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CHANNEL ESTIMATION USING EXTENDED KALMAN FILTER WITH SLICED MULTI MODULUS BLIND EQUALIZATION ALGORITHM (SMMA)

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ABSTRACT

Multiple-Input Multiple-Output (MIMO) systems use multiple number of antennas on the both sides of transmission and reception to achieve high spectral efficiency. Channel impulse responses are regularly thought to be steady over a block or packet. These blocks are assumed like stationary on channels. Though, for communications in a high mobility and fading channel, the assumption will cut down the system performance. Here we concentrate on channel estimation for a MIMO system with Orthogonal Frequency Division Multiplexing (OFDM) transmission technique. The system, estimates the channel matrix at the receiver with Extended Kalman Filter (EKF). After the estimation, we employ low cost OFDM-MIMO soft data detector. The soft outputs of soft data detection are fed back to sliced multi-modulus algorithm (SMMA) for an improved channel estimation. Iteratively using EKF and SMMA overall performance has been achieved. Convergence characteristics of EKF-SMMA is simulated using MATLAB and it is shown that it gives better steady-state performance with regard to inter-symbol interference (ISI) & Bit-error rate. It additionally demonstrates that the researched calculation shows reduced steady-state misadjustment contrasted with the best reported multi-modulus algorithm (MMA).

Keywords: *Multiple-Input Multiple-Output, Orthogonal Frequency Division Multiplexing, Constant Modulus Algorithm, Multi-Modulus Algorithm, Sliced Multi-Modulus Algorithm, Extended Kalman Filters.*

1. INTRODUCTION

A MIMO transmission channel have a large number of antennas at the transmitter & the receiver end. Utilizing advanced modulation at the transmit antenna & receive antenna for signal processing, MIMO channel provides lower delays, greater data rates to multipath fading (duplication), & also provide support for a number of users like mobile & broadband communication frameworks contrasted with conventional frameworks [1], [2], [3]. Channel estimation is an essential thing of a receiver as channel response is not change in a particular time period. Furthermore, space-time coding technique is frequently employed in MIMO systems to lessen channel fading without giving up bandwidth & getting to be attractive in broadband wireless systems. A system that joins MIMO, space-time coding & OFDM can give spectral efficiency & higher data transmission over a fading channel [4], [5]. Basically, Channel State Information (CSI) makes it at ease to achieve the benefits of MIMO technology while reducing the complexity effect incurred through MIMO transmission & reception. So, channel estimation remains a significant part in the signal processing stages at the receiver of both the present & the essential wireless communication systems [6].

ISI occurs in MIMO-OFDM system because of bandwidth limited channels or multipath propagation. To reduce impact of ISI, Channel equalization is one amongst the procedures. Adaptive algorithms are utilized to initialize & regulate equalizer coefficients for unknown channel. Usually, a primary setting of equalizer weights is accomplished through a training sequence before data transmission [7]. Then again, it is essential to equalize a channel without the support of a pilot sequence. It is unfeasible to transmit a reference pilot signal sequence at the time of transmission of signal. This technique, known as blind equalization. This algorithm matches inverse impulse response with regard to the communication medium. So, opening the eye of the communication framework & permitting for a

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correct retrieval of transmitted symbols [8], [9]. Modulus algorithm family is presented to enhance ISI in blind channel. Modulus Algorithm has some important drawbacks in past decades like poor Signal Error Rate (SER) in multi signal & contour variation in coefficients degrades SER & BER. Sliced MMA provides improved performance compare with CMA (Constant Modulus Algorithm) & MMA. Because of multipath symbol interference & power degradation, adaptive filters are required to fix this problem [10], [11], [12].

Here, SMMA & EKF in MIMO channel is modelled & simulated to decrease the multipath noise & power degradation in the channel. Our objective is to compare the performance of convergence analysis, error analysis, & means square with the existing methods CMA, MMA, SMMA & the suggested algorithm EKF-SMMA in Rayleigh channel.

2. LITERATURE REVIEW

S. Ghazi-Maghrebi et al 2013, have discussed about the possibility to improve OFDM modulation through employing SMMA equalization. SMMA method was utilized for weight adaptation & to reduce the BER in the OFDM multicarrier modulation. Both analysis & simulations have demonstrated better performance of SMMA in comparison with least mean square (LMS) & MMA algorithms, in standard channels with additive heat noise & ISI impairment simultaneously. It showed that the SMMA equalization was a decent choice for high speed & real-time applications for instance OFDM based systems.

