IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 3, Ver. IV (May-Jun .2016), PP 01-08
www.iosrjournals.org

Channel Estimation in MIMO-Communication Using Recursive Kalman Filtration

G.Rajender, Dr.T. Anilkumar, Dr.K.Srinivasa Rao
Research Scholar, Department of ECE, JNTU Hyderabad, Telangana State, India.
Professor & Principal, SVS Institute of Technology, Bheemaram, Hanamkonda, Warangal, TelanganaState, India.
Professor & Principal, TRR College of Engineering, Inole, Patancheru, Hyderabad, Telangana State, India.

Abstract: *With the evolution of wireless communication, the limitation of signal estimation under channel variant condition and their effects were increasing. Various techniques were proposed in past for the improvement of signal estimation efficiency based on reference information using adaptive, blind or semi blind approaches. Where blind and semi blind are observed to outperform the adaptive based approaches, further enhancements are still on research to improve the efficiency with minimum time convergence. To achieve this objective, estimation algorithms in time, frequency and time-frequency domain were developed. These approaches try to achieve the efficiency objectives by either increasing the estimation recursion or limiting the error probability. This paper presents an approach for achieving improved estimation efficiency with minimum time convergence and lesser error probability, in MIMO communication system using the kalman filtration approach. A spectral estimation logic based on energy of the signal spectrum is made. An approach towards signal estimation under channel variant condition is proposed. The evaluation of the suggested approach is analyzed with various benchmark estimation approaches.*

Keyword: *Signal Estimation, time variant channel condition,MIMO communication, spectral coding*

I. INTRODUCTION

With the evolution of wireless communication system, the limitation of signal estimation and their effect are increasing. Signal estimation for wireless communication remains research objective from the evolution of communication systems. Various techniques were proposed in past for the improvement of signal estimation efficiency based on reference information using adaptive, blind or semi blind approaches. Where blind and semi blind are observed to outperform the adaptive based approaches, further enhancements are still on research to improve the efficiency with minimum time convergence. As the wireless systems are rapidly getting improved, various new standards have got evolved to achieve better and reliable communication with the development of large areacoverage, based on cellular architecture. In the approach of channel estimation, the estimation process is governed by a state transition logic, where the process of estimation and updation is carried out to obtain an estimate. In the process of MIMO-OFDM channel estimation, the application of kalman filters are made for its simpler coding and estimation performance. The kalman filtrations are been developed and used in various models of communications. Towards estimation of channel diversity, kalman filters were used as an optimal solution. Among different usage of Kalman filter, in recent past these filters are effectively been used in OFDM, MIMO system with Space time block code (STBC). In [1] an approach to STBC coding using an alamouti STBC with channel diversity is been developed. A channel estimation approach based on multiple antenna systems, for Multi input single output (MISO) and multiple input multiple output (MIMO) system is proposed. the system was developed using a BPSK and QPSK modulation, with time varying channel conditions. An improved format of iterative joint channel estimation in STBC MIMO OFDM system for fast fading environment was presented in [2]. The time and frequency correlation information was suggested, with the utilization of cyclic prefix (CP) signal. Two variations of Expectation maximization (EM) using CP based on forward backward estimation approach was suggested. In [3], a blind channel estimation for STBC transmission was developed. The approach was developed based on a second order statistics (SOS), and Eigen channel estimation is suggested for STBC coding based on a pre-coding approach made of rotation or permutation of transmit antennas. In [4] channel estimation for OFDM/OQAM, based on iterative channel estimation was outlined. The iterative approach was made for improving channel estimation by using the imaginary interference at the receiver side. A M-QAM system was studied for OFDM system in [5]. The joint channel estimation a frequency flat modeling for transmitter and receiver I/Q imbalance for OFDM system was outlined. The Gaussian approximation of I/Q interference was observed ideal. To achieve estimation under variable channel condition the estimation approach were improved from adaptive methods to blind estimation approaches. Blind estimation approach estimates thesignals with no-priori information regard to wireless medium. Blind estimation is suitably being proved in unknown channel estimations. Though this approach is preferable with no-priori information, this technique find high convergence time and does not provides estimation accuracy under dynamic variation. A Hybrid technique with the property of both blind and adaptive estimation called “Semi-Blind” estimation for wireless communications is presented. This technique estimates the received signal with adaptive approach of priori based information and converges the estimation error with a blind recursive approach. This technique observed to provide better estimation under dynamic channel condition at the cost of heavy computation. These estimation techniques were observed to be better performing under limited environmental condition in both spatial & time domain and deviates in performance either with accuracy or computation time and complexity for given system. These estimations were also improved for estimation improvement in time-frequency domain. This approach leads to heavy mathematical transformation and computationally very complex in approach. The objective of this work is to achieve improvement in estimation efficiency with minimum time convergence and higher estimation probability, by modifying the existing time-frequency estimation approach for multicarrier communication system. For a multicarrier communication system, the time-frequency approach tries to estimate the signal based on spatial or frequency information, which gets corrupted due to different sub-carrier spacing. This results in degradation in estimation accuracy. In the proposed approach spectral information is incorporated with time-frequency to achieve estimation accuracy for such a multicarrier communication system. The spectral feature reveals the energy content of received information which is analyze with spatial and frequency information to estimate the information under dynamic channel conditions. An estimation algorithm in time, frequency and time-frequency domain were developed.

