive weighted ZFE employed for channel estimation and impulsive noise reduction in OFDM is implemented in the MATLAB tool with simulation.

B. Evaluation indicators

In order to validate the efficacy of the Adaptive weighted ZFE, the analysis is performed using different indicators, which are detailed below.

a) **MSE:** The MSE is used to estimate the deviation between the output of the equalizer from the actual transmitted signal, and is designated as,

$$MSE = E \left(\left\| W_p^* - W_p \right\|^2 \right) \quad (25)$$

In the expression, the original transmitted signal is represented as W_p^* , and W_p is the estimated output.

b) **BER:** The BER is used to identify the robustness of Adaptive weighted ZFE in reducing impulsive noise, and is used to accurately determine the quality of communicated channels. The BER is given by,

$$BER = \frac{I}{J} \quad (26)$$

Here, I is the number of error bits, and J symbolize the number of transmitted bits.

c) **SER:** SER is used to estimate the interference of the channels, which is designated as,

$$SER = E \left[q \left(\frac{\alpha + \beta}{\sqrt{\lambda}} \right) \right] \quad (27)$$

where, the weight is signified as α , the dominant interference is represented as β , the noise variance is given by λ , the Q function is symbolized as q , and E is the expectation.

d) **Throughput:** The rate at which the data is transmitted or processed over a specific time period is termed throughput.

C. IdentiComparative Models

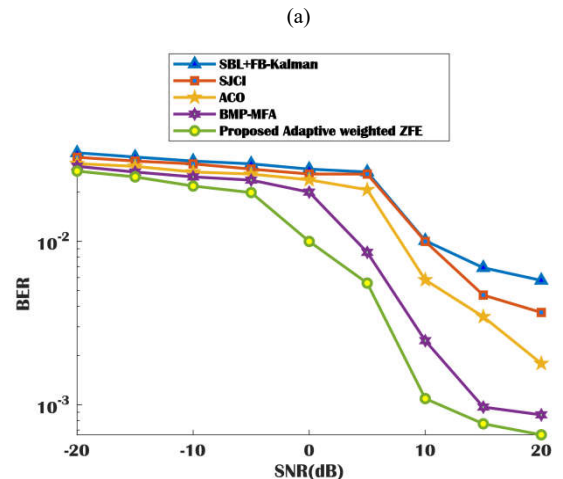
The efficacy of Adaptive weighted ZFE is validated by comparing it with prevailing channel estimation and impulsive noise reduction schemes, like SBL+FB-Kalman [4], Successive JCI (SJCI) [7], Ant Colony Optimization (ACO) [13], and Bayesian matching pursuit-Moth-Flame algorithm (BMP-MFA) [9].

D. Comparative Assessment

The quantitative validation to assess the supremacy of Adaptive weighted ZFE, is performed based on Rayleigh channel by varying SNR. The investigation performed is demonstrated below,

For Rayleigh Channel:

Figure 2 portrays the evaluation of Adaptive weighted ZFE model designed for channel estimation and reduction of impulsive noise based on SNR for Rayleigh channel. Figure 2(a) depicts the investigation of Adaptive weighted ZFE using throughput by varying SNR. For SNR of 10dB, the Adaptive weighted ZFE measured throughput of 95.898Mbps, and the throughput recorded by existing schemes, like SBL+FB-Kalman, SJCI, ACO, and BMP-MFA is 75.098 Mbps, 81.978 Mbps, 86.876 Mbps, and 91.876 Mbps. In figure 2(b), the analysis of Adaptive weighted ZFE utilizing BER by varying SNR is elucidated. The BER of 6.55×10^{-4} is observed by Adaptive weighted ZFE, whereas the BER recorded by previous works is 5.76×10^{-3} by SBL+FBKalman, 3.67×10^{-3} by SJCI, 1.78×10^{-6} by ACO, and 8.68×10^{-4} by BMP-MFA for SNR of 10dB. The valuation of Adaptive weighted ZFE by means of SER under varying SNR is demonstrated in figure 2(c). The Adaptive weighted ZFE attained SER of 0.0050, and the SER observed by baseline techniques, such as SBL+FB-Kalman is 0.0083, SJCI is 0.0079, ACO is 0.0075, and BMP-MFA is 0.0064 for 10dB SNR. Moreover, the validation of Adaptive weighted ZFE utilizing MSE by varying SNR is shown in figure 2(d). The MSE of 0.0006 is recorded by Adaptive weighted ZFE for SNR of 10dB, whereas the MSE recorded by existing schemes is 0.0065 by SBL+FB-Kalman, 0.0046 by SJCI, 0.0023 by ACO, and 0.009 by BMP-MFA.