Jenq-Tay Yuan and Tzu-Chao Lin 2010, have derived a method for normalized error surface curvatures by utilizing a CMA, MMA, & two blind carrier phase recovery algorithms (CPRA) at stationary points by means of arbitrary 2-D symmetric signal constellations. If any additive noise added in communication channel, then it is not possible to recover the phase. So, here we are trying to analyze through filter techniques.

G. Ignatius et al. 2012, have introduced a method for carrying out a powerful channel estimation for MIMO-OFDM frameworks when they experience a fast fading environment. Proposed algorithm modeled the parameters to be assessed utilizing an auto-regressive model which was executed utilizing Burg Method. The channel estimation has been executed utilizing an EKF. The channel was modelled as L-path parametric Rayleigh flat fading. The evaluation done based on Rayleigh complex amplitudes (CA) & pilot frequency offset.

3. PROPOSED METHODOLOGY FOR CHANNEL ESTIMATION

In a wireless communication framework, estimation & equalization of the MIMO digital communication channels has been of great interest in recent days. Major difficulties are not just to separate these signals, however concurrently equalize the MIMO channel so as to achieve the highest quality communication. The blind channel equalization technique is one of the effective methods to detach the signals & remove the channel distortion. Equalization method & Blind MIMO channel prediction method has gained a lot of interest in multiple access signal detection, as blind method doesn't gamble on training signals nor require any kind of information of MIMO channels & retrieves all the inputs simultaneously. Current procedures for equalizing the channels do not select the channel, but directly design an equalizer for the channel. Figure 1 displays about the block diagram of blind equalization.

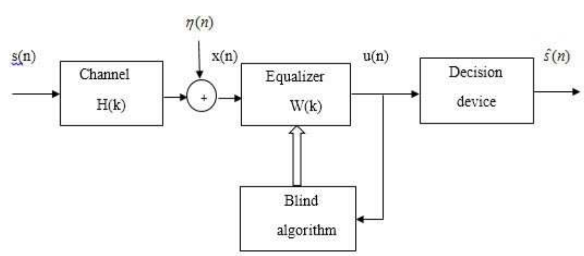

Figure 1: Block Diagram of Blind Equalization

3.1 Channel Estimation and Channel Equalization

Channel estimation algorithms concede the receiver to estimate channel's impulse response & describe the channel's behavior. To solve the issues of ISI channel estimation has been employed by adaptive channel equalizers. To reduce mean squared error (MSE), maximum likelihood detectors employ channel estimates. The channel outcome x (n):

$$x(n) = H(n) * s(n) + \eta(n) \qquad (1)$$

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where $\eta(n)$ is the adaptive noise, $H(n)$ is channel matrix, $s(n)$ is input signal. Main aim of channel estimation algorithms is to reduce MSE, $E[\eta 2(n)]$ while using as limited resources as possible in the evaluation process. Major benefits of channel estimation are that it allows coherent demodulation. Coherent demodulation needs the information of the phase of the signal. This can be formulated through utilizing channel estimation methods.

Blind equalization is the process of equalizing a channel deprived of training sequence. Blind equalization in digital medium is a field, which has achieved more interest over the past decades. Main objective of blind equalization is to help equalizer to match with the impulse reaction of the channel. Efficiency of blind equalization can be calculated based on convergence rate, Bit Error Rate (BER), ISI & symbol rate. The convergence rate is considered to be most important among other performance methods as it relates to the amount of time that the service would be interrupted on the network in the course of initialization, a variation in the features of the channel, or in the event that there is significant interference in the channel being used. SER helps to relate the equalizer's capability to produce upon convergence. Therefore, adaptive equalizer must deliver the optimal convergence-time without compromising the SER.

At blind channel reception an amount of interference is calculated and it will reduce with the help of extended Kalman adaptive filters. These kind of filters does not manipulate any previous information regarding channel state, & it can only be applied in time invariant channel. The channel state mathematical statement is made grounded on the information symbol & driving noise. For unknown channel, the state model required to improve the unknown parameters by adding information symbol & the channel state. The EKF method applies to the joint estimation of all subcarriers & additionally works in the per-subcarrier fashion with a much reduced complexity. Additionally, in the channel estimation, the EKF could directly give symbol detection. Channel matrix is estimated from equation (1).