II. MODELING AND ANALYSIS

The operation efficiency of a channel estimator is dependent on the channel impulse response estimation in MIMO-OFDM system. In [6,7] a channel impulse response estimation based on the correlation of transmits or receive antennas. An approach of concatenated wiener filters for the optimization of channel estimation by optimizing the channel characteristic in time and frequency domain. In [8], to estimates channels in different high speedmobiles environments, a wiener filter based approach with basis expansion model (BEM) is presented. The suggestive approach provides a better estimation under time variant channel condition. Towards effective estimation, in [9] a novel a symmetric extension method was suggested for OFDM system to reduce the MSE, leakage power and noise of conventional KALMAN. The estimation of partial frequency response is symmetrically extended as well as reduced MSE and noise eliminated with very small power loss. In [10] a SCM based blind channel estimation method for zero padding MIMO–OFDM systems have the distinctive features. The identifiability condition is very simple and is more relaxed than the irreducible or column reduced condition. It can apply to the more transmit antennae case under a certain condition. Through numerical simulation, it yields improved BER performance in the low-to-moderate SNR region. In [11] a first order approximation method as well as a second order approximation method for joint CFO and CIR estimated in OFDM systems. In first order approximation method provides adaptive iteration algorithm with excellent estimation and tracking range compare to the conventional. The Second order approximation method will improve frequency tracking range and channel estimation compare to first order method. In [12] a channel estimator computes the long-term features through a subspace tracking algorithm by identifying the invariant (over multiple OFDM symbols) space–time modes of the channel. On the other side, the fast-varying fading amplitudes are possibly tracked by using LS techniques that exploit temporal correlation of the fading process. In particular, MIMO-OFDM with BICM and MIMO-Kalman equalization has been selected as a benchmark for performance evaluation in terms of BER. In [13] a semi-blind timing synchronization and channel estimation scheme for OFDM systems was developed based on unit vectors. Semi blind approach having three stages, (i) coarse timing offset with maximum gain is obtained in multipath fading channel, (ii) a fine time adjustment algorithm to find actual time position in channels, (iii) based on final timing estimation obtained frequency-domain in channel response. In [14] a time-varying estimation of MIMO-OFDM channels was presented for high-mobility communication systems by means of discrete evolutionary transform. The parametric channel model used, which allows us to obtain the channel and estimate its parameters from the spreading function and also observed that robust against large variations on the channel frequency response, that is, fast fading. The time variant channel condition is building up an uncertainty in the channel estimation resulting inhigher error rate. Towards improving performance a energy based recursive estimation logic is suggested.

III. MIMO COMMUNICATION AND ESTIMATION APPROACH

A MIMO-OFDM system with *MT* transmit and *MR* receive antennas. At the transmitter side, a serial bit stream is mapped to a symbol stream by a modulator. Then, this serial symbol stream is converted into parallel sub streams. Next, pilot symbols for the channel estimation are inserted into these parallel sub streams, in thefrequency-domain, prior to the OFDM modulation. The OFDM modulation is then implemented by performing inverse discrete Fourier transform (KALMAN). Each transmits antenna sends independent OFDM symbols. Let *Xp*(*k*) denote the information symbol sent by transmit antenna *p* at subcarrier *k*. The OFDM symbols transmitted by *MT* transmit antennas can then be presented as

$$= [X_{1,} \cdots\cdots\cdots X_{P,} \cdots\cdots\cdots\cdots X_{M_T}]^T \cdots\cdots\cdots (1)$$

Where X_P=$[X_P(0). \cdots\cdots\cdots\cdots\cdots X_P(N-1)]^T$ is the OFDM symbol transmitted from the p^{th} transmit antenna, and N is the number of subcarrier for one OFDM symbol. After performing inverse KALMAN (IKALMAN) on each transmit antenna, the time-domain modulated signal on the p^{th} transmit antenna can be expressed as

$$x_p = F^H X_P = [x_P(0). \cdots\cdots\cdots\cdots\cdots x_P(N-1)]^T \cdots\cdots (2),$$

where F is the $N \times N$KALMAN matrix with its element at row n and column k, which is defined as

$$w_{n,k} := e^{\left(\frac{j2\pi nk}{N}\right)}, \text{ for } n,k\text{=}0,\cdots\cdots\cdots\cdots\cdots N-1.$$

