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Low-Complexity Zero-Forcing Equalization for Massive MIMO-OFDM

Kun Chen-Hu, Ana García Armada
Department of Signal Theory and Communications, Universidad Carlos III de Madrid (Spain)
kchen@tsc.uc3m.es, agarcia@tsc.uc3m.es

Introduction

Massive MIMO combined with OFDM are key techniques in the evolution of mobile communications. In this context, to the best of our knowledge, the channel estimation and the equalizers have never been jointly considered. We propose an alternative low-complexity method to compute the ZF equalizers, which consists of exchanging the order of the interpolation and computation of the equalizer. For massive MIMO, this strategy provides the same performance and considerably lower number of operations, compared to the traditional scheme.

Traditional Scheme

The received signal at k-th subcarrier is

$$\check{\mathbf{y}}_k = \mathbf{H}_k \check{\mathbf{s}}_k + \check{\mathbf{w}}_k.$$

The channel matrix at k-th subcarrier is

$$\mathbf{H}_k = \begin{bmatrix} [\tilde{\mathbf{h}}_{11}]_k & \cdots & [\tilde{\mathbf{h}}_{1U}]_k \\ \vdots & \ddots & \vdots \\ [\tilde{\mathbf{h}}_{N_B 1}]_k & \cdots & [\tilde{\mathbf{h}}_{N_B U}]_k \end{bmatrix}.$$

Interpolation of the channel matrices

$$[\tilde{\mathbf{h}}_{vu}]_k = [\tilde{\mathbf{h}}_{vu}]_p + \frac{k}{N_f}\left([\tilde{\mathbf{h}}_{vu}]_q - [\tilde{\mathbf{h}}_{vu}]_p\right),$$

$q = p + N_f,\ \forall\{q,p\} \in \mathcal{A}_p\ \ p < k < q,\ \ \forall k \in \mathcal{A}_d.$

Computation of the ZF matrices

$$\mathbf{G}_k^{ZF} = \left((\mathbf{H}_k)^H \mathbf{H}_k\right)^{-1} (\mathbf{H}_k)^H,\ \ \forall k \in \mathcal{A},$$

$$\mathbf{G}_k^{ZF} = \begin{bmatrix} [\mathbf{g}_{11}^{ZF}]_k & \cdots & [\mathbf{g}_{1N_B}^{ZF}]_k \\ \vdots & \ddots & \vdots \\ [\mathbf{g}_{U1}^{ZF}]_k & \cdots & [\mathbf{g}_{UN_B}^{ZF}]_k \end{bmatrix}.$$

Simulation parameters

K	128	I	7
Δf	15 KHz	N_f	8, 25
N_B	10, 100	L_{CH}	5
U	2	L_{CP}	9
Chan. Model	LTE EVA	**Constellation**	QPSK

References

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[3] Antonia M. Tulino and Sergio Verdú. Random matrix theory and wireless communications. *Foundations and Trends in Communications and Information Theory*, 1(1):1–182, 2004.

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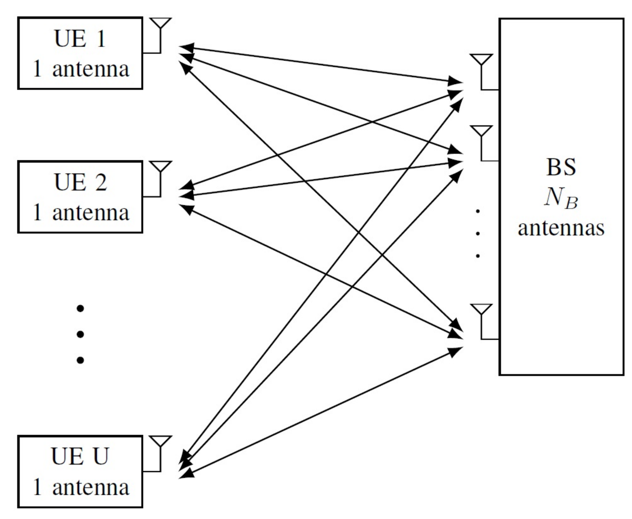
System Model

