ANALYSIS AND DESIGN OF H-INFINITY CHANNEL ESTIMATION IN MULTICELL MULTIUSER DISCRETE WAVELET BASED MIMO-OFDM SYSTEMS

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Abstract
This paper investigates the uplink transmission in multicell multiuser a couple of-enter multiple-output (MIMO) orthogonal frequency-depart multiplexing (OFDM) systems. The system version considers imperfect channel estimation, pilot contamination (PC), and multicarrier and multipath channels. Analytical expressions are first offered on the Minimum square errors (MSE) of classical channel estimation algorithms [i.e., least squares (LS) and minimum mean square error (MMSE)] inside the presence of PC. Then, a discrete Wavelet Transformation (DWT) channel estimation method is proposed to have excellent suppression to PC. This technique exploits the space-alternating generalized expectation–maximization (SAGE) iterative method to decompose the multicell multiuser MIMO (MU-MIMO) hassle into a sequence of single-mobile single-consumer single-input single-output (SISO) issues, which reduces the complexity notably. According to the analytic results given herein, growing the quantity of pilot subcarriers cannot mitigate PC, and a clue for suppressing PC is acquired. It is proven from the results that the DWT has higher suppression functionality to PC than classical estimation algorithms. Its overall performance is close to that of the optimal MMSE as the duration of channel impulse reaction (CIR) is expanded. By using the SAGE manner, the overall performance of the DWT does no longer degrade while the number of antennas is massive at the bottom station (BS).

Index Terms*:* PC, MIMO, OFDM, LS, MMSE, DWT, SAGE

I. INTRODUCTION

Future wireless communications require the extraordinary capability to combat multipath fading and to offer high spectral performance. MIMO combined with orthogonal frequency-department multiplexing (OFDM) has been widely taken into consideration to be a promising one [2], [3]. Unlike the factor-to-point MIMO, a multiuser MIMO (MU-MIMO) machine that has low cost in terminals and better tolerance to wireless propagation environment has been considered for destiny wireless communications [4]. In a multicell situation, it's widely recognized that correct channel State information (CSI) is essential for attaining excessive gadget overall performance. Since the mobility of users and the limited bandwidth, it is not feasible to allocate dedicated pilots for the users in every mobile, and consequently, the reuse of pilots is mandatory for users in one-of-a-kind cells [1].

PC is indulging a danger performance on the system when compared with system noise. The occurrences of quick fading and uncorrelated interference will disappear when the MIMO system is employed with huge number of antennas at BS [6]-[14]. However, PC due to the reuse of non-orthogonal pilots in other cells does not vanish. In this sort of multicell MU-MIMO system, with best CSI on the BS, the ability blessings in throughput, reliability, and power performance might be received [5]. These advantages are analyzed specifically based totally on single-provider and flat-fading device version; however, an extra practical performance evaluation that considers multicarrier and frequency-selective fading channels for future cellular cell structures is crucial [15]-[19]. Since the BS can't have best CSI in exercise, it is vital to take into account the effect of PC on channel estimation based totally on a multicarrier multipath machine model.

A. Related Work and the Contribution of This Paper

There are few researches specially targeted on channel estimation algorithms within the presence of PC in multicell MU-MIMO structures, although single-provider and flat-fading transmission state of affairs has been taken into consideration. In [7], a blind channel estimation algorithm primarily based on eigen value decomposition became proposed; however, it calls for an extended-records document and employs the prior information of stochastic facts and excessive computational complexity. A coordinated channel estimation approach with correlated pilot sequences turned into developed to tackle the problem of PC [8]; but, the complexity due to making use of 2nd-order statistical information is excessive. The asymptotic evaluation on the effect of channel getting older on both the up hyperlink and the down hyperlink practicable rates become provided, and a finite-impulse-response Wiener predictor became proposed to overcome channel getting old effects [9].

For Multipath cases, pilot based channel estimation in MIMO OFDM systems for multipath cases are aggressively studied for the past years on only single-mobile single-consumer cases [20]-[22].

