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# Blind Channel Estimation Using Enhanced Independent Component Analysis for MIMO-OFDM System

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**Abstract:** Blind Source Separation (BSS) is a process of separating a set of source signals from mixed-signal without the help of information of source signals. In some noisy acoustic surroundings, instinctive class detection is completely dependent on vocalization which remains a stimulating task. To identify the definite classes easily, the source signals have to be detached from the mixed signals and this separation procedure is considered as a substantial pre-processing phase before the detection procedure takes place. This research mainly focuses on the issues of BSS in bio-acoustic mixed signals. Independent Component Analysis (ICA) is current technique in the area of BSS that can discrete the mixed-signal and also utilizes Negentropy as its objective function. However, this method is penetrating to the separation matrix and it cannot diverge. So, the bootstrap ICA procedures with Fast and Robust Bootstrap (FRB) method is developed which is applicable for all the signals. The quality of separated source signals using Enhanced-ICA and other algorithms are compared and evaluated according to MATLAB toolbox metrics. The results show that Enhanced-ICA with negentropy is used for finding a maximum non-gaussianity which achieves the BER performances of 0.00019 which is better than existing Discrete Wavelet Transform based BSS (DWT-BSS) and Modified Newton with Improved Animal Migration Optimization (MN-IAMO).

**Keywords:** Blind source separation, Bit error rate, Fast and robust bootstrap, Independent component analysis, Negentropy.

## Notations

| Notation | Description |
|---|---|
| $x(n)$ | DWT sequence |
| $Y_t$ | Non-linear function |
| $a$ | Scale factor |
| $b$ | Translation |
| $W(a, b)$ | High Coefficients |
| $\varphi$ | Protected wavelet |
| $X_{gauss}$ | Identical Correlation |
| $H(X)$ | Calculation of entropy |
| $J(X)$ | Gaussian size |
| $G^1$ and $G^2$ | Non-quadratic functions |
| $E(.)$ | Average Value |
| $K_1$ and $K_2$ | Normal Values |
| $V$ | Gaussian variable |
| $\beta$ | Constant |
| $q$ | Average sample |
| $X$ | Correlation matrix |
| $Q: R_d \rightarrow R_d$ | Continuous and Differential functions |
| $\widehat{W}_k *$ | Bootstrap replicated estimator |
| $\widehat{W}_k$ | Actual bootstrap replications |
| $\widehat{W}_k^{R*}$ | Linear Correction term |
| $\nabla Q(.) \in R^{d \times d}$ | Matrix of partial derivatives |

## 1. Introduction

Unlike the conventional robust single-user detection and Multi-User Detection (MUD) takes explicit account of the structure of interferers in present days. Also, MUD can lessen the harm to the location of the ideal sign. The objective of a MUD is to accomplish single client execution within the sight of interferers and release the orthogonalization rules to expand the limit of the structure [1, 2]. In a multiuser system, the clients discuss at the same time with a given recipient by adjusting data images into unique signature waveforms [3]. The received signal comprises an energetic adaptation of the superposition of the communicated waveforms [4]. MUD needs to distinguish the images of all clients at the same time. In recent years, remote communication turns into the most encouraging field due to late imaginative procedures for future communication of customer items [5]. To accomplish future proficient correspondence, inventive methods are required for different applications and ensure that the right work is utilized for applications that will be utilized by the clients in the future. Remote communication has gigantic difficulties in using the assets adequately and to overcome these difficulties numerous techniques are presented [6, 7].

In the middle of conventional air-interface methods, Orthogonal Frequency Division Multiplexing (OFDM) systems have recently attracted great interest [8, 9]. Nowadays, the strategies of the Multiple Input Multiple Output (MIMO) based OFDM system are the main patterns of future remote communications that have been adopted by the 4th generation of communication standards [10]. For the MIMO OFDM receiver, the channel state information commonly contains the features of adaptive detection, decorrelation detection and optimum detection [11, 12]. Moreover, there are a few disservices of the traditional identification strategies. Moreover, the constraint of the Channel State Estimation (CSI) may cause a wrong multiuser identification in the MIMO OFDM system [13]. Finally, the customary techniques reduce the divert limit in the MIMO OFDM system. One of the attractive solutions is to separate multiuser without the CSI in MIMO-OFDM [14]. Multiuser detection by numerous methods are selected as a new and effective method without prior constraints in MIMO OFDM systems [15]. The Enhanced ICA algorithm and the underlying contrast functions have a number of desirable properties when compared with existing methods for ICA. The algorithm finds directly independent components of (practically) any non-Gaussian distribution using any nonlinearity It is computationally simple, parallel, distributed and requires little memory space. Stochastic gradient methods seem to be preferable only if fast adaptively in a changing environment is required. This is useful in exploratory data analysis, and decreases the computational load of the method in cases where only some of the independent components need to be estimated.

