# An Adaptive Widely Linear Per-Group Frequency-Domain Semiblind Multiuser Receiver

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Manuscript received :October 4, 2011
Revised: October 31, 2011

ABSTRACT

***In this paper, a widely-linear (WL) technique is applied into an adaptive per-group frequency-domain (PG-FD) semiblind multiuser equaliser. This algorithm is designed for space-frequency block code (SFBC) downlink multiple-input multiple-output (MIMO) multi-carrier code division multiple access (MC-CDMA) with common pilot channel (CPICH) systems and without cyclic-prefix (CP). The update algorithm relies on information from blind and non-blind parts, and the projection on the subspace spanned by the training and the desired user spreading codes matrices. Numerical results illustrate that the proposed adaptive WL PG-FD semiblind multiuser equaliser significantly outperforms and more robust than existing adaptive PG-FD semiblind multiuser and adaptive PG-FD training-based equalisers in fast time varying multipath 3GPP2 MIMO channel model with high mobility.***

***Keywords***: *WL, PG-FD Semiblind receiver, SFBC, MC-CDMA, MIMO, CPICH, without CP.*

## 1. Introduction

Currently, much research in design and development of the systems that are robust against time varying multipath propagation channel with respect to high data rate and high spectral efficiency is of interest. Orthogonal frequency division multiplex (OFDM) is a very attractive multicarrier transmission technique for wireless communications that satisfies the above mentioned requirements. Multi-carrier code division multiple access (MC-CDMA) technique supports multiple users at a high data rate. It combines OFDM and code division multiple access (CDMA) together with the aim to employ the benefits from both techniques. MC-CDMA schemes meet the requirement of the next generation downlink mobile wireless communication [1]. MC-CDMA transmission scheme spreads the data symbol, using spreading codes, on difference orthogonal sub-carrier and therefore offers diversity in multiple access schemes [2].

Modern advance in wireless communication systems with multiple-input multiple-output (MIMO) are significantly attractive due to its satisfying performance with the increasing demand of high data rate services. Space-time coding (STC) schemes [3] – [4] were introduced in order to combat fading channels via the use of diversity of MIMO array antennas. Nevertheless, the original STC have been developed for signaling over frequency-flat channel, and do not enable multipath diversity which presents in frequency-selective fading MIMO channels. A space-frequency block coding (SFBC) scheme was proposed in [5]. This technique offers space and frequency diversity over multi-antenna and fast time varying frequency-selective fading channels. As appeared in [5], [6], the SFBC using code division multiplexing (CDM) in OFDM system has better performance and more robust than STBC OFDM system.

In MC-CDMA systems, a cyclic prefix (CP) of adequate length is inserted in the transmit sequence. If the channel is time-invariant within a MC-CDMA block, the intersymbol interference (ISI) and the intercarrier interference (ICI) caused by the multipath channel are effectively canceled. This simplifies the receiver hardware implementations, since the equaliser is just a single-tap frequency-domain (FD) filter. Nevertheless, next generation mobile wireless systems are expected to operate at high transmit frequency, high data rate and high level of mobility, resulting in the channel to be frequency-selective fading ones [7] – [9]. The channel variations over block cannot be avoided. Hence, it destroys the orthogonality among subcarrires resulting ISI, ICI and performance of the receiver degradation [7] – [10]. Therefore, the traditional one-tap FD equaliser is not sufficient any more.

Referring to a standard of 3GPP2 downlink MIMO mobile wireless communication systems [11], training and multiuser data signals are altogether transmit in the channel which is called common pilot channel (CPICH). This technique avoids loss of bandwidth efficiency resulting the addition of training symbol, and is very beneficial for an equaliser to estimate the channel information and detect the desired user in fast time varying multipath channel. The optimal transmit power ratio of the training and the data signals was analysed in [12]. This ratio improves the capacity in MIMO OFDM systems.

Until now, many research contributions focus to a semiblind receiver for high data rate mobile communication systems. The criterion of semiblind combines information of both training signal (known) and estimated signal (unknown) for tracking fast time varying channel. The semiblind receiver provides superior performance than blind or training-based ones which was proven in [13] – [14].

