CARRIER FREQUENCY OFFSET COMPENSATION FOR OFDMA SYSTEMS USING CIRCULAR BANDED MATRICES

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***Abstract*— Orthogonal frequency division multiple access (OFDMA) is a multiuser communication technique that allocates to each user a set of orthogonal carriers. In the presence of carrier frequency offset (CFO) the orthogonality among carriers is lost and it is impossible to recover the information of the users without CFO compensation. The resulting multiple access interference (MAI) can be described as an interference matrix of large dimensions. In order to compensate for the CFO, this matrix must be inverted, what is computationally complex. Therefore, a banded matrix approximation is usually introduced. In this paper we propose a circular banded matrix which is a better approximation to the actual interference matrix. Also, by means of numerical simulation, we show that neither banded nor circular banded matrices approximations work well for normalized CFO close to 0.5.**

***Keywords*— OFDMA, CFO compensation, Banded Matrix.**

I. INTRODUCTION

Orthogonal frequency division multiple access (OFDMA) is considered one of the most promising techniques to deliver high data rate in a multiuser wireless system. OFDMA is based on the inherited orthogonality of the orthogonal frequency-division multiplexing (OFDM) modulation. Then, a subset of subcarriers are assigned to each user according to a carrier allocation scheme (CAS).

The usual CASs are: subband, interleaved and generalized. In subband CAS, each user take a contiguous set of subcarriers. In interleaved CAS, the carriers of each user are uniformly distributed over the entire signal bandwidth to exploit the frequency diversity. Nevertheless, the more advantageous scheme is generalized CAS since it allows users to be allocated in the best subcarriers currently available for each one of them.

OFDMA provides high spectrum efficiency, robustness against multipath fading, simple equalization and low multiple access interference (MAI). On the other hand, as OFDM, OFDMA is highly sensitive to frequency synchronization errors. The carrier frequency offset (CFO) between the transmitter and the receiver destroys the orthogonality among carriers and, therefore, produces MAI. Downlink synchronization is a single parameter estimation problem and many algorithms proposed for OFDM can be used in that case (Schmidl and Cox, 1997; Ghogho *et al.*, 2001; Morelli and Mengali, 1999). On the other hand, synchronization in the uplink is more challenging since it is a multiparameter estimation problem. The reason is that each user is characterized by particular CFO and channel parameters.

Frequency synchronization depends on the CAS and results in a two step procedure: 1) CFO estimation and 2) CFO compensation. Considering generalized CAS, CFO estimation employs a training sequence inserted at the beginning of the frame (Pun *et al.*, 2007). On the other hand, CFO compensation uses iterative interference cancellation (Letaief and Huang, 2005; Sun and Zhang, 2009) or linear cancellation (Cao *et al.*, 2007). Despite its larger computational complexity, the later compensation scheme is preferred since it leads to a better performance in bit error rate (BER) (Pun *et al.*, 2007).

In Cao *et al.* (2007), the authors model the MAI as an interference matrix with the same dimension as the OFDMA system. Considering nowadays systems, this value could be as large as 2048 (IEEE, 2004). To compensate the CFO, the authors propose to use either the least squares (LS) or the minimum mean squared error (MMSE) criteria. Unfortunately, LS and MMSE requires the interference matrix inversion and a multiplication with the received symbol that results in a huge computational load. As a consequence, Cao *et al.* (2007) also proposes a banded system simplification to reduce the complexity of the linear cancellation. This simplification leaves some residual MAI which degrades the system performance. Additionally, as the nature of CFO interference is cyclic (depends on trigonometric functions), the actual interference matrix is circular banded. This means that the first and last carriers interfere with each other in case that the bandwidth of the banded matrix is less than the amount of virtual carriers of the system.

In this paper we propose a novel approximation of the interference matrix with *cyclic banded* structure that takes into account the interference at the edges and, of the OFDMA symbol if the virtual or null system carriers are not enough. As a consequence, it results in a better approximation than the banded matrix. Also, we derive low-complexity versions of the LU factorization, the forward and backward substitution for the inversion of