The organization of this research work is offered as follows: The literature review of previous researches associated with MIMO-OFDM is specified in Section 2. Section 3 presents the problem statement. The objectives of this research are declared in section 4. The proposed method and its mathematical equations are discussed in Section 5. The simulation results of the proposed method are obtainable in Section 6. Lastly, the conclusion is stated in Section 7.

## 2. Literature review

Chittetti Venkateswarlu, Nandanavanam Venkateswara Rao [16] demonstrated Optimal channel estimation and interference cancellation in MIMO-OFDM system using Modified Newton (MN)-based improved Animal Migration Optimization (IAMO) model. The significant objective of this proposed approach involves the minimization of bit error rate and to enhance the system performance. In this paper, a modified Newton's method is utilized to determine the discover capability and to speed up the convergence rate thereby obtaining the optimum search space positions. However, the conversion process does not determine effortlessly because of inconsistency coding formula.

Shovon Nandi [17] presented a Novel Adaptive Blind Channel Estimation for Cyclic Prefix Coded MIMO-OFDM System. This method was implemented to support multiple users at the same time over the same frequency band. The proposed method was used to reduce the error rate included in the Blind Channel Estimation. Also which effectively reduces the cost and provides good SER performance. But this method failed to consider the Bit Error Rate of the MIMO system.

Amr Elnakeeb and Urbashi Mitra [18] demonstrated a Convex Optimization Approach (COA), based on the atomic norm to estimate the channel parameters. The Cramér Rao bound (CRB) for the leaked channel parameters is derived and also exhibits decoupling in delay and Doppler. Training sequences that optimize the CRBs for delay and Doppler parameters are determined via solving key fixed-point equations. CRB simulation shows that the proposed algorithm is essentially near optimal solutions. Unfortunately, trying to directly estimate the delay component led to performance degradation.

Vahid Karami, Behzad Mozaffari Tazehkand [19] presented modest blind MUD in overdetermined MIMO frequencies that were analyzed by means of DWT to reduce the noise interference. The proposed method (DWT-BSS) was supplementary operative in the intelligence of BSS and easy to channel sound in small SNR. However, Sum of Squared Errors is still high in all the circumstances.

Chung Buiquang and Zhongfu Ye [20] demonstrated a Constrained Alternative Least Square (ALS) based Tensor Blind Receivers for Multi-User MIMO Systems to reduce the complexity. The proposed ALS evading the arbitrary initializations which normally suggests a rapid conjunction and accordingly a low complication. Due to the absence of an inferred channels, the initialization process was done erratically which suggests a deliberate divergence.

From the above-mentioned literature reviews, it clearly shows that the conventional methods do not meet the obtainable BER at certain circumstances due to poor convergence rate. So, here, an Enhanced ICA is proposed with high benefit as quickly changing to adaptive environment to achieve the better BER characteristics.

## 3. Problem statement

The problems of the present work are mentioned as follows:

- In the present scenario, the main problem for high-speed data is reducing the service quality where the spectrum is inadequate.
- The traditional multiuser recognition systems have problems in the CSI transmission and channel resources.
- Blind MUD approaches are not appropriate for uplink transmission where space-time coding MIMO OFDM structures moving from mobile users to base station.
- The conventional systems cannot deliver better computational complexity and Bit Error Rate (BER) in MIMO OFDM systems.

## 4. Objectives

The objectives of this research are

- Blind multiuser detection methods are used to consume developed channel deployment and protect the channel assets when related through the existing systems in MIMO OFDM.
- By implementing Enhanced ICA algorithm for blind user detection to reduce the noise interference.
- The combination of the proposed scheme with a linear MSE scheme is used to minimize the computational complexity.
- The combination of the proposed scheme with a linear BER process is used to attain the finest performance.