We consider a multiuser massive MIMO system in TDD mode

$$y_v[n] = \sum_{u=1}^{U} h_{vu}[n] * x_{cp,u}[n] + w_v[n],$$

$x_{cp,u}[n]$ is the signal transmitted from the u-th UE.
$w_v[n]$ is the AWGN at the input of v-th antenna of the BS distributed according to $w_v[n] \sim \mathcal{CN}(0, \sigma_w^2)$.
$h_{vu}[n]$ denotes the multipath channel impulse response with L_{CH} coefficients from the single antenna of u-th user to the v-th antenna of the BS $\left(h_{uv}[n] \sim \mathcal{CN}(0, \sigma_h^2[n]),\ \ n \in \{1, 2, \cdots, L_{CH}\}\right)$.



Low-Complexity Scheme

Computation of ZF matrices

$$\mathbf{G}_k^{ZF} = \left((\mathbf{H}_k)^H \mathbf{H}_k\right)^{-1} (\mathbf{H}_k)^H,\ \ \forall k \in \mathcal{A}_p.$$

Interpolation of the ZF matrices

$$[\mathbf{g}_{uv}]_k^{LZF} = [\mathbf{g}_{uv}^{ZF}]_p + \frac{k}{N_f}\left([\mathbf{g}_{uv}^{ZF}]_q - [\mathbf{g}_{uv}^{ZF}]_p\right),$$

$q = p + N_f,\ \forall\{q,p\} \in \mathcal{A}_p\ \ p < k < q,\ \ \forall k \in \mathcal{A}_d.$

Complexity Analysis

The number of complex multiplications (NCM) for the required matrix inversion is

$$C_{ZF} = K\left(\frac{3}{2}N_B U^2 + \frac{1}{3}U^3\right),$$

$$C_{LZF} = K_p\left(\frac{3}{2}N_B U^2 + \frac{1}{3}U^3\right).$$

Average Square Error Distance

The ASED of two techniques is given by

$$\epsilon_k = \mathbb{E}\left\{\left|[\mathbf{g}_{uv}^{LZF}]_k - [\mathbf{g}_{uv}^{ZF}]_k\right|^2\right\},\ \ \forall k \in \mathcal{A}_d.$$

Making use the asymptotic analysis

$$\frac{1}{N_B}(\mathbf{H}_k)^H \mathbf{H}_k \xrightarrow{N_B \gg U} \mathbf{I}_U,$$

we can lower-bound the ASED as

$$\epsilon_k \geq \frac{1}{N_B^2} \frac{4(\rho-1)^2(N_f-k)^2k^2(N_f^2-2N_fk+2k^2)}{N_f^2(N_f^2+2N_f(\rho-1)k-2(\rho-1)k^2)^2}$$

Hence, it shows that the ASED between two techniques will decrease as N_B is increased, which means that the large number of antennas at the BS helps to improve the performance of our proposed low-complexity technique and get it closer to the traditional one.