In MIMO frequency-selective fading channels, optimal maximum likelihood equaliser suffers from high computational complexity where exponentially increases with channel memory length. For such a reason, suboptimal equalisers have been typically proposed in order to achieve an acceptable compromise between performance and computational complexity. Widely linear (WL) is a promising class of linear algorithms to be used in the adaptive filter estimation [15] – [18]. The linear process takes advantage of both real and imaginary part separately, without a significant increase in computational complexity. This technique significantly improves the performance of the linear multiuser receivers.

A WL blind minimum-output-energy (MOE) algorithm [19] and WL blind channel identification algorithm [20] were proposed. The blind receivers are attractive because the bandwidth and power are not consumed by the training signal. However, blind algorithms require a long duration of observing estimate resulting in a phase ambiguity. Furthermore, the operating channel is required to be time invariant over a long period. Therefore, for STBC scheme [4] operates in MIMO frequency selective-fading channel. It is impossible to achieve a blind receiver due to implicit ambiguity [13]. A WL MMSE receiver [21] was proposed for STBC downlink systems. However, this receiver achieves a reasonable trade-off between complexity and performance. Moreover, as far as we concern, the WL technique has not yet been applied to the semiblind receiver.

In this paper, we apply the advantage of WL technique to improve the performance of an adaptive PG-FD semiblind multiuser receiver for SFBC downlink MIMO MC-CDMA with CPICH system and without CP.

The contribution of this paper is two-fold: First, a mathematical framework of a synchronous SFBC downlink MIMO MC-CDMA with CPICH and without CP signal model and formulated matrix using the advantage of diversity from space-frequency (SF) technique and array antennas are proposed in section 2. Second, the WL technique is applied to adaptive per-group (PG) FD semiblind multiuser equaliser. The multiuser detection is based on the projection to orthogonal FD subspace which spans by the training and the desired users spreading code matrices. The algorithm is updated using the information from complex FD received multiuser shifted block signal sequence matrix at the block rate that is presented in section 3. Simulation results in section 5 show that the performance of the proposed WL PG-FD semiblind multiuser receiver outperforms existing PG-FD semiblind and PG-FD training-based receivers in bit error rate (BER) over 3GPP2 MIMO scenarios.

## 2. SFBC DOWNLINK MIMO MC-CDMA WITH CPICH SYSTEM SIGNAL MODEL

In the rest of this paper, we use the following notations. Matrices are denoted with upper case bold face letters, lower case bold face letters for vectors. Also, $*$ denotes the convolution operation, $(\bullet)^T$ for transpose, $(\bullet)^H$ for Hermitian matrix, $(\bullet)^*$ for complex conjugate and $(\bullet)^\dagger$ for matrix inversion. Throughout this paper, receiver and equaliser are the same meaning.

The block diagram for high data rate downlink baseband system model for SFBC MIMO MC-CDMA with CPICH system and without CP is proposed in Fig. 1. We consider the systems with two transmit antennas and two receive antennas, where the base station (BS) has $K$ symbol-synchronous users. The $k^{\text{th}}$ user is assigned using an orthogonal complex FD spreading code of length $N$, where the user $k$=1 is reserved for the training signal or CPICH. Following this, the modulated data and spreading code signal from all users are combined

$$\mathbf{t}(m) = \mathbf{C}\mathbf{x}(m)\,, \tag{1}$$

where $\mathbf{C} = \left[\mathbf{c}_1, \text{K}\,, \mathbf{c}_K\right]$ is the all users complex FD spreading code matrix, $\mathbf{c}_k = \left[c_{k,1}, \ldots, c_{k,N}\right]^T$ the $k^{\text{th}}$ complex FD spreading code vector of length *N*, $\mathbf{x}(m) = [\sqrt{A_1(m)}b_1(m), \ldots, \sqrt{A_K(m)}b_K(m)]^T$, $A_k(m)$ and $b_k(m)$ are power and data at *m* symbol sequence for the $k^{\text{th}}$ user, respectively.

