OFDM/OQAM PREAMBLE-BASED LMMSE CHANNEL ESTIMATION TECHNIQUE

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Abstract

OFDM/OQAM is a special type of multi-carrier modulation that can be considered as an alternative to conventional OFDM with cyclic prefix (CP) for transmission over multipath fading channels. Indeed, as it requires no guard interval, it has the advantage of a theoretically higher spectral efficiency. In this paper, preamble-based least squares (LS) channel estimation in OFDM systems of the QAM and offset QAM (OQAM) types is considered, in both the frequency and the time domains. In this work a preamble-based linear minimum mean square error (LMMSE) estimation technique for filter bank multicarrier (FBMC) modulations. Channel estimation considers as important process in digital communication systems, techniques have been developed to reduce the impact of noise on the channel estimation process. Until recently, non-orthogonal multicarrier modulations such as FBMC were unable to use OFDM-like estimation techniques due to the non-orthogonality. The interference approximation method (IAM) is one of the most popular methods among preamble based estimation techniques with a limited complexity. In this paper a unique combination of IAM and LMMSE based algorithm is proposed to achieve reliable LMMSE estimation approach in FBMC.

Keywords: OQAM, OFDM, LMMSE, Preamble, IAM

1. INTRODUCTION

In broadband wireless communications, MIMO (Multiple Input Multiple Output) OFDM becomes more efficient to achieve high data rate and better performance. Accurate and efficient channel estimation plays a key role in MIMO-OFDM wireless communications. Channel capacity of MIMO-OFDM system is increased by channel estimation. The increase in the demand for bandwidth and different high performance services opened the door for using multiple antennas at transmitter and receiver. The wireless channel properties are dynamic in nature as it is frequency selective and time-dependent. Multiple Input Multiple Output (MIMO)-OFDM is widely recognized as a key technology for future wireless communications due to its high spectral efficiency and superior robustness to multipath fading channels.

In general, there are two groups of channel estimation schemes for MIMO-OFDM system. The first one is nonparametric channel estimation scheme, which adopts orthogonal frequency-domain pilots or orthogonal time-domain training sequences to convert the channel estimation in MIMO systems to that in single antenna systems. However, such scheme suffers from high pilot overhead when the number of transmit antennas increases. The second category is parametric channel estimation scheme, which exploits the sparsity of wireless channels to reduce the pilot overhead. The parametric scheme is more favorable for future wireless systems as it can achieve higher spectral efficiency. However, path delays of sparse channels are assumed to be located at the integer times of the sampling period, which is usually unrealistic in practice.

This paper deals with the combination of the OFDM quasi-optimal estimation algorithm in with an IAM estimation process to achieve nearly optimal preamble-based channel estimation in OFDM/OQAM. Observing that current OFDM/OQAM estimations are sensitive to both noise and intrinsic interference, using a LMMSE algorithm that smooths the estimated channel frequency response by mitigating the noise and interferences appears to be relevant. In addition, to our knowledge, no LMMSE-based estimator has been proposed for OFDM/OQAM in the literature yet.

2. CHANNEL ESTIMATION

Channel estimation is used to obtain the channel state information to know the channel properties using blind channel estimation and pilot-based channel estimation. This information describes how a signal gets propagate from the transmitter to the receiver and represents the combined effect of fading, scattering etc. and power decay with distance.

The Channel State Information (CSI) makes it possible to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication. In this paper, only the block pilot based channel estimation technique is investigated. Channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol. The block type pilot channel estimation is developed under the assumption of slow fading channel.

3. CHANNEL ESTIMATION IN OFDM/OQAM AND OFDM SYSTEMS

Channel estimation may be a crucial part of communication receivers. As a result, numerous estimation techniques are developed for OFDM and a lot of recently for FBMC. Among them, we are going to currently present the 2 ones we are going to concentrate on.