Where $P[n,k]$ denotes the pilot symbols which is another form of $s[n,k]$ as equation (2) shows.

$$\tilde{H}[n,k] = P^{-1}[n,k]X[n,k] \qquad (2)$$

Thus, channel state information $\tilde{h}_l[n]$ can be achieved by applying an inverse fast Fourier transform (IFFT) to the transfer function $\tilde{H}[n,k]$.

$$\tilde{h}_l[n] = h_l[n] + z_l[n] \qquad (3)$$

Here $z_l[n]$ is a complex Gaussian vector whose distribution is $N(0,\sigma_z^2)$. The Kalman filter exploits the state space model in time/delay domain as shows in equation 4:

$$h_l[n+1] = Fh_l[n] + \omega_l[n] \qquad (4)$$

Here F is $M \times M$ matrix, $M = N_T \times N_R$ and $\omega_l[n]$ is the $M \times 1$ innovation noise vector. If $F, \sigma_z^2, \sigma_\omega^2$ are known parameters, the estimated channel state parameter $\tilde{h}_l[n]$ can be obtained by exploiting Kalman filtering from the equation (3) and (4). But it is impossible to discover the significant parameter in advance, so estimated Kalman filtering has been utilized to estimate channel parameters.

Innovations noise variance & the channel noise variance is essential for EKF filtering. But the innovations noise variance cannot be estimated directly due to $\omega_l[n]$ not being observed. So we construct an equation (5) to estimate $\omega_l[n]$.

$$\hat{\omega}_l[n] = \hat{h}_l[n \mid n] - \hat{F}[n \mid n]\hat{h}[n-1 \mid n-1] \quad (5)$$

Here in, since $\hat{h}_l[n \mid n]$ and $\hat{F}[n \mid n]$ can be obtained from the equations mentioned above, we can obtain the innovations noise variance $\hat{\sigma}_\omega^2[n]$ which can be expressed as:

$$\hat{\sigma}_\omega^2[n] = \frac{1}{LnM}\sum_{l=0}^{L-1}\sum_{m=1}^{n}\|\hat{\omega}_l[m]\|^2 \quad (6)$$

The measurement noise variance also cannot be observed, but estimated. We attain it as below.

$$\hat{z}_l[n] = \hat{h}_l[n] - \hat{h}_l[n \mid n-1] \qquad (7)$$

Here,

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$$\hat{h}_l[n \mid n-1] = \hat{F}[n-1 \mid n-1]\hat{h}[n-1 \mid n-1]$$

So the measurement noise variance can be expressed as:

$$\hat{\sigma}_z^2[n] = \frac{1}{LnM}\sum_{l=0}^{L-1}\sum_{m=1}^{n} \| \hat{z}_l[m] \|^2 \quad (8)$$

Because $\hat{h}_l[n]$ can be drawn, we can obtain channel transfer functions in time/frequency domain by FFT as

$$\hat{H}[n,k] = \frac{1}{N_T}\sum_{l=0}^{L-1}\hat{h}_l[n]e^{-j2kl/K} \quad (9)$$

After the estimation of channel matrix $\hat{H}(n)$, MMA is introduced to optimize estimation error (e_{MMA}). SMMA, an algorithm for use to digital transmission has been proposed. In SMMA, cost function integrates dispersion constant & slicer output. Several desirable features, comprising of multiple-modulus, symmetry, & (almost) uniformity fulfils by SMMA cost function. The SMMA cost function shows a much lower misadjustment compared to other algorithms, for example, CMA & MMA.

Here the pilot symbol considers as the input signal at the receiver end. So, P has been denoted in terms S. Equation (1) rewritten as Equation (10).

$$x(n) = \sum_{i=0}^{N-1}\hat{H}(i)s(n-i) + \eta(n) \quad (10)$$

where $\hat{H}(i)$ represents Estimated baseband channel form EKF, N is the length of the equalizer tap weights, $x(n)$ is complex received signal, $s(n)$ is source signal & $\eta(n)$ is additive white Gaussian noise. Equalizer complex tap weight-vector & input-vector are separately described as $W(n) = [w_0(n), w_1(n), \ldots, w_{L-1}(n)]^T$, $X(n) = [x(n), x(n-1), \ldots, x(n-L+1)]^T$ where T represents transpose of vector. $a(n) = W^T(n)X(n)$ as the channel equalizer output, result of the decision block is presented as $\hat{s}(n)$ which is calculated as the neighbor constellation symbol to a(n). The main purpose is to achieve an estimate of the transmitted sequence s(n) without employing training signal available at the receiver, such that $\hat{s}(n) = s(n-\Delta)$, where Δ is the bulk due to channel-equalizer combined impulse response. Here the equalizer accurately evaluates the received symbol that was transmitted Δ baud times earlier.