## 5. Proposed method

DWT is a controlling tool that consecutively decomposes the signal into rough calculation and feature statistics at dissimilar periods through various determinations. The denoising process is completely dependent upon the arbitrary errors perceived in a signal which are existing in entire coefficients whereas a lesser quantity of large coefficients encompasses deterministic deviations. The NG procedure is used to compute a separate matrix which is given in Eq. (1)

$$W_{Ic+1} = W_{IC} + \mu(I - Y_t \hat{S}_t) W_{IC} \tag{1}$$

where, $Y_t = g(\acute{S})$ and $g(.)$ is a nonlinear function known as the Bussgang Nonlinearity (BN) or the score function. Additionally, the traditional sigmoid functions display low presentation because of their individualities in the composite field. Due to these shortcomings and by deliberating that BN displays less and slow divergence, as a result, the symmetric manner of complex-ICA in the BSS phase is exploited. The symmetric manner in distinction to the deflation manner is selected to achieve an improved convergence rate and to distribute every source signal instantaneously. The wavelet transform decomposes data into approximate range through forwarding the signal over both high/low pass filters. The expression for the DWT sequence $x(n)$ is given in Eq. (2)

$$W(a, b) = \sum_n \frac{1}{\sqrt{a}} x(n) \varphi * (\frac{n-b}{a}) \tag{2}$$

where $a$ denotes the scale factor and the discrete-time parameter $b$ represents the translation, and the function $\varphi$ is called the protected wavelet. At the point when the sign is deteriorated into its premise capacities, the high coefficients of $W(a, b)$ address great relationships of the sign with the wavelet premise capacities. This permits fixing the small coefficients to zero which is a high likelihood and addresses commotion coefficients. For this reason, need to use some approach to appraise the signal and noise correctly.

### 5.1 Negentropy

An imperative degree of non-gaussianity is assumed by negentropy which is completely based on the data hypothetical degree of entropy. The entropy of an arbitrary variable can be deciphered as the level of data that the perception of the variable offers. A major consequence of data hypothesis is Gaussian parameters which contains the biggest entropy among all irregular factors of equivalent change.

### 5.2 Enhanced ICA model with estimator

Usually, the character of Gaussian size may use negentropy to evaluate which is expressed as Eq. (3)

$$J(X) = H(X_{gauss}) - H(X) \quad (3)$$

where the identical correlation with random character is expressed as $X_{gauss}$ and calculation of entropy is mentioned as $H(X)$ which is specified in Eq. (4)

$$H(X) = \int Xlogp(X)dX \quad (4)$$

An operative calculation of possibility is roughly comprehensive for a high-level environment that is formulated as Eq. (5).

$$J(X) \approx K_1 \left(E\left(G^1(X)\right)\right)^2 + K_2(E\left(G^2(X)\right) - E\left(\left(G^2(V)\right)\right)^2 \quad (5)$$

Where non-quadratic functions are specified as $G^1$ and $G^2$; $E(.)$ designates the average value; normal values are mentioned as $K_1$ and $K_2$. Gaussian variable is represented as $V$. Deliberating the constraints of Kuhn-Tucker conditions [8] and $\|W = 1\|, for\ E(XG(W^T X))$ its optimal value can be obtained as Eqs. (6) to (8):

$$E(Xg(W^T X)) + \beta W = 0 \quad (6)$$

$\beta\ is\ constant$

$$J(E(XG(W^T X))) \approx E(XX^T)E(\acute{g}\ (W^T X) = E(\acute{g}\ (W^T X) \quad (7)$$

Once the evaluation is done, the iterative formulation is shortened to

$$W \leftarrow (E(XG(W^T X)) - E(\acute{g}\ (W^T X)\ W) \quad (8)$$

In instant, the complete Enhanced ICA method is designated as follows:

1. Clear the data;
2. Reset the vector form of weight as $W$;
3. Choose a function as non-quadratic,

$$g_1(u) = \tanh(a_1 u), g_2(u) = ue^{-u^2/2} \quad (9)$$

4. According to $W \leftarrow (E(XG(W^T X)) - E(\acute{g}\ (W^T X)\ W$, loops continually iterate until their convergence. Fig. 1 shows the overview of the proposed method.