II. SYSTEM MODEL

We take into account a multicell MU-MIMO device with Q cells, as proven. Each cell consists of one BS with M antennas and K single-antenna terminals. OFDM transmission with N subcarriers is taken into consideration. The frequency-selective fading channel is modeled as a finite-length CIR with L taps. We count on that the uplink transmission from all customers inside the Q cells are synchronized, which constitutes a worst-case state of affairs from the perspective of PC. Furthermore, the alerts acquired for each antenna on the BS are assumed to enjoy independent fading.

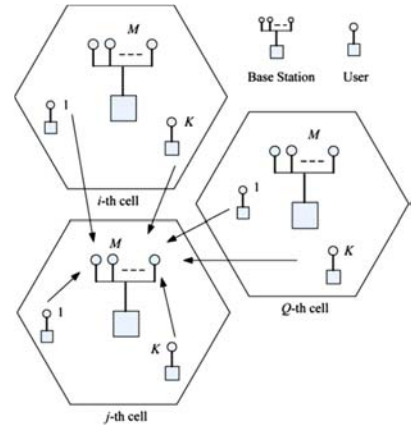

Fig 1: Uplink Transmission in Multicell MU MIMO Systems

The received Nx1 signal vector n all N subcarriers at rth antenna of the jth base station can be expressed as

$$Y_j = XH_j + Z_J \quad (1)$$

Where $Y_j = \left[Y_j(0), \ldots, Y_j(N-1)\right]^T$, $Y_j = \left[X_1, \ldots, X_Q\right]$ where X_q is the diagonal matrix containing the transmit signal from qth cell and $Z_j = \left[Z_j(0), \ldots, Z_j(N-1)\right]^T$ is a vector of independent identically distributed complex zero-mean guassian noise variables with variance σ^2. $H_j = \left[H_{J1}^T, \ldots, H_{JQ}^T\right]^T$, H_{jq} is the frequency response of the channel between jth and qth cells. $H_{jq} = \left[H_{Jq1}^T, \ldots, H_{Jqk}^T\right]^T$, $H_{jqk} = F_{N,L}C_{jqk}$, $F_{N,L}$is $1/\sqrt{N}$ times the first L columns of Discrete Wavelet Transform (DWT) matrix, C_{jqk} is the $L \times 1$ propagation coefficients between jth base station and kth user in the qth cell and denoted as:

$$C_{jqk} = D_{jqk}^{\frac{1}{2}} G_{jqk} \quad (2)$$

The received vector at jth BS can be rewritten as:

$$Y_j = \sum_{q=1}^{Q} \sum_{k=1}^{K} \boldsymbol{X}_{qk} \boldsymbol{H}_{qk} + \boldsymbol{Z}_j \quad (3)$$

Where $\boldsymbol{X}_{qk} = \boldsymbol{S}_{qk} + \boldsymbol{B}_{qk}$, $\boldsymbol{S}_{qk}$ is an arbitrary $N \times N$ signal diagonal matrix and $\boldsymbol{B}_{qk}$ is an $N \times N$ pilot diagonal matrix.

III. IMPACT OF PILOT CONTAMINATION ON LS AND MMSE ALGORITHMS IN MULTICELL MU-MIMO OFDM SYSTEMS

This section deals with the MSE and inquires the effectiveness of Pilot Contamination (PC) on LSE and MMSE channel estimation algorithms in Multi-cell Multiuser DWT based MIMO-OFDM systems.

a. LS Channel Estimation

The following assumptions are made: 1) Each subcarrier has the same electricity; 2) for distinctive users in each mobile, section-shift orthogonal pilot sequences are used and 3) Equal pilot sequences are reused in other cells. Hence setting, $A_j^{\dagger} A_{il} = I_{LK}$ and $A_j^{\dagger} T_q = O_{LK}; 1 \leq j, q \leq Q$. The channel vector between *j*th Base station and *k* users in *j*th cell is given as:

$$C_{jj}^{LS} = A_j^{\dagger} Y_j \quad (4)$$

The MSE expression of LS algorithm for Multicell MU-MIMO OFDM system is given as,

$$MSE_{LS} = \frac{1}{L} \sum_{q \neq j}^{Q} d_{jq} + \frac{N}{P} \sigma^2 \quad (5)$$