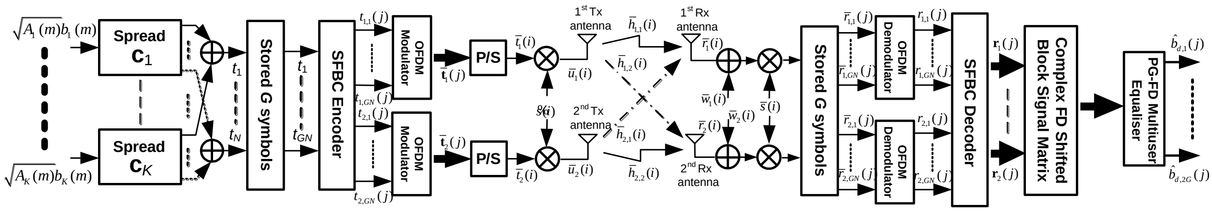


***Fig. 1*** *The SFBC downlink MIMO MC-CDMA with CPICH system and without CP scheme.*

The multiuser signal $\mathbf{t}(m)$ is stored until *2G* symbols (data block) and is loaded into the SFBC encoder for use the diversity from space-frequency and an array antennas techniques which is based on the STBC Alamouti's scheme [4], [5]. Therefore, the even $(2j)$ and odd $(2j+1)$ encoding multiuser block signal sequence prepared for transmit at antenna $M_T$=1 and $M_T$ =2 are given by

$$\begin{bmatrix} \mathbf{t}_{M_T=1}(2j) & \mathbf{t}_{M_T=1}(2j+1) \\ \mathbf{t}_{M_T=2}(2j) & \mathbf{t}_{M_T=2}(2j+1) \end{bmatrix}, \tag{2}$$

where $\mathbf{t}_{M_T}(2j)$ and $\mathbf{t}_{M_T}(2j+1)$ block signal sequences have the length $1\times GN$

$$\mathbf{t}_{M_T=1}(2j) = \left[t(2(j-1)GN+1), \ldots, t(2(j-1)GN+GN)\right],$$
$$\mathbf{t}_{M_T=2}(2j) = \left[t(2(j-1)GN+GN+1), \ldots, t(2(j-1)GN+2GN)\right], \tag{3}$$

and

$$\mathbf{t}_{M_T=1}(2j+1) = -\mathbf{t}^*_{M_T=2}(2j)\mathbf{P}_{GN},$$
$$\mathbf{t}_{M_T=2}(2j+1) = \mathbf{t}^*_{M_T=1}(2j)\mathbf{P}_{GN}, \tag{4}$$

where $\mathbf{P}_{GN}$ is a *GN*×*GN* permutation matrix and *j* is block rate index. The even $\mathbf{t}_{M_T}(2j)$ and odd $\mathbf{t}_{M_T}(2j+1)$ encoding multiuser block signal sequences are loaded into the OFDM modulator for use an efficient fast Fourier transform (FFT) technique. After, the FD encoding multiuser block signal $\mathbf{t}_{M_T}(j)$ is transformed to the time-domain (TD) encoding multiuser block signal $\bar{\mathbf{t}}_{M_T}(j)$. In this paper, we consider the systems without CP. Therefore, additional CP or zero padding block is neglected from the SFBC downlink MIMO MC-CDMA scheme. Finally, the TD encoding multiuser block signal both even $\bar{\mathbf{t}}_{M_T}(2j)$ and odd $\bar{\mathbf{t}}_{M_T}(2j+1)$ sequences are loaded into parallel-to-series (P/S)

converter $\bar{t}_{M_T}(i)$, multiplied by a cell-specific long scrambling code sequence $\bar{s}(i)$, and is transmit at the $M_T$ transmit antenna

$$\bar{u}_{M_T}(i) = \bar{t}_{M_T}(i) \times \bar{s}(i), \tag{5}$$

where *i* is the chip rate index.

In practice, the signals arrived at the mobile receive antenna are propagated through time varying multipath channels. Here, we model using a finite impulse response (FIR) filter with the impulse response $\bar{h}(i)$, $l \in \{0, \ldots, L_h\}$, where the $L_h$ is the order of multipath channel. Therefore, the receive signal at $M_R$ antenna is then the convolutional result of the transmit signal $\bar{u}_{M_T}(i)$ and MIMO multipath channel impulse response $\bar{h}_{M_T,M_R}(i)$, and corrupted with an additive white Gaussian noise (AWGN) $\bar{w}_{M_R}(i)$ with the variance $\delta_w^2$, i.e. $\bar{r}_{M_R=1}(i) = \bar{u}_{M_T=1}(i) * \bar{h}_{M_T=1,M_R=1}(i) + \bar{u}_{M_T=2}(i) * \bar{h}_{M_T=2,M_R=1}(i) + \bar{w}_{M_R=1}(i)$ and $\bar{r}_{M_R=2}(i) = \bar{u}_{M_T=1}(i) * \bar{h}_{M_T=1,M_R=2}(i) + \bar{u}_{M_T=2}(i) * \bar{h}_{M_T=2,M_R=2}(i) + \bar{w}_{M_R=2}(i)$.