### 5.3 FRB method

FRB is appropriate for calculations which could be stated as a resolution to structure with fixed point equivalences. In the development, symbolization for few variables such as $q$ which signifies average sample in excess of a data set. The example

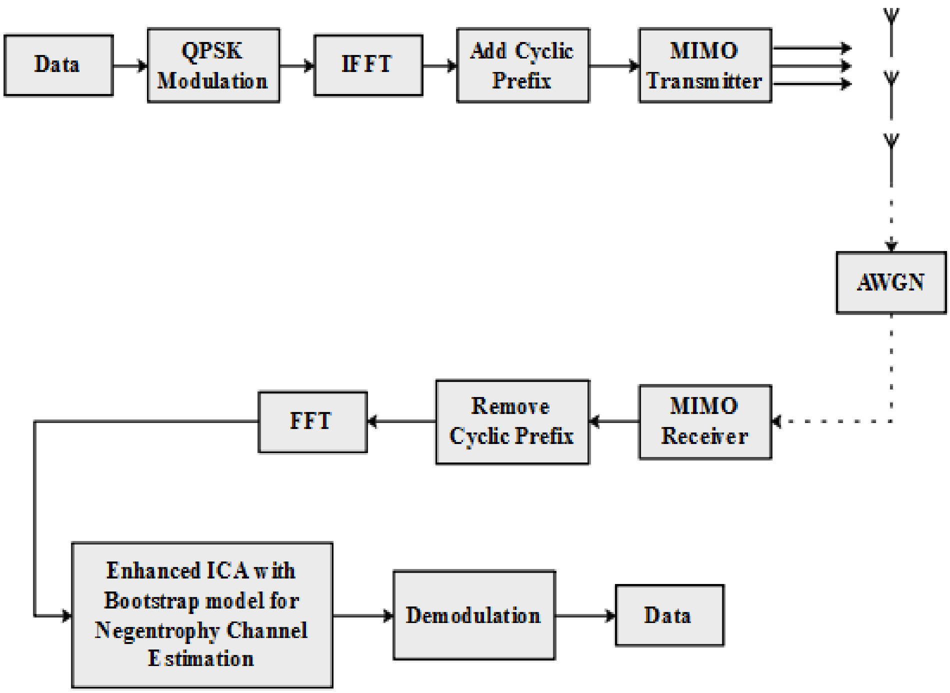


Figure. 1 Overview of the proposed method

Table 1. Performance analysis of BER with various methods at 2X2 Channel

| | | | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| 2x2 | Rician Channel | LS | 0.4800 | 0.4350 | 0.3685 | 0.2514 | 0.1262 | 0.0380 | 0.0094 |
| | | MMSE | 0.4692 | 0.4224 | 0.3563 | 0.2501 | 0.1264 | 0.0398 | 0.0080 |
| | | ICA | 0.4505 | 0.4013 | 0.3435 | 0.2324 | 0.1143 | 0.0329 | 0.0075 |
| | | Proposed | 0.4502 | 0.4007 | 0.3433 | 0.2321 | 0.1136 | 0.0320 | 0.0070 |
| | Rayleigh Channel | LS | 0.4817 | 0.4524 | 0.3902 | 0.3038 | 0.1866 | 0.0883 | 0.0362 |
| | | MMSE | 0.4677 | 0.4418 | 0.3830 | 0.2962 | 0.1860 | 0.0912 | 0.0373 |
| | | ICA | 0.4546 | 0.4237 | 0.3638 | 0.2789 | 0.1773 | 0.0832 | 0.0358 |
| | | Proposed | 0.4501 | 0.4196 | 0.3602 | 0.2759 | 0.1756 | 0.0823 | 0.0353 |

correlation matrix of data set $X$ is expressed as Eq. (10),

$$\hat{C} = E_{Fn}[XX^T] = \frac{1}{n}\sum_{l=1}^{n} X_l X_l^{\,T} \tag{10}$$

Let $\widehat{W_k} \in R^{d\times d}$ be an estimator of $k^{th}$ vector, $\widehat{W_k} \in R^{d\times d}$ based on a data set $X$ is specified as Eq. (11).

$$\widehat{W_k} = Q\ (\widehat{W_k}; X) \tag{11}$$

where $Q: R_d \to R_d$ is a continuous, differentiable function. The bootstrap replicated estimator $\widehat{W_k} *$ then solves $\widehat{W_k} * = Q\ (\widehat{W_k}\ ; X^*)$, and written as Eq. (12).