A. Channel estimation in OFDM/OQAM

Channel estimation in OFDM/OQAM systems has been a tough task because of the lack of CP, and to the necessary interference caused by the non-orthogonality of the system. The IAM estimation relies on the subsequent idea: during a scenario while not channel nor noise, it's doable to predict the value of received symbols, if we all know which of them are transmitted. This ideal received is written

$$\check{C}_{m,n} = C_{m,n} + jU_{m,n} \qquad (4)$$

with U the intrinsic interference assuming an ideal channel (G = 1). In those conditions and under the hypothesis of a flat channel over$\Omega_{m,n}$, from (3) one can approximate that the received symbol by:

$$\hat{C}_{m,n} \approx G_{m,n}\left(\check{C}_{m,n}\right) + W_{m,n} \qquad (5)$$

In this process, it has become possible to estimate the channel coefficients, under the hypothesis of a locally flat channel as

$$\hat{G}_{m,n} = \frac{\hat{C}_{m,n}}{\check{C}_{m,n}} \qquad (6)$$

This observation is base of the IAM estimation techniques. The IAM processes enable to understand a simple zero forcing equalization, however remain quite sensitive to noise, and they are restricted by the hypothesis of a locally flat channel. The less this hypothesis is verified throughout the transmission, residual interference from neighboring transmitted values will remain same. In such conditions, employing a LMMSE algorithm appears to be extremely interesting option, for it permits to considerably decrease the interferences. But, as aforesaid before, LMMSE needs the covariance of the channel that's a priori unknown at the receiver. Consequently, it's difficult to implement.

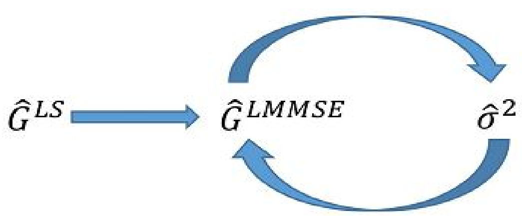

Figure.1: Joint estimation algorithm fundamental principle

In a OFDM context, a joint channel/noise estimation algorithm is for preamble-based estimation in order to overcome this drawback. Hereafter, we present the latter and propose to adapt it to OFDM/OQAM modulation scheme.

B. LMMSE-based estimation algorithm

Classical LMMSE estimation relies on the following expression:

$$\hat{G} = R_G(R_G + \sigma^2 Id)^{-1}\hat{G}^{LS} \qquad (7)$$

with R_G the channel covariance matrix, Id the identity matrix and $\hat{G}^{LS}$ the LS channel estimation that is quite similar to (6). The algorithm presented here asserts these issues, following the scheme illustrated in Fig. 2, and is described as follows:

1) Initialization: an LS estimation $\hat{G}^{LS}$ is performed, leading to the covariance matrix

$$\underline{\tilde{R}}_G^{LS} = \hat{G}^{LS}\left(\hat{G}^{LS}\right)^H, \qquad (8)$$

with $(\cdot)^H$ the Hermitian matrix transposition.

2) At the first step $(i = 1)$, a LMMSE channel estimation is performed, based on $\underline{\tilde{R}}_G^{LS}$:

$$\hat{G}_{(i=1)}^{LMMSE} = \underline{\tilde{R}}_G^{LS}\left(\underline{\tilde{R}}_G^{LS} + \hat{\sigma}_{(i=0)}^2 Id\right)^{-1}\hat{G}^{LS} \qquad (9)$$

with $\hat{\sigma}_{(i=0)}^2$the noise variance initialization, strictly positive value.

3) Estimation of the noise variance:

$$\hat{\sigma}_{(i=1)}^2 = \frac{1}{N}E\left\{\left\|\hat{G}^{LS} - \hat{G}_{(i=1)}^{LMMSE}\right\|^2\right\} \qquad (10)$$

4) Estimation of a more accurate covariance matrix:

$$\underline{\tilde{R}}_G^{LMMSE} = \hat{G}_{(i=1)}^{LMMSE}\left(\hat{G}_{(i=1)}^{LMMSE}\right)^H \qquad (11)$$

5) For $i \geq 2$, we estimate the channel iteratively:

$$\hat{G}_i^{LMMSE} = \underline{\tilde{R}}_G^{LMMSE}\left(\underline{\tilde{R}}_G^{LMMSE} + \hat{\sigma}_{(i-1)}^2 Id\right)^{-1}\hat{G}^{LS} \qquad (12)$$

$$\hat{\sigma}_{(i=1)}^2 = \frac{1}{N}E\left\{\left\|\hat{G}^{LS} - \hat{G}_{(i)}^{LMMSE}\right\|^2\right\} \qquad (13)$$

with E {.} the mathematical expectation.