Multi-modulus algorithm permits concurrent joint blind equalization & carrier phase recovery by eliminating the necessity for an adaptive phase rotator to carry out separate constellation phase recovery. Earlier many MMA have been developed to recover the misadjustment caused by other algorithms like CMA. Some of the MMA schemes, especially for MIMO constellations, fix the phase offset error without utilizing any rotator toward the equalizer's end stage. Therefore, MMA gives reliable convergence & does not require rotator in steady state operation. The MMA penalizes dispersion of real & imaginary parts, u_R and u_I, of $u(n)$ separately. The MMA, unlike the CMA don't observe cross term $u_R u_I$. Here u_R is in-phase & u_I is quadrature components. Subsequently, MMA cost function is not a 2-D cost function & it is pseudo two-dimensional because it contains $u_R(n)$ and $u_I(n)$ only. MMA cost function & its parameter are given by

$$J = E\left[\left(u_R^2(n) - \gamma_R\right)^2 + \left(u_I^2(n) - \gamma_I\right)^2\right] \quad (11)$$

Where $E[\cdot]$ denotes the statistical expectation. $u_R(n)$, $u_I(n)$ are real & the imaginary parts of $u(n)$ respectively. γ_R is dispersion constant for real parts & γ_I is dispersion constant for imaginary parts of a transmitted signal, which presented as followings

$$\gamma_R = \frac{E\left[s_R^4(n)\right]}{E\left[s_R^2(n)\right]} \quad (12)$$

$$\gamma_I = \frac{E\left[s_I^4(n)\right]}{E\left[s_I^2(n)\right]} \quad (13)$$

Where $s_R(n)$ & $s_I(n)$ are real & imaginary parts of a transmitted signal s(n), respectively. The corresponding MMA weight tap updating algorithm is

$$W(n+1) = W(n) + \mu \cdot e_{MMA}(n) \cdot X^*(n) \quad (14)$$

The error function $e_{MMA}(n)$ can be expressed as

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$$e_{MMA}(n) = u_R(n)\left(\gamma_R - u_R^2(n)\right) + j \cdot u_I(n)\left(\gamma_I - u_I^2(n)\right) \quad (15)$$

MMA cost function can be calculated as the summation of two 1-dimensional cost functions, that helps to decrease dispersion of u_R & u_I around second contours. So the MMA is suitable to take advantage of the symbol statistics on specific kinds of signal constellations, for example, non-square & very dense constellations.

Though CMA provides accurate convergence & is capable of reducing inter-symbol interference (ISI) level to a significantly low level, it suffers from phase error when the signal constellations become very large. Hence, in steady-state operation the complexity increases with the receiver because of the requirement to a rotator at the output of the equalizer. The traditional MMA also has some complications with dense constellations. Therefore, SMMA algorithm has been proposed to increase the performance of MMA by decreasing the mismatch values. Since the proposed algorithm is devised by integrating the sliced symbols in the dispersion constants, it is known as SMMA.

The SMMA cost function penalizes dispersion of real & imaginary parts of u(n) separately, which is presented as following

$$J_{S-MMA} = E\left[\left(u_R^2(n) - |\hat{a}_R(n)|^c \gamma_R\right)^2 + \left(u_I^2(n) - |\hat{a}_I(n)|^c \gamma_I\right)^2\right] \quad (16)$$

The corresponding SMMA tap updating algorithm is

$$W(n+1) = W(n) + \mu \cdot e_{MMA}(n) \cdot X^*(n) \quad (17)$$

Where μ a step-size parameter & asterisk is represents complex conjunction. The error $e_{MMA}(n)$ function is given by

$$e_{SMMA}(n) = u_R(n)\left(|\hat{s}_R(n)|^c \gamma_R - u_R^2(n)\right) + j \cdot u_I(n)\left(|\hat{s}_I(n)|^c \gamma_I - u_I^2(n)\right) \quad (18)$$