InterSymbol Interference (ISI) is caused due to a multipath delay spread, this effect is eliminated by a cyclic prefix of length equal or greater than the expected maximum time delay of the channel is inserted in each OFDM symbol prior to transmission. This prefix serves as guard interval (GI) between OFDM symbols. Finally, the symbol streams are converted from a parallel to a serial form and allocated to corresponding transmitters for transmission. At the receiver side, once the GI is removed, the received signal at the q_{th} receive antenna and time *n* can be represented as

$$r_q(n) = \sum_{p=1}^{MT} \left(h_{p,q}(l,n) \otimes x_p(n)\right) + w_q(n)$$

$$= \sum_{p=1}^{M_T} \sum_{l=0}^{L-1} h_{p,q}\,(l,n) x_p(n-l) + w_q(n) \cdots\cdots\cdots\cdots (3)$$

Where $\otimes$ is the cyclic convolution, $w_q(n)$is the additive white Gaussian noise (AWGN), and $h_{p,q}(l,n)$is the impulse response of the l_{th} channel tap between the p_{th} transmit antenna and the q_{th} receive antenna at time *n*. After performing the kalman on the received signal in (3), the symbol for the q_{th}receive antenna and the k_{th} subcarrier can be expressed as,

$$R_q(k) = \sum_{p=1}^{M_T} \sum_{m=0}^{N-1} \sum_{l=0}^{L-1} H_l^{p,q}\,(k-m) w_{l,m} X_P(m) + W_q(k) \cdots\cdots\cdots\cdots (4)$$

Where $W_q(k)$the KALMAN is noise, and $H_l^{p,q}(k)$ denotes the IKALMAN of time-varying frequency-selective channel $h_{p,q}(l,n)$ i.e.

$$H_l^{p,q}(k) = \frac{1}{N} \sum_{n=0}^{N-1} h_{p,q}\,(l,n) e^{-\frac{j2\pi nk}{N}} \cdots\cdots\cdots\cdots\cdots (5)$$

$R_q(k)$is the summation of the desired signal and original signal and ICI component.

$$R_q(k) = \sum_{p=1}^{M_T} H_l^{p,q}(0) w_{l,k} X_P(k) + \sum_{p=1}^{M_T} \sum_{m\neq k}^{N-1} \sum_{l=0}^{L-!} H_l^{p,q}\,(k-m) X_p(m) w_{l,m} + W_Q(k) \cdots (6)$$

The channel is time variant during one OFDM symbol period the value of (5) would be non-zero only if k=0 $\left(\sum_{n=0}^{N-1} h_{p,q}\,(l,n) e^{-\frac{j2\pi nk}{N}} = 0\; fork = 0, \ldots\ldots N-1\right)$ under this condition, the ICI component in (6) disappears. however, if there is a non zero Doppler spread, this assumption is no longer true.

The received signal for all M_R receive antennas can be represented as

$$\text{R}=\mathcal{H}X + \text{W} \cdots\cdots\cdots (7)$$

Where R= $[R_{1.} \cdots\cdots\cdots R_{M_R}]^T$ and $R_q = \left[R_q(0), \cdots\cdots\cdots\cdots R_q(N-1)\right]^T$ is the received signal for the q_{th} receiver antenna,$W = \left[W_{1,} \cdots\cdots\cdots\cdots W_{M_R}\right]^T$, is the effective channel matrix in the frequency domain, which is defined as

$$H = \begin{bmatrix} H_{1,1} & H_{2,1} \cdots & H_{M_T}, 1 \\ H_{1,2} & H_{2,2} \cdots & H_{M_T}, 2 \\ H_{1,M_R} & H_{2,M_R} \cdots & H_{M_{T,M_R}} \end{bmatrix} \cdots\cdots\cdots\cdots\cdots (8)$$

Here, the $(m,n)_{th}$ element of matrix $H_{p,q}$ is denoted as $\alpha_{m,n}^{p,q}$ and is defined as

$$\propto_{m,n}^{p,q} = \sum_{l=0}^{L-1} H_l^{p,q}\,(n-m) w_{l,m} \cdots\cdots\cdots\cdots (9)$$

$$0 \leq n; m \leq N-1$$

The total number of pilots in one OFDM symbol be $N_p$and assume that the pilot symbols for the P_{th} transmit antenna, which are denoted by$X_P(p_i)$, are inserted at subcarriers *pi*,*i*= 0, $\cdots\cdots\cdots$ *Np* − 1. Let us denote by $P_p \coloneqq \left\{p_0, \cdots\cdots\cdots p_{N_{p-1}}\right\}$the set of the subcarriers used for pilot symbols for the P_{th}transmit antenna. Here, the pilots are considered tobe grouped together in *Ng* groups, where each of these groups is of size *d*. It is assumed that the pilot symbols are placed in each OFDM symbol, in equispaced groups (i.e., the groups of pilot symbols are uniformly partitioned on the OFDM symbol). This type of pilot placement structure is shown to be optimal for high-mobility systems. Also assume that the pilot subcarriers for different transmit antennas are orthogonal in the frequency domain.