After, the TD multiuser receive signal at the chip rate $\bar{r}_{M_R}(i)$ is descrambled by cell-specific long scrambling code $\bar{s}(i)$, stored until *2G* symbol for regenerated even $\bar{\mathbf{r}}_{M_R}(2j)$ and odd $\bar{\mathbf{r}}_{M_R}(2j+1)$ received multiuser block signal sequences, are transformed to FD using OFDM demodulator $\mathbf{r}_{M_R}(i)$, and is loaded into SFBC decoding

$$\begin{bmatrix} \mathbf{r}_{M_R=1}(2j) & \mathbf{r}_{M_R=1}(2j+1) \\ \mathbf{r}_{M_R=2}(2j) & \mathbf{r}_{M_R=2}(2j+1) \end{bmatrix}, \quad (6)$$

where

$$\mathbf{r}_{M_R=1}(2j+1) = \mathbf{r}^*_{M_R=2}(2j+1)\mathbf{P}_{GN},$$
$$\mathbf{r}_{M_R=2}(2j+1) = \mathbf{r}^*_{M_R=1}(2j+1)\mathbf{P}_{GN}, \quad (7)$$

where $\mathbf{r}_{M_R}(2j)$ and $\mathbf{r}_{M_R}(2j+1)$ are FD even and odd received multiuser block signal sequences that have the length $1\times GN$

$$\mathbf{r}_{M_R}(2j) = \left[r_{M_R}(2(j-1)GN+1), ..., r_{M_R}(2(j-1)GN+GN)\right],$$
$$\mathbf{r}_{M_R}(2j+1) = \left[r_{M_R}(2(j-1)GN+GN+1), ..., r_{M_R}(2(j-1)GN+2GN)\right] \quad (8)$$

For using the advantage of diversity from SFBC technique and array antennas, we formulate the complex FD received multiuser shifted block signal sequence matrix $\mathbf{R}(j)$, has the size $L_f\times GN$, using $\mathbf{r}_{M_R}(2j)$ and $\mathbf{r}_{M_R}(2j+1)$ are

$$\mathbf{R}(j) = \begin{bmatrix} r_{M_R=1}\left(2(j-1)GN+\left(\lfloor L_f/4\rfloor+1\right)\right) & \cdots & r_{M_R=1}\left(2(j-1)GN+\left(\lfloor L_f/4\rfloor\right)+GN\right) \\ \vdots & \vdots & \vdots \\ r_{M_R=1}(2(j-1)GN+1) & \cdots & r_{M_R=1}(2(j-1)GN+GN) \\ r_{M_R=2}\left(2(j-1)GN+\left(\lfloor L_f/4\rfloor+1\right)\right) & \cdots & r_{M_R=2}\left(2(j-1)GN+\left(\lfloor L_f/4\rfloor\right)+GN\right) \\ \vdots & \vdots & \vdots \\ r_{M_R=2}(2(j-1)GN+1) & \cdots & r_{M_R=2}(2(j-1)GN+GN) \\ r_{M_R=1}\left(2(j-1)GN+GN+\left(\lfloor L_f/4\rfloor+1\right)\right) & \cdots & r_{M_R=1}\left(2(j-1)GN+GN+\left(\lfloor L_f/4\rfloor\right)+GN\right) \\ \vdots & \vdots & \vdots \\ r_{M_R=1}(2(j-1)GN+GN+1) & \cdots & r_{M_R=1}(2(j-1)GN+GN+GN) \\ r_{M_R=2}\left(2(j-1)GN+GN+\left(\lfloor L_f/4\rfloor+1\right)\right) & \cdots & r_{M_R=2}\left(2(j-1)GN+GN+\left(\lfloor L_f/4\rfloor\right)+GN\right) \\ \vdots & \vdots & \vdots \\ r_{M_R=2}(2(j-1)GN+GN+1) & \cdots & r_{M_R=2}(2(j-1)GN+GN+GN) \end{bmatrix},$$

(9)

where $L_f$ denotes order of equaliser which is selected.