$$\widehat{W}_k^{1*} = Q(\widehat{W_k}; X^*) \tag{12}$$

where one-step estimator of $\widehat{W_k} *$ with initial value is expressed as $\widehat{W_k}$. But a linear correction term is expressed as Eq. (13):

$$\widehat{W}_k^{R*} = \widehat{W_k} + [1\text{-}\nabla Q(\widehat{W_k}; X)]\text{-}1\ (\widehat{W}_k^{1*} - \widehat{W_k}) \tag{13}$$

where $\nabla Q(.) \in R^{d\times d}$ is the matrix of partial derivatives w.r.t. $\widehat{W}$. While in the case of regularity conditions, $\widehat{W}_k^{R*}$ will be estimating the distribution as similar to the actual bootstrap replications $\widehat{W_k}$. The enhanced process permits by means of bootstrap-dependent statistical inference in a diversity of applications in which ICA is most frequently utilized.

## 6. Result and discussion

To validate the behavior of the proposed method, it achieved few signal model experimentations with the help of MATLAB. In some applications, the usage of the Enhanced ICA algorithm with symmetric ortho-normalization in every vector is impartially treated and contains parallel computation of ICA. In order to minimize the complexity, the Enhanced ICA block is divided into several sub-modules and each of the submodules is employed in different channels at various intervals. Furthermore, the proposed method is useful for exchanging linear algebra of multiplexed arrays. In the area of signal processing, it is being extensively used for blind signal detection and parameter estimation.

Table 1 shows the performance analysis of BER with various methods at 2X2 Channel. From table 1, it indicates the proposed enhanced ICA achieves the better BER when compared with other existing methods such as LS, MMSE, ICA at 2X2 Rician channel estimations. Fig. 2 displays the performance of BER at 2X2 Rician Channel. Correspondingly, the same procedure of the Rician channel is followed for the Rayleigh channel which is tabulated in table 2. The results achieved in table 1 shows that enhanced ICA accomplished a better BER index when compared with existing methods. The corresponding representation for the Rayleigh channel estimation has demonstrated in Fig. 3.

From the obtained results, it is obvious that the proposed approach is fundamentally Enhanced and more powerful under substantial clamor conditions. Nonetheless, it is generally broad in the writing to gauge and clarify the complexity as far as iteration. This calculation requiring not many iterations to combine might include weighty calculations at every iteration. In addition, in another writing, the normal time taken by a calculation to accomplish an answer is getting complexity, likewise, the calculation time relies upon the real algorithmic execution. These perceptions bring up that the quantity of genuine esteemed coasting point tasks required for obtaining a better solution.

Table 2 shows the performance analysis of BER with various methods at the 4X4 Channel. Table 2, clearly indicates the proposed enhanced ICA achieves the better BER when compared with other existing methods such as LS, MMSE, ICA at 4X4 Rician channel estimations. While Fig. 4 displays the performance of BER at 4X4 Rician Channel. Correspondingly, the same procedure is followed for the Rayleigh channel. The results achieved in Table

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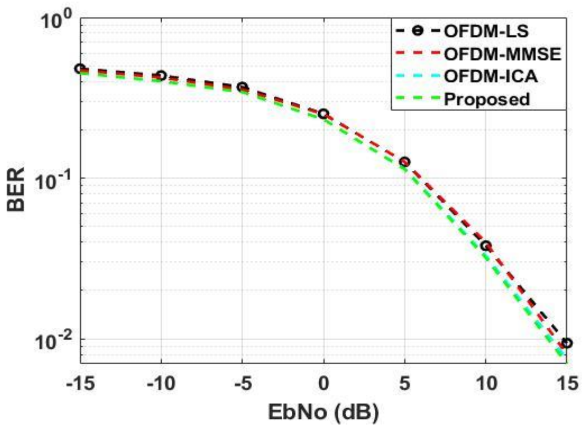