IV. RECURSIVE KALMANESTIMATION

A new iterative State-assisted channel estimation scheme that exploits the State spread, time-domain channel correlations, and estimates of data symbols is proposed. The Doppler spread $f_d$is calculated by using the user's velocity v(in meters per second) at the receiver as

$$f_d = \frac{vf_c}{C} \cdots\cdots\cdots\cdots (10)$$

Where f_c is the carrier frequency, and C = 3 × 108 m/s is the speed of light. Note that the normalized Doppler spread is defined as F_d= (f_d/Δ_f, where Δ_f is the subcarrier spacing. In the proposed iterative State -assisted channel estimation scheme, each time-domain channel coefficient is expressed as a weighted interpolation of the selected channel coefficients referred to as time-domain markers.

The interpolation weights are designed in a way that the channel estimation error is minimized. The interpolation process utilizes the State spread information to calculate the time-domain channel correlations at the receiver. In the proposed scheme, in each iteration, the detected data symbols at the receiver are sent back to the channel estimator. These data symbols, together with the pilot symbols, are employed to estimate the time-domain markers by an LS method. Thus, the estimation of the time-domain markers is iteratively refined by exploiting pilot and data symbols. The proposed algorithm mainlyconcentrates on the channel estimation of high-mobility terminals, such as a moving vehicle or a mobile access point mounted on top of a high-speed train. In this case, the velocity of a high-speed moving vehicle is known. In the proposed algorithm, this known information is then used to calculate the Doppler spread and, thus, the timedomain channel correlations. Hence velocity estimation techniques are not required for the proposed algorithm.

V. TIME-DOMAIN POINTER SELECTION

$$h_n^{p,q} := [h_{p,q}(0,n), \dots\dots\dots h_{p,q}(L-1,n)]^T, \qquad 0 \leq n \leq \text{N-1} \cdots\cdots\cdots\cdots (11)$$

Where $h_n^{p,q}$ represents the non-zero elements of the n_{th} row in the time domain channel matrix $C_{p,q}$ has L non-zero elements.NL parameters are calculated to estimate the wireless channel in a time varying environment. This impacts the computational complexity of the receiver.An interpolation is used between time-domain channel coefficients to reduce number of parameters for the channel matrix. The time-domain matrix $C_{p,q}$ by utilizing a small number if its rows, which are denoted by M. Physically, this puts M markers in the time domain, where the channel coefficients are estimated. Then the channel coefficients at other times are interpolated by using the time-domain markers. This assumption will reduce the number of parameters to be estimated from $NL$to ML, where $M \ll N$.

$$h_{p,q}(l,n) = a_{l,n,p,q}^T [hp,q(l,m(1),\dots\dots\dots\dots h_{p,q}(l,m(M)]^T \cdots 12)$$

Where for $0 \leq l \leq L-1$

$$a_{l,n,p,q} = [a_{l,n,p,q}(m(1),\dots\dots., a_{l,n,p,q}(m(M))]^T \cdots\cdots\cdots (13)$$

In the channel estimation we need to regenerate the received signal in terms of time-domain markers. Here we assumed that, in the t_{th}iteration, the transmitted data symbol vector$X^{(t-1)}$, which is detected in the $(t-1)th$ iteration, is available at the receiver.

$$R_q(k) = \sum_{p=1}^{M_T}\sum_{s=0}^{N-1}\sum_{l=0}^{L-1}\sum_{i=1}^{M} b_{m(i),p,q}^{k,s}(l) h_{p,q}\big(l,m(i)\big) X_p^{(t-1)}(s) + e_q(k) \cdots\cdots\cdots\cdots (14)$$

Where $e_q(k)$ denotes the summation of the estimation error at subcarrier k and AWGN at the q^{th} receive antenna, and

$$b_{m(i),p,q}^{l}(l) = \frac{1}{N} w_{s,l} \sum_{r=0}^{N-1} \left[A_{m(i)}^{p,q}\right]_{r,r} e^{j\frac{2\pi r(s-m)}{N}} \cdots\cdots\cdots (15)$$

VI. EXPERIMENTAL RESULTS

Table I: LTE Parameters of Simulation System

PARAMETER	VALUE
Modulation	QAM
Operating Frequency	5GHz
Bit Transmission Rate	7.2Mbps
Sampling time	0.16μs
Sampling Frequency	7.68 MHz
Number of sub-carrier	512
Number of data sub-carrier	240
Number of pilot sub-carrier	48