## 3. ADAPTIVE WL FD-PG SEMIBLIND MILTIUSER EQUALISER

A combination an efficient of FFT, SFBC and MIMO array antennas boosts the throughput on OFDM and MC-CDMA systems [22] – [23]. On the one hand, at very high throughput, the MIMO channel becomes frequency-selective fading channel which amplitude, phase and tapped delay are varied with time. Therefore, the insufficient CP problem occurs when the channel order is larger than the length of CP and can not be avoided at the mobile wireless receivers. In MC-CDMA systems, ICI, ISI and multi user interference (MUI) are not canceled only by using one-tap FD equaliser (FEQ). For simplification the problem, this paper focuses to the high throughput downlink MIMO MC-CDMA systems without CP.

In this section, we apply the advantage of WL technique into adaptive PG-FD semiblind multiuser equaliser for SFBC downlink MIMO MC-CDMA with CPICH system and without CP.

The WL PG-FD chip semiblind multiuser equaliser cost function defines as

$$J_{\text{odd}} = \min_{\hat{\mathbf{f}},\hat{\mathbf{g}}} \mathrm{E}\left\{\left\| \underbrace{\hat{\mathbf{f}}(2j+1)\mathbf{R}(j) - \hat{\mathbf{b}}_d^f(2j+1)\mathbf{C}_d(2j+1) - \mathbf{b}_p\mathbf{C}_p(2j+1)}_{\text{term 1}} \atop + \underbrace{\hat{\mathbf{g}}(2j+1)\mathbf{R}^*(j) - \hat{\mathbf{b}}_d^g(2j+1)\mathbf{C}_d(2j+1) - \mathbf{b}_p\mathbf{C}_p(2j+1)}_{\text{term 2}} \right\|^2\right\},$$

$$J_{\text{even}} = \min_{\hat{\mathbf{f}},\hat{\mathbf{g}}} \mathrm{E}\left\{\left\| \underbrace{\hat{\mathbf{f}}(2j)\mathbf{R}(j) - \hat{\mathbf{b}}_d^f(2j)\mathbf{C}_d(2j) - \mathbf{b}_p\mathbf{C}_p(2j)}_{\text{term 1}} \atop + \underbrace{\hat{\mathbf{g}}(2j)\mathbf{R}^*(j) - \hat{\mathbf{b}}_d^g(2j)\mathbf{C}_d(2j) - \mathbf{b}_p\mathbf{C}_p(2j)}_{\text{term 2}} \right\|^2\right\}, \quad (10)$$

where $\hat{\mathbf{f}}$ and $\hat{\mathbf{g}}$ are estimated tap-weight coefficients vector of the proposed semiblind multiuser equalisers, $\mathbf{b}_p = \mathbf{1}_{1\times G}$ is the training data symbol, $\hat{\mathbf{b}}_d^v(j) = [\hat{b}_1^v(j), ..., \hat{b}_G^v(j)]$ the estimating desired user data at $j$ block sequence

$$\hat{\mathbf{b}}_d^f(2j+1) = \hat{\mathbf{f}}(2j+1)\mathbf{R}(j)\mathbf{C}_d^H(2j+1)$$
$$\hat{\mathbf{b}}_d^g(2j+1) = \hat{\mathbf{g}}(2j+1)\mathbf{R}^*(j)\mathbf{C}_d^H(2j+1)$$

and

$$\hat{\mathbf{b}}_d^f(2j) = \hat{\mathbf{f}}(2j)\mathbf{R}(j)\mathbf{C}_d^H(2j)$$
$$\hat{\mathbf{b}}_d^g(2j) = \hat{\mathbf{g}}(2j)\mathbf{R}^*(j)\mathbf{C}_d^H(2j), \quad (11)$$

where $\mathbf{C}_d(j)$ and $\mathbf{C}_p(j)$ are the FD spreading code matrices of the desired user and the training at $j$ block sequence

$$\mathbf{C}_k(j) = \begin{bmatrix} \mathbf{c}_k^T & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{c}_k^T \end{bmatrix}, \quad (12)$$