Figure. 2 Performance of BER at 2X2 rician channel

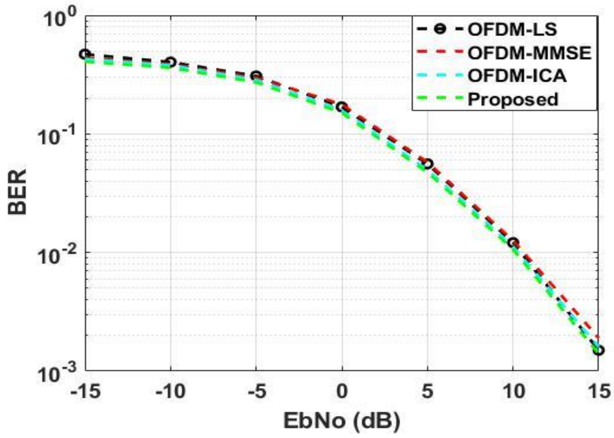


Figure. 3 Performance of BER at 2X2 rayleigh channel

Table 2. Performance analysis of BER with various methods at 4X4 Channel

| | | | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| 4x4 | RicianChannel | LS | 0.4698 | 0.4032 | 0.3077 | 0.1688 | 0.0559 | 0.0121 | 0.0015 |
| | | MMSE | 0.4380 | 0.3879 | 0.2980 | 0.1772 | 0.0576 | 0.0126 | 0.0019 |
| | | ICA | 0.4271 | 0.3792 | 0.2858 | 0.1577 | 0.0498 | 0.0112 | 0.0016 |
| | | Proposed | 0.4064 | 0.3611 | 0.2718 | 0.1505 | 0.0474 | 0.0106 | 0.0014 |
| | Rayleighchannel | LS | 0.4616 | 0.4188 | 0.3364 | 0.2261 | 0.1273 | 0.0650 | 0.0272 |
| | | MMSE | 0.4472 | 0.3992 | 0.3271 | 0.2252 | 0.1241 | 0.0633 | 0.0247 |
| | | ICA | 0.4320 | 0.3883 | 0.3157 | 0.2120 | 0.1190 | 0.0579 | 0.0238 |
| | | Proposed | 0.4280 | 0.3841 | 0.3125 | 0.2098 | 0.1181 | 0.0577 | 0.0236 |