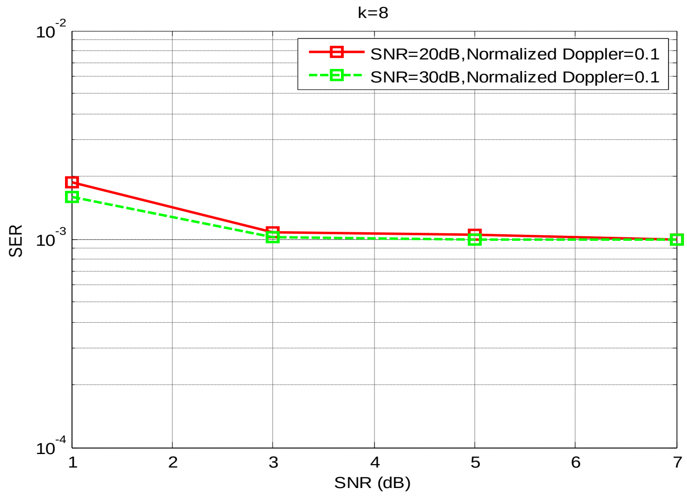

Fig:1 convergence characteristics of proposed iterative channel estimation with the PIC-DSC interface cancellation scheme under various normalized Doppler spreads.

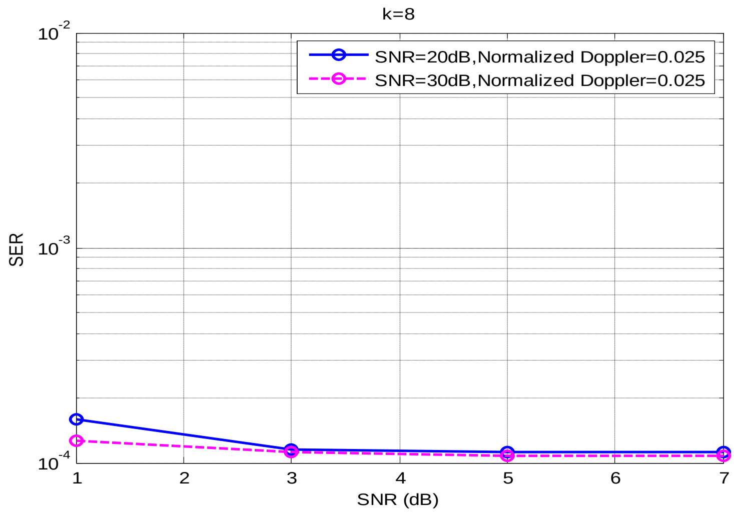

Fig: 2 convergence characteristics of proposed iterative channel estimation with the PIC-DSC interface cancellation scheme under various normalized Doppler spreads.

The SER performance of the proposed iterative Doppler-assisted channel estimation with PIC-DSC interference cancellation scheme for various numbers of iterations ($I_{CE} = 1,3,5,7$) under different normalized Doppler spreads. It can be seen that the proposed scheme converges after five iterations.

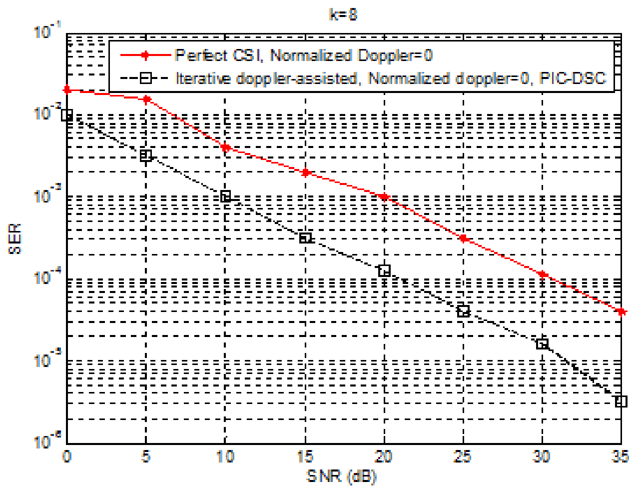

Fig: 3 Comparison of SER performance of the proposed iterative Doppler-assisted channel estimation scheme under PIC-DSC, ZF, and MMSE interference cancellation techniques for the normalized Doppler spread of 0.1