To combat ICI, ISI and MUI in the presence of noise and fast time varying frequency-selective fading channel, we apply the least squares (LS) method to the cost function (10). By substituting the estimated desired user data odd $\hat{\mathbf{b}}_d^v(2j+1)$ and even $\hat{\mathbf{b}}_d^v(2j)$ block sequence into e.q. (10), and minimizing with respect to $\hat{\mathbf{f}}$ and $\hat{\mathbf{g}}$, the adaptive estimating tap-weight coefficients vector of equaliser odd $\hat{\mathbf{f}}(2j+1)$, $\hat{\mathbf{g}}(2j+1)$ and even $\hat{\mathbf{f}}(2j)$, $\hat{\mathbf{g}}(2j)$ block sequences are obtained as

$$\hat{\mathbf{f}}(2j+1) = \left(\mathbf{b}_p(2j+1)\mathbf{C}_p(2j+1)\mathbf{R}^H(j)\right) \times\left(\mathbf{R}(j)\left(\mathbf{I}_{GN} - \mathbf{C}_d^H(2j+1)\mathbf{C}_d(2j+1)\right)\mathbf{R}^H(j)\right)^{\dagger},$$

$$\hat{\mathbf{g}}(2j+1) = \left(\mathbf{b}_p(2j+1)\mathbf{C}_p(2j+1)\mathbf{R}^T(j)\right) \times\left(\mathbf{R}^*(j)\left(\mathbf{I}_{GN} - \mathbf{C}_d^H(2j+1)\mathbf{C}_d(2j+1)\right)\mathbf{R}^T(j)\right)^{\dagger}$$

$$\hat{\mathbf{f}}(2j) = \left(\mathbf{b}_p(2j)\mathbf{C}_p(2j)\mathbf{R}^H(j)\right) \times\left(\mathbf{R}(j)\left(\mathbf{I}_{GN} - \mathbf{C}_d^H(2j)\mathbf{C}_d(2j)\right)\mathbf{R}^H(j)\right)^{\dagger},$$

$$\hat{\mathbf{g}}(2j) = \left(\mathbf{b}_p(2j)\mathbf{C}_p(2j)\mathbf{R}^T(j)\right) \times\left(\mathbf{R}^*(j)\left(\mathbf{I}_{GN} - \mathbf{C}_d^H(2j)\mathbf{C}_d(2j)\right)\mathbf{R}^T(j)\right)^{\dagger}. \quad (13)$$

Finally, the *2G* estimated desired user data symbols from odd $\hat{\mathbf{b}}_d(2j+1)$ and even $\hat{\mathbf{b}}_d(2j)$ block sequence can be directly defined as

$$\hat{\mathbf{b}}_d(2j+1) = \hat{\mathbf{f}}(2j+1)\mathbf{R}(j)\mathbf{C}_d^H(2j+1) + \hat{\mathbf{g}}(2j+1)\mathbf{R}^*(j)\mathbf{C}_d^H(2j+1)$$

and

$$\hat{\mathbf{b}}_d(2j) = \hat{\mathbf{f}}(2j)\mathbf{R}(j)\mathbf{C}_d^H(2j) + \hat{\mathbf{g}}(2j)\mathbf{R}^*(j)\mathbf{C}_d^H(2j) \quad (14)$$

Considering eqs. (10-14), the operation of the proposed WL adaptive PG-FD semiblind multiuser algorithm contributions from the following factors

-Information from both training (non-blind part) and the estimated design user data (blind part) that are used in the updated equaliser.

-The diversity technique from SFBC and array antennas, which is formulated passing the complex FD received multiuser shifted block signal sequence matrix $\mathbf{R}(j)$. It is exploited for the update equaliser.

-Information from all carriers (1,…,*NG*) or group used for updated tap-weight coefficients vector of equaliser. Therefore, the algorithm can be operated in either system with sufficient CP, insufficient CP or even without CP.

-The update algorithm projected to the orthogonal FD of the subspace which is spanned by the training $\mathbf{C}_p(j)$ and the desired $\mathbf{C}_d(j)$ users spreading code matrices.

-The WL technique takes the advantage of utilising the correlation among the receive signal sequence and its conjugate version that is applied into the semiblind algorithm.

The computational complexity of the proposed algorithm relies on the matrix inversion terms which is generally of $O(L_f)^3$ operation. However, many techniques were proposed to reduce the operation to $O(L_f)^2$ [24]. Hence, the total possessed computational complexity of the proposed algorithm for estimated 2*G* desired user data symbols at odd and even block sequence is $O(L_f)^2$. +

## 4. SYSTEMS PARAMETERS

The system parameters were derived according to an outdoor propagation scenario. We used a link level MIMO channel model which had been specifically developed within the multi element transmit receive antennas (METRA) model for mobile broadband wireless access system (MBWA) MIMO channel project [25]. This link level channel model was based on 3GPP/3GPP2 proposal [11] for mobile broadband wireless MIMO channel exploiting multipath angular characteristics. It consisted of elaborating a spatial model from the hybrid approach between a geometrical concept depending on cluster position and the tapped delay line model describing the average power delay profile with a fixed number of taps. The spatial parameters were defined at the BS and MS. The angular distribution was modeled from parameters leading to an average of angle spread [26].