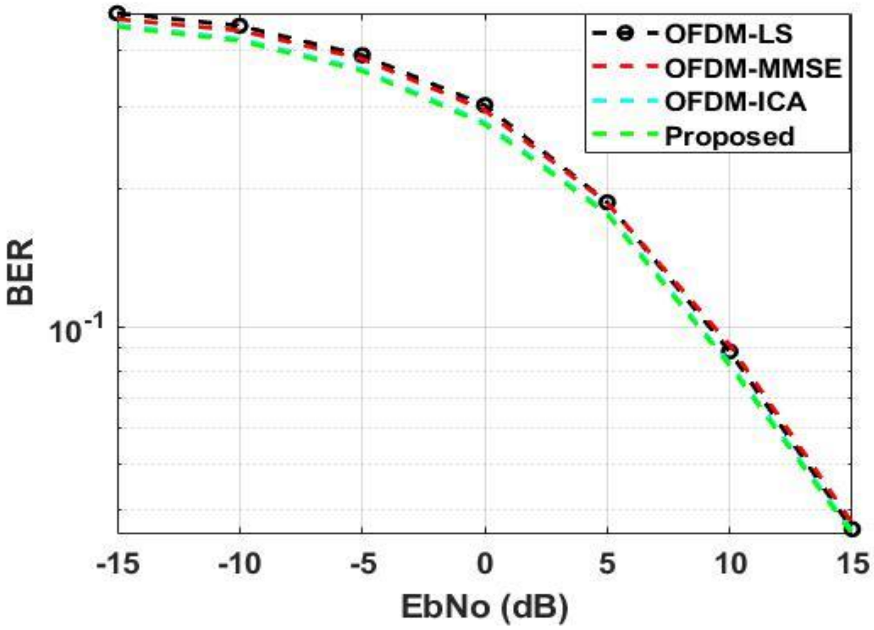


Figure. 4 Performance of BER at 4X4 rician channel

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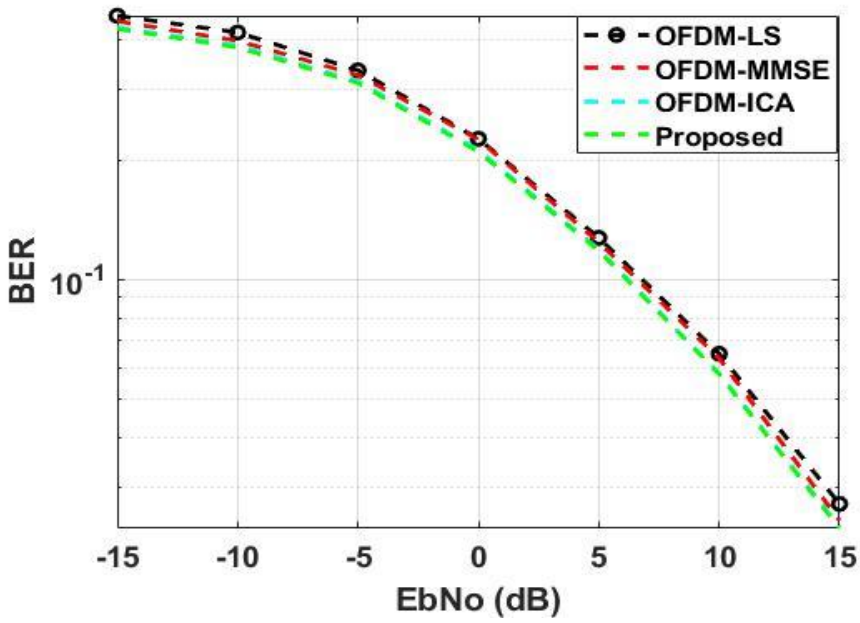


Figure. 5 Performance of BER at 4X4 rayleigh channel

Table 3. Comparative analysis of BER with existing method

| BER Characteristics | Existing DWT-BSS Method [19] | Proposed Enhanced-ICA |
|---|---|---|
| -20 | 1.8 | 1.3 |
| -15 | 1.8 | 1.4 |
| -10 | 1.8 | 1.5 |
| -5 | 1.8 | 1.6 |
| 0 | 1.9 | 1.7 |
| 5 | 0.15 | 0.010 |
| 10 | 0.0017 | 0.015 |
| 15 | 0.0015 | 0.001 |
| 20 | 0.0012 | 0.00019 |