The above expression is composed of two terms: the first indicating the PC and the second term introduced by noise. For a single cell, the PC term becomes zero, and the noise term can be diminished by taking more pilot subcarriers. The improvement in the first term can be achieved by considering a large CIR length L. The expression also indicates the approximate pilot reuse that can be developed to reduce the cross gain impact.

b. MMSE Channel Estimation

By employing the channel traits, MMSE generally obtains premier estimation performance. Due to the excessive computational complexity in MMSE for MIMO systems, we just keep in mind a simplified version with the aid of using an expectation maximization iterative system proposed. The channel frequency vector among the *j*th BS and the *k*th user in the *j*th cellular is given as follows:

$$\hat{H}_{jjk}^{MMSE} = R_{HH} \left(R_{HH} + \sigma^2 \left(X_{jjk}^H X_{jjk} \right)^{-1} \right)^{-1} \hat{H}_{jjk}^{LS}$$

(6)

where R is a correlation Matrix. Assuming normalized constellation power, equal probable constellation points and independent data symbols, $\left(X_{jjk}^H X_{jjk} \right)^{-1}$ can be replaced by $E\left\{ \left(X_{jjk}^H X_{jjk} \right)^{-1} \right\} = \beta I_q$ where β=1 for QPSK.

$$\hat{H}_{jjk}^{MMSE} = U \Delta_v U^H \hat{H}_{jjk}^{LS} \quad (7)$$

Where U is unitary matrix and Δ_v is defined as diagonal matrix with entries given as

$$\delta_n = \begin{cases} \dfrac{\lambda_n}{\lambda_n + \dfrac{\beta}{SNR}} ; n = 1,2, \dots p \\ 0 ; n = p+1, \dots N \end{cases} \quad (8)$$

Hence MSE of MMSE algorithm for Multicell MU-MIMO-OFDM system in presence of PC is given as:

$$MSE_{MMSE} = \frac{1}{N} \sum_{q \neq j}^{Q} \sum_{n=1}^{p} \lambda_n \delta_n^2 + \frac{\sigma^2}{N} \sum_{n=1}^{p} \lambda_n + \frac{1}{N} \left(\sum_{n=1}^{p} (\delta_n - 1)^2 \lambda_n + \sum_{n=p+1}^{N} \lambda_n \right) \quad (9)$$

The terms in (9) are much smaller compared to that of LS. With large number of subcarriers the first term decreases. But the usages of large number of subcarriers are restricted by OFDM since the system becomes highly sensitive to the non-orthogonal pilots. Hence, similar to that of MSE of LS, the huge number of subcarriers cannot diminish the MSE caused by Pilot Contamination (PC).

IV. DESIGN AND ANALYSIS OF SAGE BASED H-INF ALGORITHM IN MULTICELL MU DWT BASED MIMO SYSTEMS

Earlier, we have proven that the MMSE algorithm can achieve most appropriate performance by means of using previous facts and higher suppression to PC. Although the use of SVD of channel correlation matrix is able to reduce the variety of multiplications with negligible overall performance loss, its complexity continues to be pretty high considering obtaining the SVD itself has excessive computational complexity on the order of *$O(N^3)$*. Here, we introduce the DWT algorithm, to multicell Multiuser DWT based MIMO OFDM structures.

A. H-infinity Channel Estimation

As an alternative to the classical MMSE estimation, a H-infinity channel estimator can obtain an acceptable estimation overall performance without correct know-how of the statistical information of the concerned signals.

The concept of the H-Infinity filtering is to construct a clear out that ensures the norm of the estimation lenders is less than a prescribed effective value. As for multicell MU-MIMO systems, the idea of the H-inf is to find an estimation method so that the ratio among the entire channel estimation errors (between the *j*th BS and K users in every cell) and the input noise/interference is much less than a prescribed threshold. Given a super scalar element *s*, the estimator for every obtained OFDM image wishes to satisfy the following objective feature [22], [23].

$$\sup_{\mathbf{z}_j} = \frac{\left\|\hat{C}_J - C_j\right\|^2}{\left\|Z_j\right\|^2} w < s \tag{10}$$