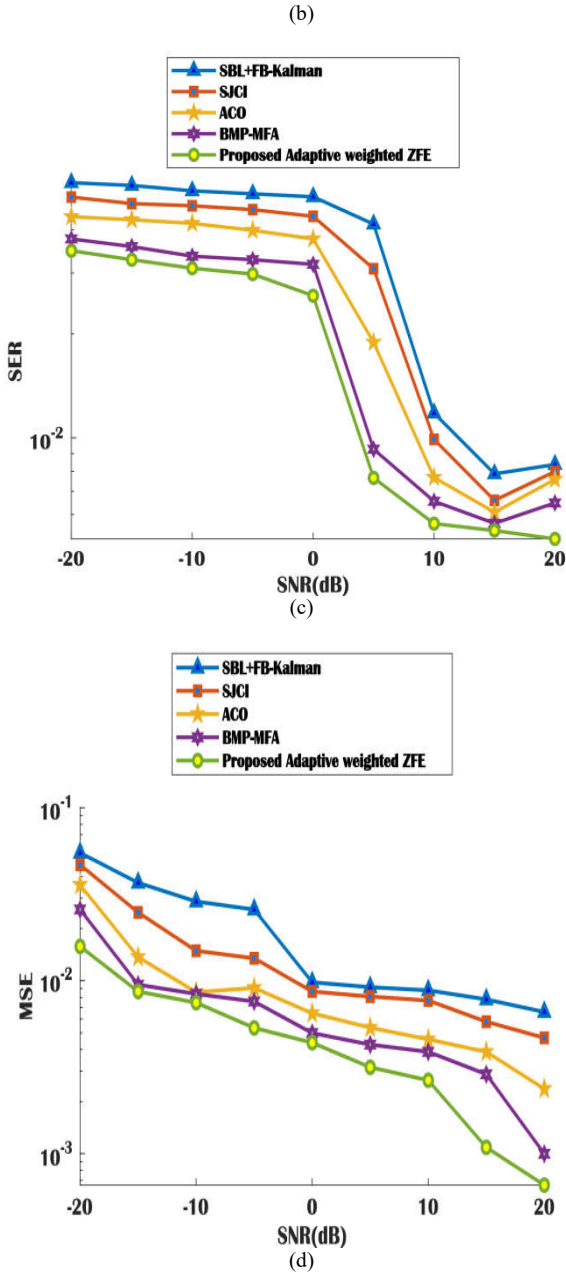


Fig 2. Investigation of Adaptive weighted ZFE utilizing (a) Throughput (b) BER, (c) SER, and (d) MSE for Rician channel

TABLE I. COMPARATIVE DISCUSSION

Evaluation Indication	Table Column Head				
	JCI	SJCI	ACO	BMP-MFA	Proposed Adaptive weighted ZFE
<i>For Rayleigh channel</i>					
BER	5.76×10^{-3}	3.67×10^{-3}	1.78×10^{-6}	8.68×10^{-4}	6.55×10^{-4}
MSE	0.0065	0.0046	0.0023	0.0009	0.0006
SER	0.0083	0.0079	0.0075	0.0064	0.0050
Throughput (Mbps)	75.098	81.978	86.876	91.876	95.898

VI. CONCLUSION

The impulsive noise is becoming a main threat to OFDM communication systems because of the inevitable corruption of signals across all subcarriers, which also degrades the performance of the OFDM system. Nowadays, various impulsive noise reduction techniques are used to reduce the performance of OFDM systems. In this article, the Adaptive weighted ZFE model is designed to accurately perform channel equalization and reduce impulsive noise in an OFDM communication system. Here, the MIMO-OFDM system is initialized, and the channel estimation in the OFDM system is executed using the SAGE algorithm. After that, Adaptive weighted ZFE is designed for channel equalization and impulsive noise reduction. Here, the Adaptive weighted ZFE is designed by incorporating the Adaptive concept with the weighted ZFE. Furthermore, the supremacy of Adaptive weighted ZFE is investigated by comparing it with previous works employed for comparison. The Adaptive weighted ZFE yielded high performance with BER, MSE, throughput, and SER of 6.55×10^{-4} , 0.0006, 0.0050, and 95.898 Mbps for Rayleigh channel. Future endeavors will focus on the utilization of hybrid deep learning techniques to accurately reduce impulsive noise in OFDM communication systems.