6) While$\left|\hat{\sigma}_{(i)}^2 - \hat{\sigma}_{(i-1)}^2\right| > e_\sigma$, where e_σ is a well-chosen threshold, go back to previous step. Else, go to next step.

7) At the final step $i = i_0$: estimation of the Signal to Noise Ratio (SNR), using the second order moment of the received pilot signal U:

$$\hat{\rho} = \frac{M^{(2)}(U)}{\hat{\sigma}^2_{(i_0)}} - 1 \qquad (14)$$

This algorithm has proven to be very effective, significantly reducing the noise perturbation on the channel estimation in OFDM systems. Applying it to OFDM/OQAM estimation sounds even more relevant, since its ability to remove interference might work as well for noise and intrinsic interference. However, due to the presence of these two kinds of interference, we will first focus on the channel estimation rather than the noise estimation that will be altered by the presence of ISI, and attempt to define criteria to transpose this estimation process to OFDM/OQAM systems.

C. How could we apply this algorithm to OFDM/OQAM ?

To the best of our knowledge, no LMMSE estimation method has been proposed for OFDM/OQAM. In order to adapt the LMMSE joint algorithm to OFDM/OQAM systems, one needs to determine which parts have to be modified:

- The initialization is made by LS estimation. As this estimation technique that is adapted to OFDM is sensitive to the noise, it cannot be satisfying in OFDM/OQAM systems due to the interference. Therefore this step must be replaced by an estimation that takes this interference into account, such as IAM as presented just before.
- The iterative part is purely mathematical and is independent from the nature of the system. It should not be modified in a first approach, except maybe for the initial noise variance estimation, as it is not anymore an LS estimation that is processed.
- This estimator can be used for Zero Forcing equalization in OFDM systems, and should be used to do Zero Forcing in OFDM/OQAM systems.

As a consequence, it seems that only the initialization needs to be modified in a first approach, first simulation results indicating that further modifications would be required, for noise variance estimation. In this paper, it seems acceptable to consider the channel estimation as a priority, noise estimation being corrected later, if needed. The process is then mostly the same as in Fig. 2, except for the initialization.