Where the denominator is a $LQK \times 1$ vector describing the channel response to be evaluated and **w** is a weighing vector**.** The H-infinity channel estimator in Multicell MU DWT based MIMO OFDM system is defined as:

$$\hat{C}_J = \eta_j \varepsilon_j^{-1} T_J^{+} \boldsymbol{Y}_j \tag{11}$$

Where $\varepsilon_j = \Theta_{r,1} + \xi_j \Theta_{r,2}$ and $\eta_j = \Theta_{r,3} + \xi_j \Theta_{r,4}$ are both $LQK \times LQK$ matrices. $\left\|\xi_j\right\|_\infty < 1$ is a $LQK \times 1$ vector and $\Theta_{r,t}$ $1 \le t \le 4$ can be written as

$$\begin{cases} \Theta_{r,1} = \Omega R_T^{1/2} + R_T^{-1/2}, \;\; \Theta_{r,2} = s^{1/2}\Omega Q^{1/2} \\ \Theta_{r,3} = \Omega R_T^{1/2}, \;\; \Theta_{r,4} = s^{-1/2}\Omega Q^{1/2} - s^{1/2} Q^{-1/2} \end{cases} \tag{12}$$

Where $R_T = T_J^{+} T_j$, $\Omega = \Lambda \Delta^{1/2} - \Delta$ and $\Delta = (R_T - s^{-1}Q)^{-1}$ and Λ can be obtained by canonical factorization of $I_{LN_t} + \Delta$.

B. SAGE based H-Infinity Channel Estimation

A straight way to (11) will result from severe calculation of the matrix inversion and multiplication operations for every OFDM image of all users in Q cells over L paths, and the complexity is at the order of $O\,(L^3\, Q^3\, K^3)$. In the case of large values of *L, K,* and *Q*, computational complexity load will be high [21]. In multicell MU-MIMO systems, propagation vectors among the BS antenna arrays and special terminals often could be taken into consideration uncorrelated. Since the SAGE can decompose the spatially multiplexed channels, we will apply this iterative set of rules to cope with the problem of high complexity. Generally, the SAGE process is advanced to keep away from matrix inversion of the ML estimator.

Instead of estimating all parameters at once, SAGE updates only a subset of unknown parameters at each iteration process, which improves the convergence rate significantly [24]. The SAGE-based H-infinity estimator can be efficiently implemented as follows:

- Initializing for *q*=1,2,…,Q and *k*=1,2,…,*K.*

$$\hat{Y}_{jqk}^{(0)} = T_{qk} \varepsilon_{jqk} \eta_{jqk}^{-1} \hat{C}_{jqk}^{(0)} \tag{13}$$

- At the *i*th iteration for *k*=1 +[i mod *K*] ,

$$\hat{\Pi}_{jqk}^{(i)} = \hat{Y}_{jqk}^{(i)} + \left[Y_J - \sum_{k=1}^{K} \hat{Y}_{jqk}^{(0)} \right]$$

$$\hat{C}_{jqk}^{(i+1)} = T_{qk}^{+} \eta_{jqk} \varepsilon_{jqk}^{-1} \hat{\Pi}_{jqk}^{(i)}$$

$$\hat{Y}_{jqk}^{(0)} = T_{qk} \varepsilon_{jqk} \eta_{jqk}^{-1} \hat{C}_{jqk}^{(i+1)} \tag{14}$$

for $1 \le k' \le K$ and $k' \neq k$

$$\hat{Y}_{jqk}^{(i+1)} = \hat{Y}_{jqk}^{(i)} \tag{15}$$

The MSE expression for the H-inf algorithm in the presence of Pilot Contamination for DWT based MU-MIMO-OFDM systems is given as:

$$MSE_{SAGE} = \frac{1}{L} r_{nn}^2 \sum_{q \neq j}^{Q} d_{jq} + \frac{1}{L} r_{nn}^2 \sigma^2 + \frac{1}{L}(1 - r_{nn})^2 \tag{16}$$

V. SIMULATION RESULTS

We considered a multicell MU-MIMO device with M antennas at every BS to investigate the impact of PC on the MSE of channel estimation algorithms. It is assumed that Q = 3 cells, and K = 10 customers in each cell. The section-shifted orthogonal pilot sequences used within the first mobile is reused within the 2nd and 3rd cells. Thus, we keep in mind a state of affairs where pilot sequences are reused. Furthermore, for all k, d_{jqk} = 1 (direct gain) if j = q, and d_{jqk} = a (pass advantage) if j not equal to q. Since the cellular layout and shadowing are captured by using the constant d_{jqk}, PC is treated by means of adjusting the cross profits. For OFDM symbols with N subcarriers, the duration of CP is sixteen, and QPSK is used. For the wide variety of iterations in SAGE system, we select K_{it} = three. Here, the consultant performances for classical LS and MMSE algorithms in multicell MU-MIMO OFDM systems for discrete wavelet are shown.