The Case I and Case II ITU Pedestrian A and Vehicular A MIMO channel parameter with 0.5λ antenna spacing, uniform power azimuth spectrum (PAS) and angle of arrival (AOA) 22 degree [26] were considered. The model had an averaged power delay profile with a fixed number of FIR filter taps [11] which was characterised by a large Rayleigh distribution and a higher mobility. The classical Rayleigh model was used to generate the uncorrelated fading signal. Besides, the correlation properties in the spatial domain of the broadband wireless 3GPP2 MIMO channel were obtained from the Kronecker product of two independent correlation matrices, which was defined by the correlation properties at the BS and MS, and the associated with Doppler spectrum of the channel part.

We considered SFBC downlink MIMO MC-CDMA with CPICH system and without CP, with two transmit antennas at the BS and two receive antennas at the mobile station (MS). The sampling frequency 57.6 MHz with a carrier frequency of 5 GHz and the number of subcarriers 1024 (*NG*) were used. The orthogonal complex FD spreading codes of length *N*=32 were employed as the user-specific code, and a complex random scrambling code was used for the cell-specific long code. The binary phase-shift keying (BPSK) modulator technique was used to transmit data and all users except training had the same power. Power of training signal was set following an optimal pilot-to-data power ratio (PDPR) that was analysed in [12]. The receiver is designed to support the mobility of high speed train 360km/s [27]. Moreover, transmit power at the BS antenna one ($M_T$=1) and BS antenna two ($M_T$=2) were normalised to one.

## 5. SIMULATION RESULTS

In this section, we now compare the performance of the proposed adaptive WL PG-FD semiblind equaliser with the theoretical adaptive PG-FD MMSE equaliser, the adaptive PG-FD training-based and the adaptive PG-FD semiblind equalisers in SFBC downlink MIMO MC-CDMA with CPICH system and without CP. The MIMO channel model is based on 3GPP2 link level model [11] with high Doppler speed. An adaptive PG-FD semiblind equaliser is applied from the cost function in e.q. (10) but the conjugate part (term2) is neglected. Adaptive PG-FD training-based equaliser is applied from methodology which was proposed in [28]. An adaptive theoretical PG-FD MMSE equaliser is applied from methodology in [29] and is assumed perfect knowledge of the channel impulse response and the variance of AWGN noise. For a fair comparison, all equalisers use the same order of $L_f$=31, the LS method and the advantage of complex FD received multiuser shifted block signal sequence matrix $\mathbf{R}(j)$ are used for updating even and odd parts at the block sequence (*2G*=32 symbols), and the transmit power of training and multiuser signal are set to optimal PDPR [12].

Fig. 2 shows an averaged bit error rate (BER) versus number of active loaded users existing in the system attaining from all equalisers in 3GPP2 MIMO Pedestrian A channel models with Doppler speed of 360 km/h. In the case of weak and medium active loaded users existing in the system, we observe that the proposed WL PG-FD semiblind multiuser equaliser achieves an improvement in reducing the transmit power as compared to the PG-FD semiblind multiuser equaliser and the PG-FD training-based equaliser [28] where compared at the same BER. In the case of heavy active loaded users existing in the system, improvement of WL PG-FD semiblind multiuser equaliser and PG-FD semiblind multiuser equaliser decrease approaching PG-FD training-based equaliser.

In a difficult 3GPP2 MIMO Vehicular A channel model with Doppler speed of 360 km/h, an averaged BER versus number of active loaded users existing in the system is shown in Fig 3. Performance of the proposed WL PG-FD semiblind multiuser equaliser still improves in reducing the transmit power as compared to the PG-FD semiblind multiuser equaliser and the PG-FD training-based equaliser [28], in the case of weak and medium active loaded users, where compared at the same BER. The disparity of performance of WL PG-FD semiblind multiuser, PG-FD semiblind multiuser and training-based [28] equalisers is less pronounced with an increasing of existing active loaded users in the system. Nevertheless, in the full loaded case (*K*=32), the performance of the WL PG-FD and the PG-FD semiblind multiuser equalisers converge closed to the PG-FD training-based equaliser the result of contribution information from the blind part diminishes.