Where c represents a positive constant ($c \leq 1$). Here we can notice that SMMA update is similar to the MMA. When c=0, the SMMA reduces to MMA. Since we use equalizer & the slicer output, the SMMA forces $u_R(n)$ and $u_I(n)$ to lie on the point contours. Point contours is described as sign $[u_R(n)]\sqrt{|\hat{s}_R(n)|^c \gamma_R}$ & sign $[u_I(n)]\sqrt{|\hat{s}_I(n)|^c \gamma_I}$. SMMA update mechanism is aware of the dispersion of u(n) away from the neighbor symbol $\hat{s}(n)$ in some statistical sense. SMMA produce faster convergence & offers the potential of multiple tap equalizer implementations.

4. COMPUTER SIMULATIONS

The simulation system applies to a 2×2 MIMO-OFDM system. The subcarrier number is 64, the length of FFT is 16, and the modulation scheme is OFDM. The computational difficulty of the LMS method is lower than the EKF method. Though the EKF method is more complex than the LMS method, the EKF method has better performance than LMS one. Hence, the choice of different methods is a trade-off between good performance and low computational complexity. Figure 2 and Figure 3, represents the BER vs EbNodB and MSE vs iteration respectively. As Figure 4 and 5 shows, the EKF-SMMA method has better convergence than existing method. Results showed that performances of the proposed EKF-SMMA method is better than those of the SMMA, MMA, and the CMA methods at 64 OFDM symbols. Though it has highest computational difficulty, the EKF method is still used to estimate channel because of its highest performance.

5. RESULT AND DISCUSSION

In this segment, a detailed analysis of the proposed system has done & makes use of BER curves to prove the validity & study the system in a detailed manner. Curves are plotted for MMA & SMMA for different cases. The sub-section 5.1 describes the overall experimental set-up & the simulation used. In the section 5.1.1 & 5.1.2, a detailed analysis of the system has been made.

5.1 Experimental Set Up & Simulation

The proposed channel estimation of MIMO-OFDM system based on EKF-SMMA is implemented in MATLAB Version 8.1.0.604 (R2013a). The system on which the technique was simulated was having 4 GB RAM with 64 bit operating systems having i5 Processor. For assessment of the proposed method, a randomly generated signal has been used.

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The Bit Error occurs when the received bits of the data sequence over a communication medium differs from the transmitted signals. The system considered Rayleigh noise channel for BER comparison. Here, we consider Rayleigh channel as a communication medium.

5.2 Effects on The Performance of the Proposed System

In this section, the length of the user input data N has been varied, to assess the performance of the system. The Rayleigh channel has been considered in all cases. BER curves for both the MMA & SMMA have been plotted.

BER Vs Eb_N0_dB, MSE Vs iteration, Convergence Vs iteration. Figure 2 shows the analysis of BER over EbN0dB of different methods such as CMA, MMA, SMMA and Proposed EKF-SMMA. When we consider the value of EbN0dB ranging from 4dB to 38dB it can be inferred that SMMA attains better BER when compared with CMA and MMA. Alternatively, EKF-SMMA achieves better BER even than SMMA ranging from 5dB to 35dB. This is due to the proposed method consist of the EKF in SMMA which predicts the channel matrix (H) instead of utilizing random channel matrix or generated channel matrix which has been used by the previous methods. The BER difference is 0.25 dB.

Figure 3 displays that, MSE in CMA is not stable throughout the iterations but vice versa in the other methods. This shows that, whenever the received strength is low, MSE is notably high and whenever the received strength is high, MSE is notably low. MSE is mostly low and even no error can be found after the 15th iteration in terms of EKF-SMMA.

Figure 4 presents that the convergence deviation is notably high between EKF-SMMA and the existing methods. We can also observe that in the initial set of iterations, the best fitness values of both EKF-SMMA and MMA are almost similar but when it is crossed around 15th iteration (approximately) EKF-SMMA shows a drastic minimization. This explains us that the strength of received signal from EKF is notably high.

Figure 5 explains the convergence error between EKF-SMMA and the existing methods. It can be witnessed that proposed and existing methods varies between 10-15dB and 20-25dB. This shows that wherever the signal reception fails, EKF-SMMA achieves peak position when compared to existing methods due to the identification of channel matrix through EKF.