The MSE overall performance of LS and MMSE algorithms versus the SNR for specific values of L at M = 50, a = 0.5, and N = 64 is observed and shown in Fig 2 and 3.

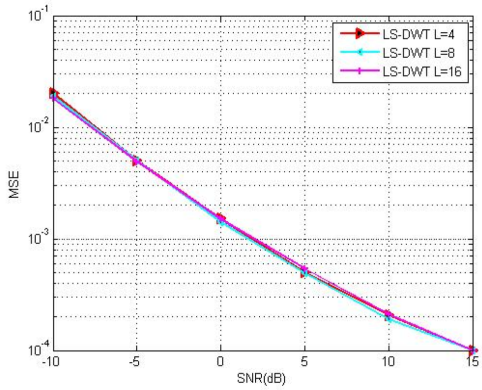

Fig 2: MSE versus SNR for different L values of Least Square Algorithm

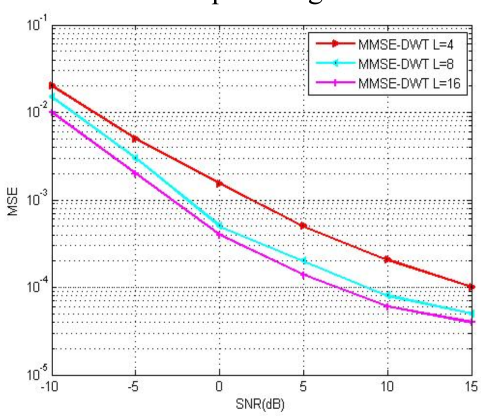

Fig 3: MSE versus SNR for different L values of MMSE algorithm

It is proven within discern that MMSE is more resistant to PC than LS. The variation in the cross gain for different L values are depicted in Fig 4. Three for exceptional values of N in the case of a = 0.6 as a characteristic of SNR. It is proven within discern that the performance of the LS is impartial of the variety of subcarriers, whereas the MSE of MMSE may be progressed via growing the wide variety of subcarriers. Since the variety of subcarriers is larger, the subcarrier spacing becomes smaller; the structures with a large quantity of subcarriers are greater touchy to PC.

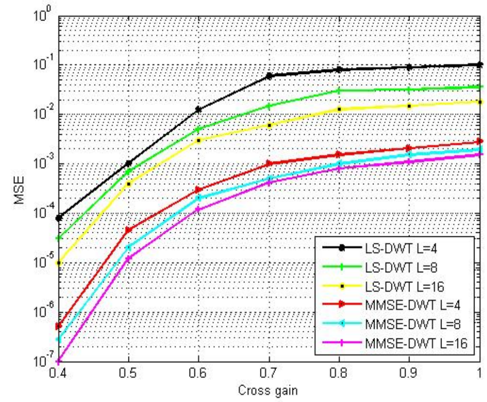

Fig 4: MSE versus Cross gain variations for different L values of LS and MMSE for SNR=5dB

The MSE overall performance of LS and MMSE algorithms for FFT and DWT Based Multicell Multiuser MIMO-OFDM systems is shown in Fig 5 and 6. This clearly shows that the both the methods outperformed in case of DWT based systems over its counterpart FFT based one.