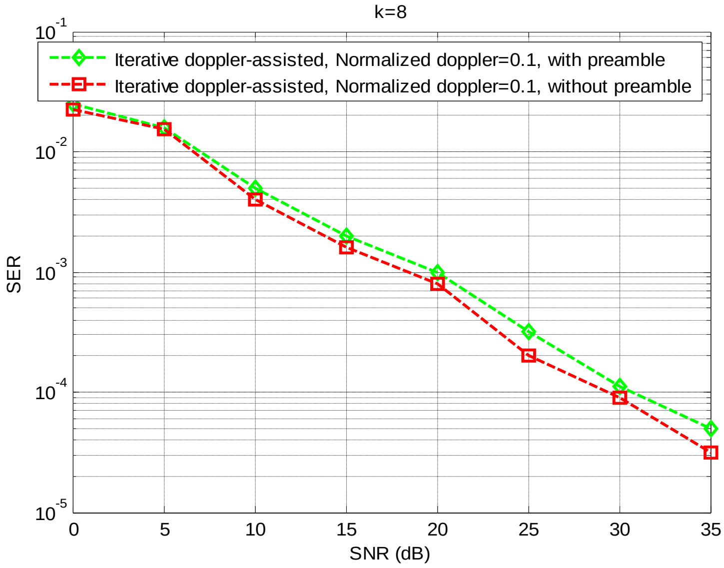

Fig: 4 comparisons of SER performance of the proposed iterative Doppler-assisted channel estimation scheme under PIC-DSC, ZF, and MMSE interference cancellation techniques for the normalized Doppler spread of 0.1

Comparison of the SER performances of the proposed iterative Doppler-assisted channel estimation scheme under three different ICI cancellation techniques, i.e., MMSE, ZF, and the proposed PIC-DSC, for the normalized Doppler spread of 0.1. This is equivalent to a user moving at the speed of 324 km/h with the LTE system parameters in Table I. It can be seen that, at high SNR, the SER performance of the proposed PIC-DSC technique degrades the SER performances ofthe ZF and MMSE methods for 0.85 and1.20 dB, respectively. However, the computational complexity orders of the MMSE and ZF methods are $N/2M_T$times higher than that for the proposed PIC-DSC technique. Thus, the extra 0.85- and 1.20-dB gain, which are obtained by the MMSE and ZF methods, are at the cost of 128 times higher computational complexity than the proposed PIC-DSC for the simulated system, where N = 512 andM_T= 2. Therefore, the proposed PIC-DSC technique is the preferred choice, where complexity and cost are the major factors in the system design. However, if the performance is more important, the MMSE and ZF methods are preferred more.

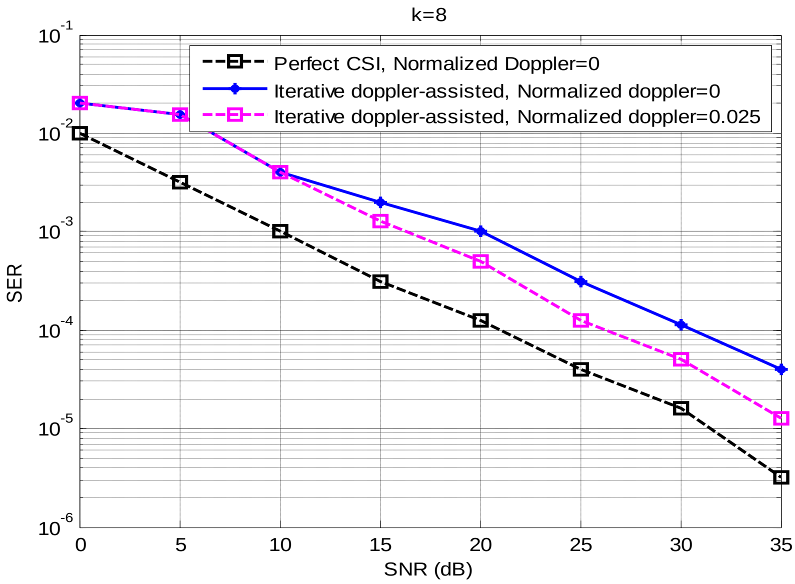

Fig:5 SER performance of the normalized Doppler spread of 0.025

Iterative Doppler assisted channel estimation with PIC-DSC interference cancellation scheme for the normalized Doppler spread of 0.025.This is equivalent to a user moving at speed of 81km/h with the LTE parameters in Table I.The normalized Doppler spread of 0.025, the channel variations are slow, and as a result, even a simple channel estimation technique performs adequately.

