SYSTEM IDENTIFICATION FROM SNR BASED PREDICTIONS

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ABSTRACT

In this work, we propose a novel approach for system identification based on predictions of signal-to-noise ratio (SNR). The method extends the traditional Wiener-Khintchine theorem by considering higher-order moments of the signal and noise processes. We demonstrate the effectiveness of our approach through simulations and experiments in both stationary and non-stationary environments. The results show improved accuracy and robustness compared to existing methods.

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 type pilot 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

\[
\hat{\mathbf{c}}_{m,n} = \mathbf{c}_{m,n} + jU_{m,n} \quad (4)
\]

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:

\[
\hat{\mathbf{c}}_{m,n} \approx g_{m,n}(\hat{\mathbf{c}}_{m,n}) + W_{m,n} \quad (5)
\]

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

\[
\hat{G}_{m,n} = \hat{C}_{m,n} \quad (6)
\]

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

\[
\hat{R}_G^{LS} = \hat{G}^{LS}(\hat{G}^{LS})^H, \quad (8)
\]

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

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

\[
\hat{G}^{LMMSE}_{(i=1)} = \hat{R}_G^{LS} \left( \hat{R}_G^{LS} + \hat{\sigma}^2_{(i=0)}Id \right)^{-1} \hat{G}^{LS} \quad (9)
\]

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

3) Estimation of the noise variance:

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

4) Estimation of a more accurate covariance matrix:

\[
\hat{R}_G^{LMMSE} = \hat{G}^{LMMSE}_{(i=1)} \left( \hat{G}^{LMMSE}_{(i=1)} \right)^H \quad (11)
\]

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

\[
\hat{G}^{LMMSE}_{(i)} = \hat{R}_G^{LMMSE} \left( \hat{R}_G^{LMMSE} + \hat{\sigma}^2_{(i-1)}Id \right)^{-1} \hat{G}^{LS} \quad (12)
\]

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

with \( E \{ \cdot \} \) the mathematical expectation.

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

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**B. LMMSE-based estimation algorithm**

Classical LMMSE estimation relies on the following expression:

\[
\hat{G} = R_G (R_G + \sigma^2 Id)^{-1} \hat{G}^{LS} \quad (7)
\]
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 \( U \):

\[
\hat{\rho} = \frac{M^{(2)}(U)}{\sigma_{(i_0)}^2} - 1 \quad (14)
\]

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](image)

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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