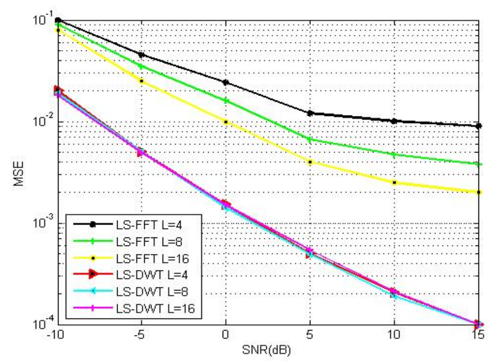

Fig 5: MSE versus SNR for LS-FFT and LS-DWT for different L values

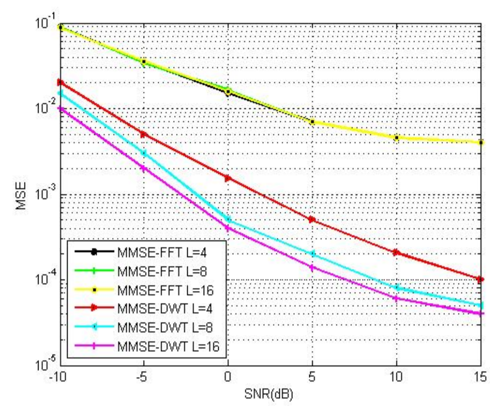

Fig 6: MSE versus SNR for MMSE-FFT and MMSE-DWT for different L values

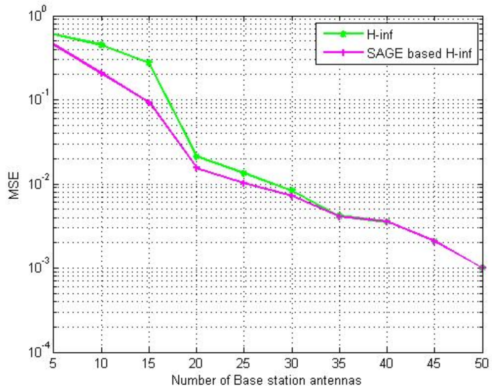

Fig 7: MSE versus Number of base stations between conventional H-inf and SAGE based-proposed method

Figure 7 shows that as the number of base stations increases MSE of both H-infinity and SAGE based H-infinity methods converge.

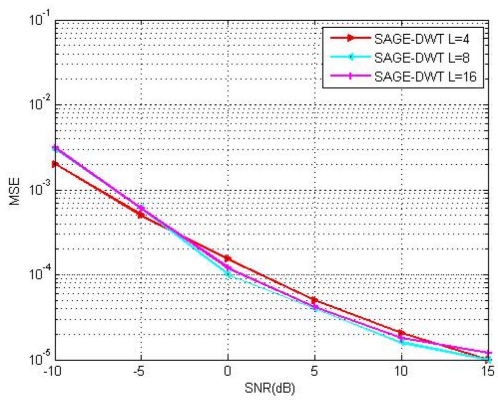

Fig 8: MSE versus SNR for Sage based- DWT for different L values

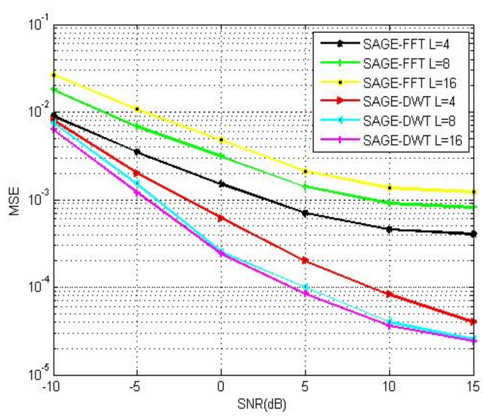

Fig 9: MSE versus SNR for SAGE-based FFT and DWT for different L values

Figure 8 and 9 depicts the performance of SAGE-based H-infinity method for DWT based Multicell MU-MIMO-OFDM systems and its comparison with FFT based systems respectively. Here the DWT based channel estimation is far superior in Mean square error reduction than the FFT based one.

VI. CONCLUSION

In this paper, we've got analytically investigated the effect of PC at the numerous pilot-based channel estimation algorithms, It may be visible that the effect of PC may be big if d_{jq} (move benefit) between cells are of the equal order in terms of d_{jj} (direct benefit) in the equal cellular. The proposed SAGE based DWT method outperformed and led to a better suppression to PC than LS and MMSE algorithms. The simulation results are compared with the existing FFT based Multicell multiuser MIMO OFDM systems and depicts that the DWT based one has a greater performance.

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