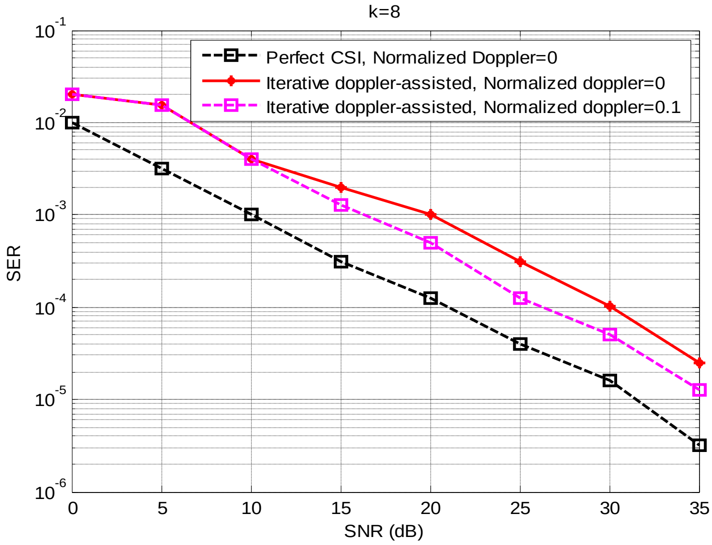

Fig 6: SER performance for the normalized Doppler spread of 0.1

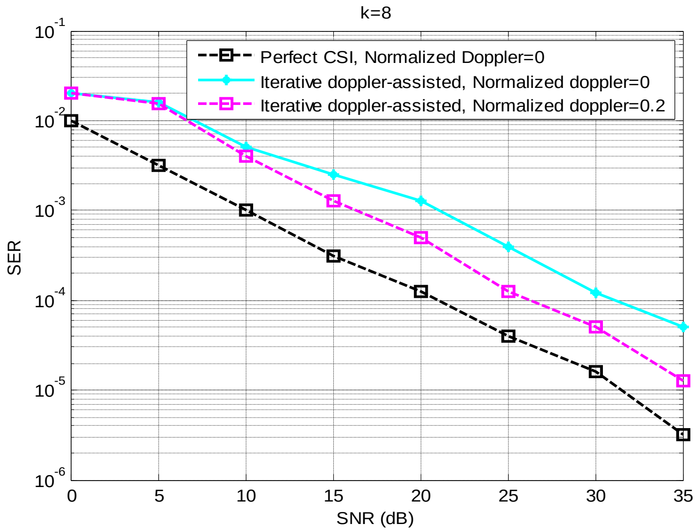

Fig 7: SER performance of the normalized Doppler spread 0.2. The achieved SER performances of the proposed iterative posed scheme with five iterations for a system with normalized Doppler spreads of 0.1 and 0.2, compared with the performance of the system with a zero Doppler spread, is only 1.1 and 3.2 dB, respectively. The normalized Doppler spread of 0.2 is equivalent to a user moving at the speed of 648 km/h with the LTE system parameters in Table I.

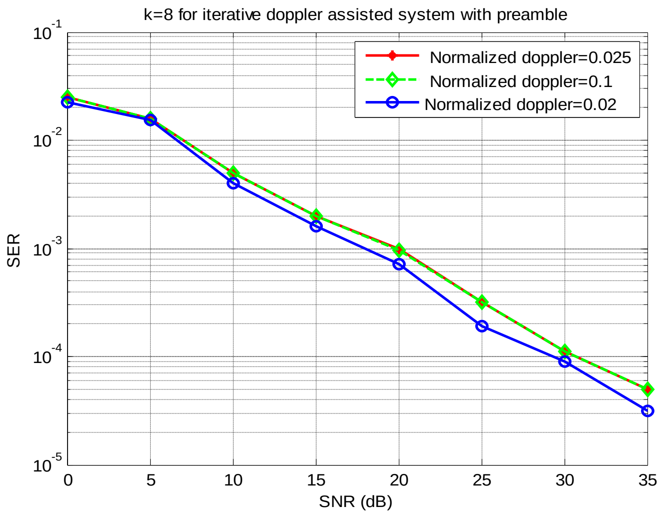

Fig 8: Comparison of the SER performance of the proposed iterative Doppler-assisted channel estimation with and without preamble

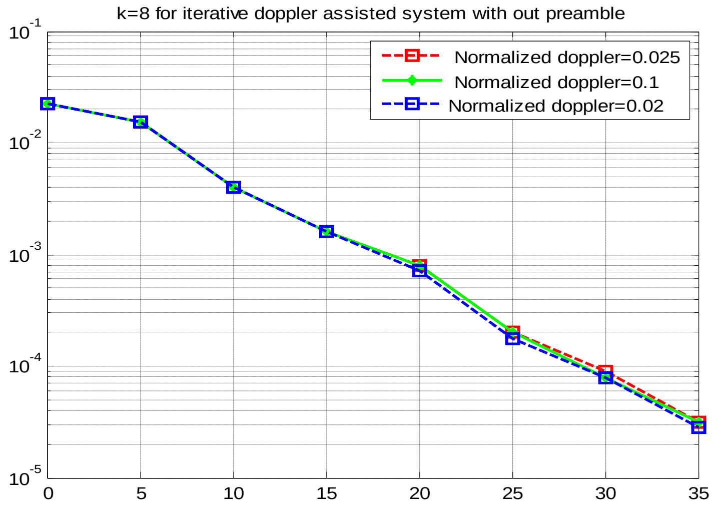

Fig 9: Comparison of the SER performance of the proposed iterative Doppler-assisted channel estimation with and without preamble.