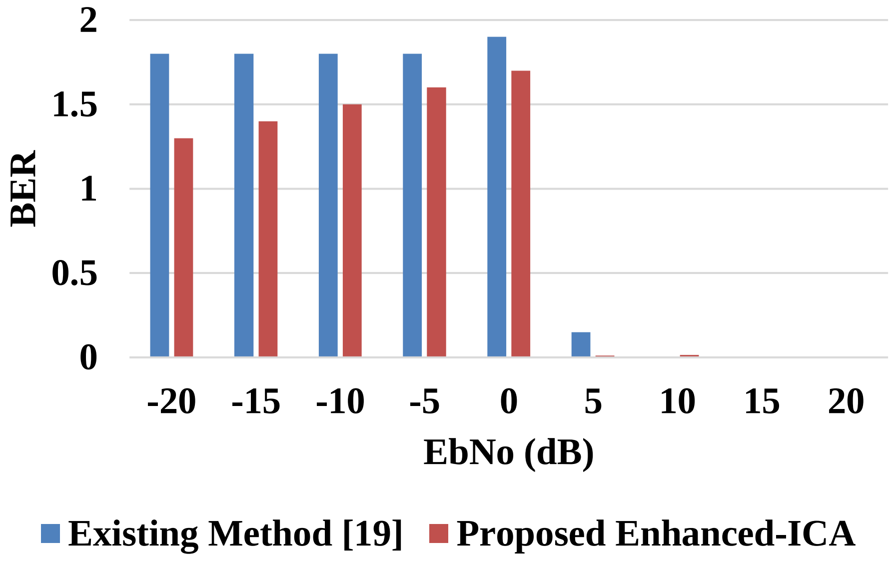


Figure. 6 Comparative analysis of BER

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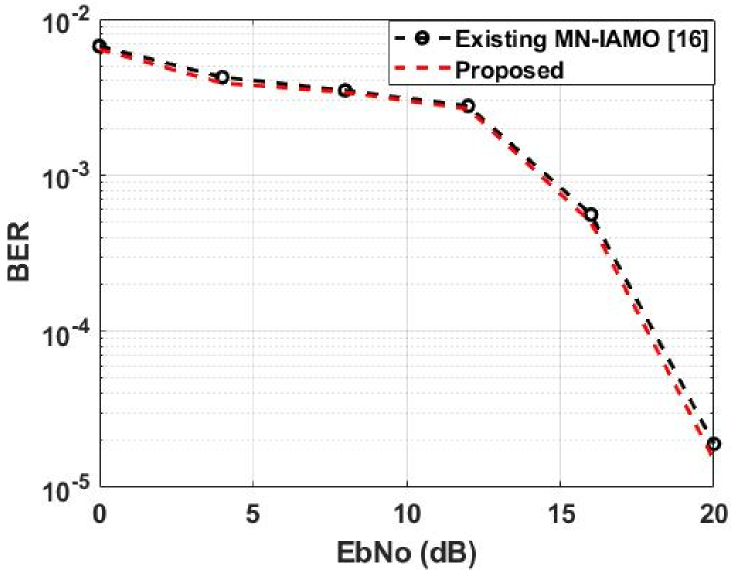

Figure. 7 Comparison of BER with existing MN-IAMO

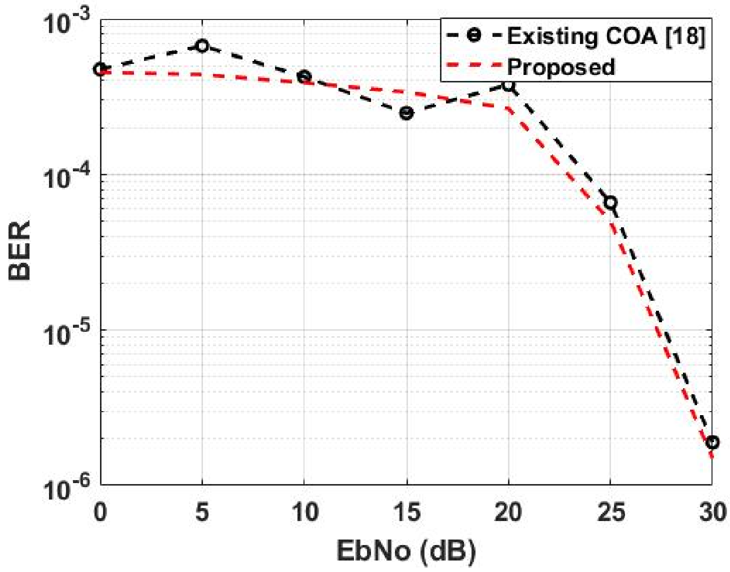

Figure. 8 Comparison of BER with existing COA

Fig. 6 shows the comparative analysis for proposed method and existing DWT-BSS [19] method. From the figure 6, it clearly shows that proposed method achieves better BER when compared with existing DWT-BSS [19] method. Fig. 7 and 8 shows the comparative analysis of BER performance with existing MN-IAMO [16] and COA [18] methods. Table 3 displays the comparative analysis of BER performance. The proposed Enhanced-ICA algorithm has a low computational time while maintaining or even decreasing BER and channel estimation error performance in comparison with the existing methods. The main features of the above figures can be qualitatively observed in this data. By using the improved Enhanced-ICA algorithm, the magnitude, sequence dissimilarity and the estimation of the output source signal improving substantially with respect to the source signal.

## 7. Conclusion

In this paper, the advantage of using BSS approaches in MIMO multiuser detection and the PCA method to transform the channels are discussed. The application and effectiveness of using DWTs in signal de-noising have been also demonstrated in the result section. It is illustrated that the proposed Enhanced ICA system is more effective in the sense of signal separation and more robust to channel noise whether BER or in impulsive noise conditions. From the results, high performance of BER is achieved and the proposed system becomes Enhanced and robust

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while decreasing the complexity of the detector system. Another achievement of the proposed system is working well even in short/long input data length and becomes more effective when the length of data increases. Compared with the existing MN-IAMO and COA algorithm, the proposed Enhanced ICA is used to solve the issues and it is sensitive to the initial values for input weight of the separation matrix. The simulation results demonstrate that the performance index of BER is enhanced to 0.00019 when compared with existing DWT-BSs method. Future work will focus on the inclusion of more objects in the dataset, which can make the dataset more efficient for the assistance of visually impaired people.

## Conflicts of Interest

The authors declare no conflict of interest.

## Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, have been done by 1st author. The supervision and project administration, have been done by 2nd author.

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