4. RESULTS

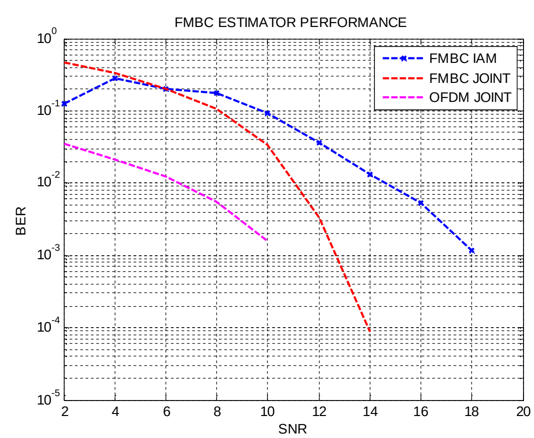

Figure 2: FMBC estimator performance in terms of BER

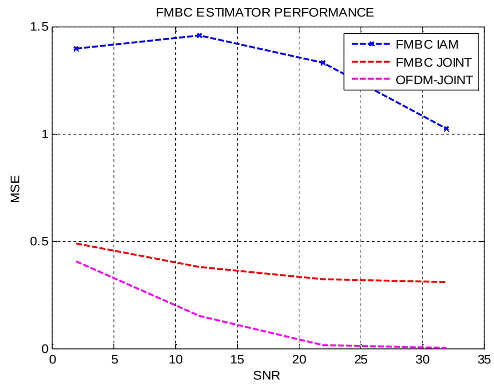

Figure 3: FMBC estimator performance in terms of MSE

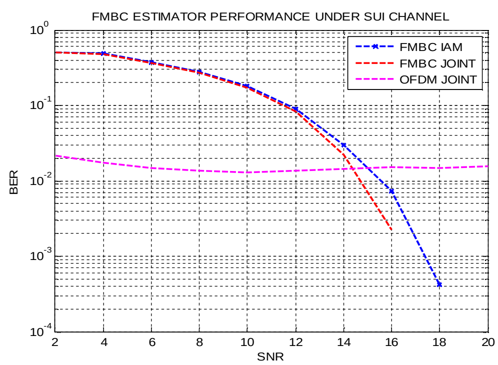

Figure 4: FMBC estimator performance in terms of BER under SUI channel

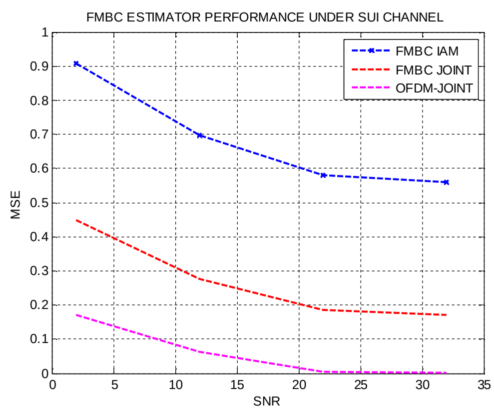

Figure 5: FMBC estimator performance in terms of MSE under SUI channel

5. CONCLUSION

Channel estimation attains attention in communication domain due to its ability to give statistics about noise data. Although tremendous progress has been made in literature but still achieving low computational complexity based estimation is a problem. A LMMSE estimation algorithm for OFDM and successfully adapted it to OFDM/OQAM systems, by combining it with an existing preamble-based OFDM/OQAM estimation process. This resulted into the development of a LMMSE preamble-based estimation for OFDM/OQAM without prior knowledge of the channel covariance matrix. To the best of our knowledge, there was no LMMSE estimation available for OFDM/OQAM, making this new algorithm the first of its kind in this modulation scheme.

REFERENCES

[1] R. V. Nee and R. Prasad, "OFDM for Wireless Multimedia Communications," Artech House, 2000.

[2] J. Scott, "The how and why of COFDM," EBU Technical review, Jan 1999.

[3] P. Vaidyanathan, "Multirate digital filters, filter banks, polyphase networks, and applications: a tutorial," Proceedings of the IEEE, vol. 78, no. 1, pp. 56–93, Jan 1990.

[4] P. N. Heller, T. Karp, and T. Q. Nguyen, "A General Formulation of Modulated Filter Banks," IEEE Trans. Signal Processing, vol. 47, pp. 986–1002, 1999.

[5] B. Le Floch, M. Alard, and C. Berrou, "Coded orthogonal frequency division multiplex,"

Proceedings of the IEEE, vol. 83, no. 6, pp. 982–996, Jun 1995.

[6] M. Biguesh and A. Gershman, "Training-based MIMO channel estimation: A study of estimator tradeoffs and optimal training signals," IEEE Trans. Signal Processing, vol. 54, pp. 884–893, 2006.

[7] O. Edfors, M. Sandell, J.-J. van de Beck, and S. K. Wilson, "OFDM channel estimation by singular value decomposition," IEEE Trans. Communications, vol. 46, pp. 931–939, 1998.

[8] V. Savaux, Y. Louet, M. Djoko-Kouam, and A. Skrzypczak, "Application of a joint and iterative MMSE-based estimation of SNR and frequencyselective channel for OFDM systems," EURASIP Journal on Advances in Signal Processing, vol. 2013, no. 1, p. 11, 2013. [Online]. Available: http://asp.eurasipjournals.com/content/2013/1/128

[9] C. L´el´e, J.-P. Javaudin, R. Legouable, A. Skrzypczak, and P. Siohan, "Channel estimation methods for preamble-based OFDM/OQAM modulations," Euro Wireless '07, Apr 2007.

[10] E. Kofidis, D. Katselis, A. Rontogiannis, and S. Theodoridis, "PreambleBased Channel Estimation in OFDM/OQAM Systems : A Review," Elsevier Signal Processing, vol. 93, pp. 2038–2054, 2013.

[11] H. G. Feichtinger and T. Strohmer, Gabor analysis and algorithms. Birkhauser, 1998.

[12] D. Lacroix-Penther and J.-P. Javaudin, "A new channel estimation method for OFDM/OQAM," in Proc. of the 7th International OFDM workshop, 2002.

[13] J.-P. Javaudin, D. Lacroix-Penher, and A. Rouxel, "Pilot-aided channel estimation for OFDM/OQAM," VTC'03 Spring, vol. 3, pp. 1581–1585, 2003.