Simulation Results

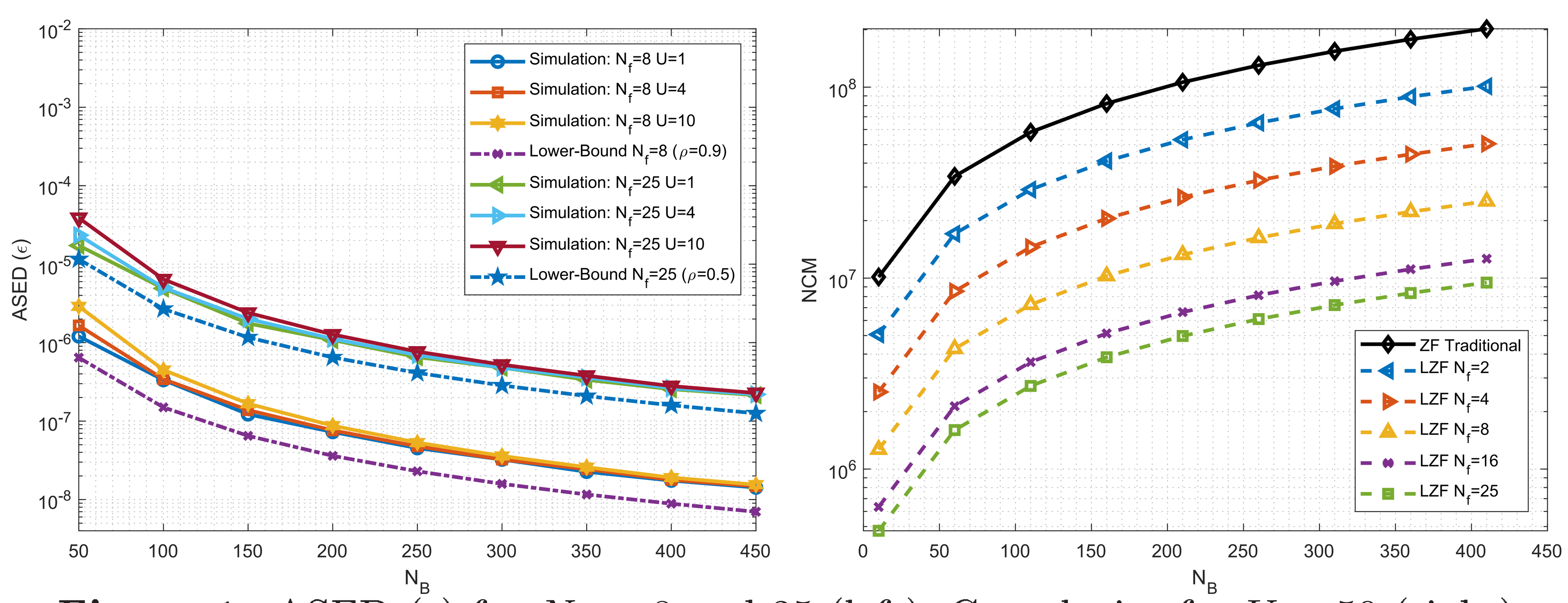


Figure 1: ASED (ϵ) for $N_f = 8$ and 25 (left); Complexity for $U = 50$ (right)