REFERENCES

- [1] Xing, C., Ran, Y., Tan, G., Meng, Q. and Lu, M., "Impulse noise mitigation and channel estimation method in OFDM systems based on TMSBL", IEEE Access, 2024.
- [2] Li, Y., Bian, X. and Li, M., "Denoising generalization performance of channel estimation in multipath time-varying OFDM systems", Sensors, vol.23, no.6, pp.3102, 2023.
- [3] Mirsalari, S.H., Haghbin, A., Khatir, M. and Razzazi, F., "Least squares support vector regression-based channel estimation for OFDM systems in the presence of impulsive noise", Wireless Personal Communications, vol.139, no.2, pp.883-898, 2024.
- [4] Zhao, Y., Li, Y., Shi, S. and Yu, J., "Joint channel and impulse noise estimation based on compressed sensing and Kalman filter for OFDM system", EURASIP Journal on Advances in Signal Processing, no.1, pp.105, 2023.
- [5] Tseng, D.F., Lin, C.S. and Tseng, S.M., "Impulse Noise Suppression by Deep Learning-Based Receivers in OFDM Systems", Wireless Personal Communications, vol.134, no.1, pp.557-580, 2024.
- [6] Duan, S., Liu, J., Pang, Y., Yu, X. and Wu, C., "A joint denoising and deep learning detector for OFDM-IM", IET Communications, vol.17, no.13, pp.1513-1523, 2023.
- [7] Sarada Devi, N.P. and Chandra, M.R., "Multi Station Approximation and Noise Mitigation Process to OFDM Systems Using Successive JCI", ICDSMLA 2021, pp.603, 2022.
- [8] Lv, X., Li, Y., Wu, Y., Wang, X. and Liang, H., "Joint channel estimation and impulsive noise mitigation method for OFDM systems using sparse Bayesian learning", IEEE Access, vol.7, pp.74500-74510, 2019.
- [9] Sarada Devi, N.P. and Ravi Chandra, M.L., "Optimized Bayesian Matching Pursuit for Joint Channel Estimation and Impulse Noise Mitigation", Journal of Circuits, Systems and Computers, pp.2550116, 2024.
- [10] Irum, A., Fayyaz, A.M., Ayub, S., Raza, M., Alhaisoni, M., Khan, M.A., Alqahtani, A., Kim, H. and Kang, B.G., "Impulsive Noise Cancellation in OFDM System Using Low Density Parity Check", Comput. Syst. Sci. Eng., vol.46, no.1, pp.1265-1276, 2023.
- [11] Tian, T., Yang, K., Wu, F.Y. and Zhang, Y., "Channel Estimation for Underwater Acoustic Communications in Impulsive Noise Environments: A Sparse, Robust, and Efficient Alternating Direction Method of Multipliers-Based Approach", Remote Sensing, vol.16, no.8, pp.1380, 2024.
- [12] Sheikh-Hosseini, M., Rahdari, F., Ghasemnezhad, H., Ahmadi, S. and Uysal, M., "A Comparative Performance Evaluation of OFDM,

GFDM, and OTFS in Impulsive Noise Channels”, IEEE Open Journal of the Communications Society, 2024.

- [13] Sarada Devi, N.P. and Parnapalle Reshma,M., “Ant Colony Optimization for Joint Channel Estimation and Impulsive Noise Mitigation Method in OFDM Systems”, NeuroQuantology, vol.20, no.8, pp. 8424-8432, 2022.
- [14] Ketonen, J., Juntti, M., Ylioinas, J. and Cavallaro, J.R., “Implementation of LS, MMSE and SAGE channel estimators for mobile MIMO-OFDM”, In Proceedings of 2012 Conference Record of the Forty Sixth Asilomar Conference on Signals, Systems and Computers (ASILOMAR), IEEE, pp. 1092-1096, 2012.
- [15] Girija, S.P. and Rao, R., “Fractional weighted ZF equalizer: A novel approach for channel equalization in MIMO-OFDM system under impulse noise environment”, Communications in Science and Technology, vol.6, no.1, pp.1-10, 2021.