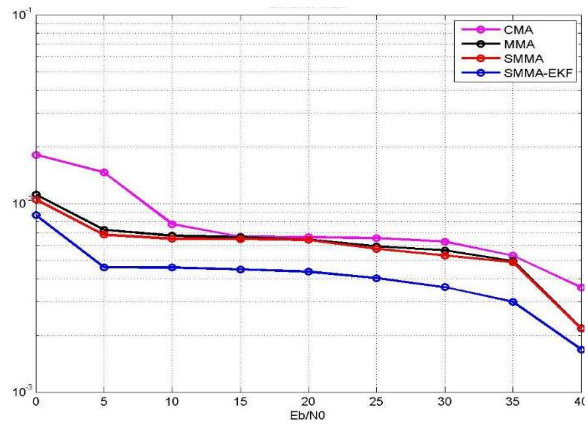

Figure 2: Comparison between BER and Eb No dB

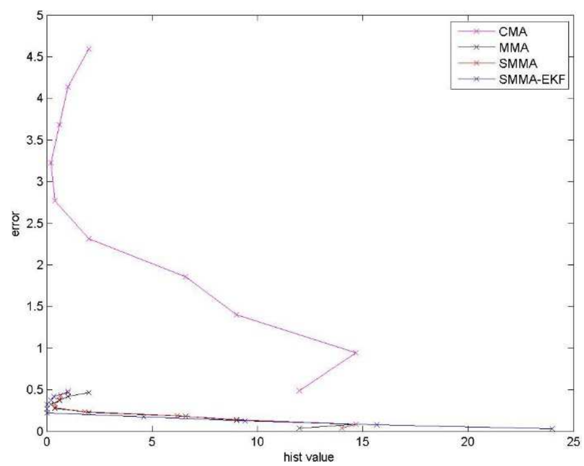

Figure 3: Comparison between MSE and iteration

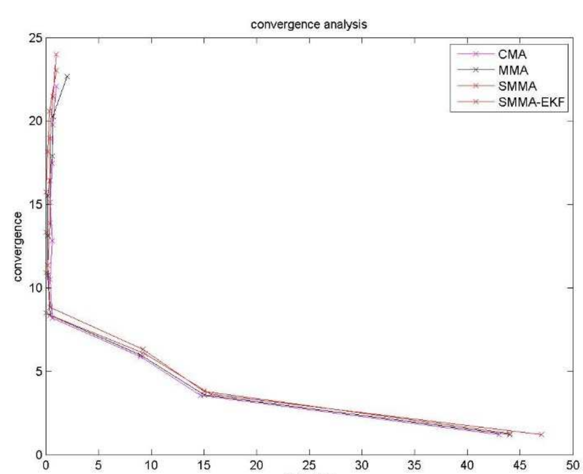

Figure 2: Convergence Analysis of MIMO-OFDM

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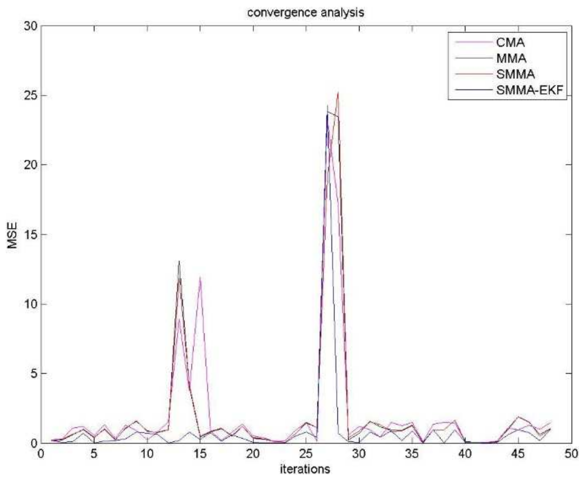

Figure 3: Comparison between Convergence and MSE

6. CONCLUSION

We have introduced EKF-SMMA for the blind equalization of OFDM signals that lessens a cost function which is composed of equalized and sliced symbols. Steady-state mis-adjustment analysis was done to compare existing and proposed technique. The outcomes of the analysis and simulations show the benefit of using the proposed BER over the traditional multi-modulus BER associated with the conventional SMMA, MMA & CMA. The experiment based on simulation showed that the EKF-SMMA shows a superior efficiency in contrast with the MMA, yielding a better BER, without compromising the convergence rate.

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