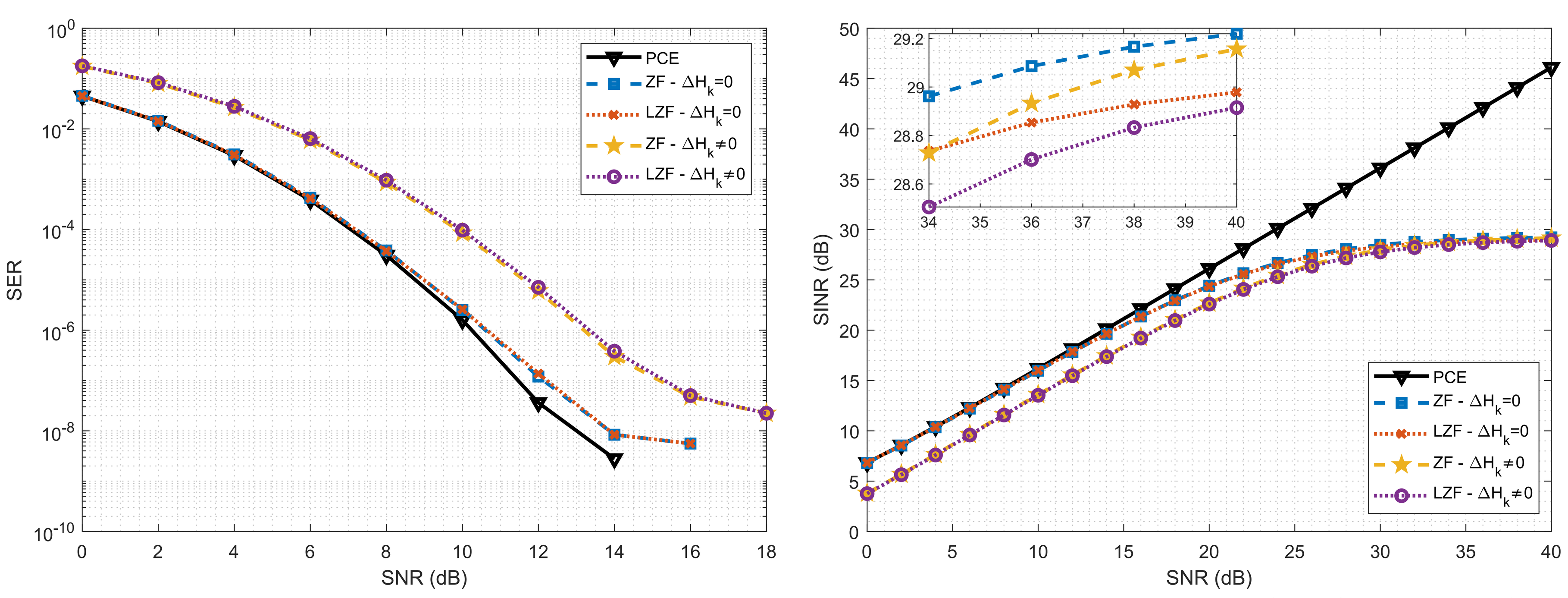


Figure 2: Simulation results for $N_f = 8$, $U = 2$ and $N_B = 10$. SER (left); SINR (right)

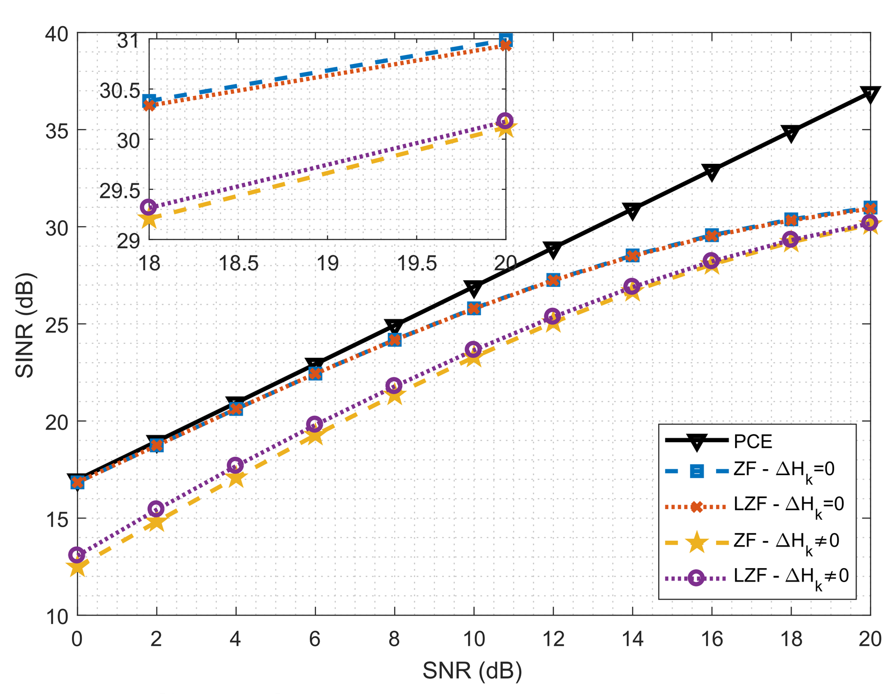


Figure 3: SER for $N_f = 8$, $U = 2$ and $N_B = 100$