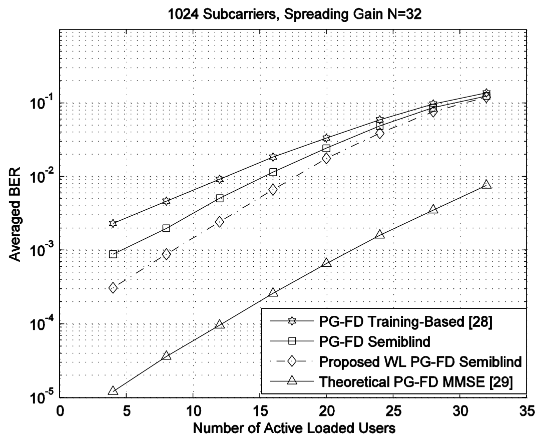


***Fig. 2*** *An averaged BER's versus number of active loaded users existing in the system obtained from the proposed WL PG-FD semiblind, PG-FD semiblind, PG-FD training-based, and theoretical PG-FD MMSE equalisers in difficult fast time varying multipath 3GPP2 MIMO Vehicular A channel models with Doppler speed of 360km/h.*

The simulation results reveal that the performance of the proposed adaptive WL PG-FD semiblind multiuser equaliser outperforms in BER and has an improvement in reducing transmit power rather than PG-FD semiblind multiuser equaliser and PG-FD training-based equaliser [28], in both fast time varying multipath 3GPP2 MIMO Pedestrian A and Vehicular A channel models. As a result, the advantage of WL technique applied into PG-FD semiblind multiuser cost function has been shown. Moreover, performance of adaptive PG-FD semiblind multiuser equaliser has an improvement in suppressing multiuser interference more effectively than the adaptive PG-FD training-based equaliser [28]. As a result of PG-FD semiblind equalisers use information from both non-blind and blind parts in the update equaliser and the cost functions are based on the projection to orthogonal FD of the subspace spanned by the training and desired users spreading code matrices. On the other hand, the cost function of training-based equaliser [28] is based on the orthogonal FD of training spreading code matrix and relies on only information from training signal to estimating the designed user data.

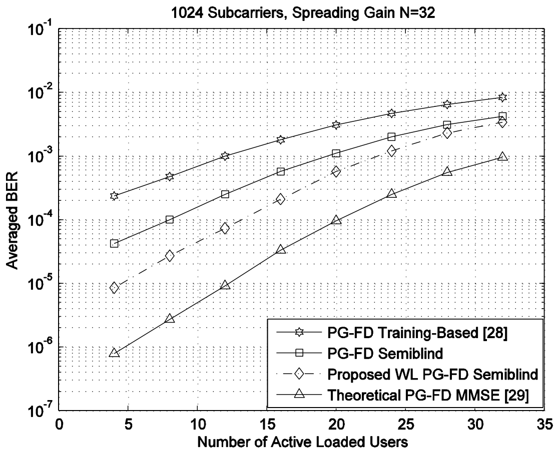


***Fig. 3*** *An averaged BER's versus number of active loaded users existing in the system obtained from the proposed WL PG-FD semiblind, PG-FD semiblind, PG-FD training-based, and theoretical PG-FD MMSE equalisers in fast time varying multipath 3GPP2 MIMO Pedestrian A channel models with Doppler speed of 360km/h.*

## 6. CONCLUSIONS

A combination of an efficient of FFT, SFBC and MIMO array antennas is proposed passing SFBC downlink MIMO MC-CDMA with CPICH system model. The complex FD received multiuser shifted block signal sequence matrix is formulated for providing the diversity at the receiver. The utilisation of the correlation among the received signal sequence and its conjugate version form the WL technique is beneficial when applied into the adaptive PG-FD semiblind multiuser equaliser. The semiblind multiuser equaliser cost function relies on the projection to orthogonal FD of the subspace spanned by the training and desired users spreading code. Simulation results reveal that adaptive WL PG-FD semiblind multiuser equaliser outperforms in the BER and robust than adaptive PG-FD semiblind multiuser equaliser and adaptive PG-FD training-based equaliser in both weak and strong 3GPP2 MIMO fast time varying frequency-selective fading channels with high Doppler speed.

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