The simulation results show that this approach slightly improves the SER performance of the proposed algorithm for the normalized Doppler spread of 0.025. However, the use of preamble reduces the throughput efficiency of the system.

VII. CONCLUSION

A New iterative Doppler assisted channel estimation with the PIC-DSC interference cancellation scheme for high-mobility MIMO-OFDM systems. In the proposed method, the wireless channel has been estimated by using the Doppler spread information, pilot symbols, and estimates of the data symbols at the receiver. Each time-domain channel coefficient is expressed as a weighted interpolation between two selected time-domain channel coefficients referred to as time-domain markers. These two time-domain markers are selected in a way that they have maximum correlation with the respective channel coefficient. The interpolation weights are designed based on Doppler spread information at the receiver. The simulation results show that the proposed scheme outperforms the best compared to the previous techniques, particularly for high Doppler spreads. The SER performance of the proposed scheme with the normalized Doppler spread of 0.1 is only 1.6 dB weaker, compared with the one with zero Doppler spread.

REFERENCES

[1]. AmirhosseinFereidountabar,Gian Carlo Cardarilli, Luca Di Nunzio, Rocco Fazzolari, “UAV Channel Estimation with STBC in MIMO Systems”, The International Conference on Advanced Wireless, Information, and Communication Technologies, Procedia Computer Science, vol. 73, pp. 426 – 434, Elsevier, 2015.
[2]. A.A.Quadeer, Muhammad S. Sohail, “Enhanced Channel Estimation Using Cyclic Prefix in MIMO STBC OFDM Sytems”, Signal Processing and Information Technology, IEEE International Symposium on,pp. 277 – 282, IEEE, 2010.
[3]. Javier V, Ignacio Santamar, and Jes us Perez, “Code Combination for Blind Channel Estimation in General MIMO-STBC Systems”, Hindawi Publishing Corporation, EURASIP Journal on Advances in Signal Processing, pp.12 , Springer, 2009.
[4]. ChrislinLele, “Iterative scattered-based channel estimation method for OFDM/OQAM”, EURASIP Journal on Advances in Signal Processing, Vol.42, Springer, 2012.
[5]. UdeshOruthota and Olav Tirkkonen, “SER/BER expression for M-QAM OFDM systems with imperfect channel estimation and I/Q imbalance”, EURASIP Journal on Wireless Communications and Networking, Vol.303, Springer, 2012.
[6]. Ji-Woong CHOIand Yong-Hwan LEE, “Complexity-Reduced Channel Estimation in Spatially Correlated MIMO-OFDM Systems”, IEICE trans. comm., vol.90, IEEE, 2007.
[7]. Jinesh P. Nair1 and Ratnam V. Raja Kumar, “Optimal Superimposed Training Sequences for Channel Estimation in MIMO-OFDM Systems”, Hindawi Publishing Corporation, EURASIP Journal on Advances in Signal Processing, pp.13, Springer, 2010.
[8]. KeZhong, Xia Lei, Binhong Dong and Shaoqian Li, “Channel estimation in OFDM systems operating under high mobility using Wiener filter combined basis expansion model”, EURASIP Journal on Wireless Communications and Networking, Vol.186, Springer, 2012.
[9]. YiWang, Lihua Li, Ping Zhang, and Zemin Liu, “KALMAN-Based Channel Estimation with Symmetric Extension for OFDMA Systems”, Hindawi Publishing Corporation, EURASIP Journal on Wireless Communications and Networking, pp.8, Springer, 2009.
[10]. Yi-Sheng Chen1 and Jwo-Yuh Wu, “Statistical covariance-matching based blind channel estimation for zero-padding MIMO–OFDM systems”, EURASIP Journal on Advances in Signal Processing, Vol.139, Springer, 2012.
[11]. Rainfield Y Yen, Hong-Yu Liu and Chia-Sheng Tsai, “Iterative joint frequency offset and channel estimation for OFDM systems using first and second order approximation algorithms”, EURASIP Journal on Wireless Communications and Networking, Vol.341, Springer, 2012.
[12]. Marcello Cicerone, Osvaldo Simeone, and Umberto Spagnolini, “Channel Estimation for MIMO-OFDM Systems by Modal Analysis/Filtering”, IEEE transactions on communications, vol. 54, no. 11, IEEE, 2006.
[13]. Te-Lung Kung and Keshab K Parhi, “Semi blind frequency-domain timing Synchronization and channel estimation for OFDM systems”, EURASIP Journal on Advances in Signal Processing, Springer, 2013.
[14]. ErolOnen, AydınAkan, and Luis F. Chaparro, “Time-Frequency Based Channel Estimation for High-Mobility OFDM Systems–Part I:MIMO Case”, Hindawi Publishing Corporation, EURASIP Journal on Advances in Signal Processing, pp.8, Springer, 2010.