OFDM CHANNEL ESTIMATION WITH NARROW BAND INTERFERENCE

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ABSTRACT

We investigate the issue of unknown narrowband interference affecting channel estimation in an OFDM (Orthogonal frequency-division multiplexing) system. NBI results in major performance degradation of estimation algorithms designed for traditional OFDM transmissions. To get around this issue we are proposing to pursue a pilot based approach. In this approach, we propose that we treat interference power on each pilot subcarrier as a nuisance parameter. This nuisance parameter is then averaged out from the corresponding likelihood function. Expectation-maximization (EM) principle or the Jacobi-Newton algorithm will then be applied in iterations to maximize the latter. Computer simulations will be used to measure their accuracy. And appropriate Cramer- Rao bound will be used for comparison.

***Keywords*: *Channel Estimation, Expectation-Maximization, Frequency-Division Multiplexing (OFDM), Jacobi- Newton Algorithm, Narrow Band Interference (NBI)*.**

I. INTRODUCTION

OFDM (Orthogonal frequency-division multiplexing) is a parallel transmission technique. OFDM is a proven and effective technique to counter multipath fading as well as impulsive noise [2]. For example Emerging Spectrum-Sharing systems [5] in which the secondary users i.e. unlicensed user, monitor the radio environment and a communication link is established by filling existing gaps in the frequency spectrum. This operation is done without disrupting primary users i.e. licensed users. An interfered scenario might occur in the future mobile cell applications. These applications are used to provide broadband wireless access to building areas that an outdoor base station (BS) can't reliably cover. Since mobile cells operate on the same frequency band as macro BSs.

In OFDM systems, the channel frequency response is estimated at the start of the data frame by using one or more training blocks carrying known symbols. A second approach is based on periodically adding pilot tones within the signal spectrum. In such cases, channel state information (CSI) is first gathered at the pilot positions and channel response over the information-bearing subcarriers is estimated using interpolation techniques [3]. These schemes provide good results. To solve the frequency synchronization problem some methods are explained in [3], such as the NBI is assumed to be Gaussian distributed in the frequency domain with zero mean and unknown power, and maximum likelihood (ML).

By following the same approach in [3], we derive novel channel estimation schemes for OFDM systems plagued by unknown interference. We use some training blocks or pilot symbols and estimate the channel impulse response (CIR) by treating the interference power on each pilot subcarrier as a nuisance parameter. To reduce the computation we use expectation-maximization (EM) algorithm.We also describe an alternative approach in which the likelihood function is maximized by means of the Jacobi-Newton algorithm.

II. BLOCK-TYPE PILOT CHANNEL ESTIMATION

In a time-frequency plane, the fading channel of the OFDM system can be viewed as a 2D lattice, in which the sampled at pilot positions and the channel characteristics between pilots are estimated by interpolation.Figure 2 shows the two basic 1D channel estimations in OFDM systems. The first one is block-type pilot channel estimation. It is developed under the assumption of slow fading channel. It's operation is performed by inserting pilot tones into all subcarriers of OFDM symbols within a specific period. The second one is comb-type pilot channel estimation. It is used to satisfy the need for equalizing. Thus it is performed by inserting pilot tones into certain subcarriers of each OFDM symbol. The interpolation is needed to estimate the conditions of data subcarriers.

In block-type pilot-based channel estimation we are going to estimate the channel conditions (specified by$\bar{H}$ or $\bar{g}$) given the pilot signals (specified by matrix X or vector$\bar{X}$). The received signals (specified by$\bar{Y}$), with or without using certain knowledge of the channel statistics. In this the estimation can be based on least square (LS), minimum mean-square error (MMSE), and modified MMSE.

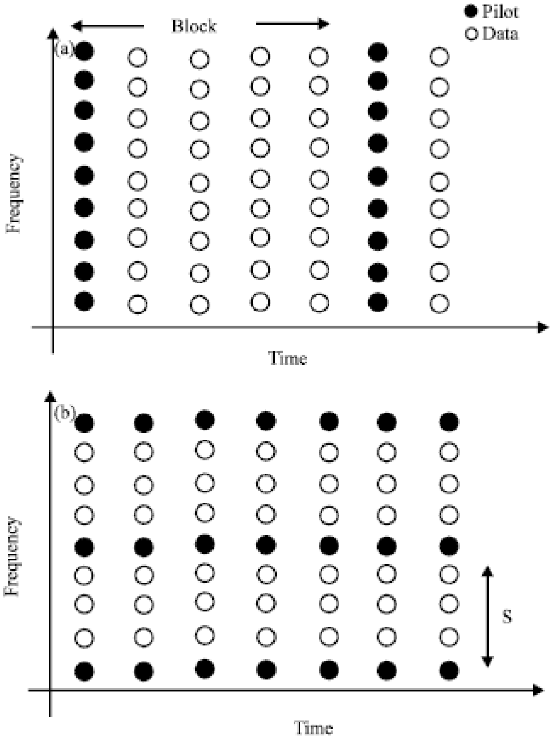

Fig 1. Two Basic Types of Pilot Arrangement for OFDM Channel Estimations

2.1 LS Estimator

The LS estimator minimizes the parameter$(\bar{Y} - X\bar{H})^H(\bar{Y} - X\bar{H})$where $(.)^H$known as the conjugate transpose operation. It is shown by [2].

$$\hat{H}_{LS} = X^{-1}\bar{Y} = \left[\frac{X_k}{Y_k}\right]^T \qquad (k = 0, \ldots, N-1) \tag{4}$$

The LS estimators are calculated with very low complexity without using any knowledge of the statistics of the channels. They suffer from a high mean-square error.

2.2 MMSE Estimator

The MMSE estimator gives the second-order statistics of the channel conditions to minimize the mean-square error. MMSE is calculated by

$$\hat{H}_{MMSE} = R_{HH}[R_{HH} + \sigma_N^2 (XX^H)^{-1}]^{-1}\hat{H}_{LS} \tag{5}$$

The MMSE estimator gives better performance than LS estimators, for the low SNR scenarios. It has high computational complexity, which is the major drawback of the MMSE estimator.

III. SYSTEM MODEL

The OFDM system divides the available frequency spectrum into several subcarriers. In OFDM, the frequency responses of subcarriers are overlapping and orthogonal to obtain high spectral efficiency. The orthogonalitycan be maintained with a small price in a loss in SNR. In this cyclic prefix (CP) is used.

Fig.1 shows the block diagram of baseband OFDM baseband OFDM system.

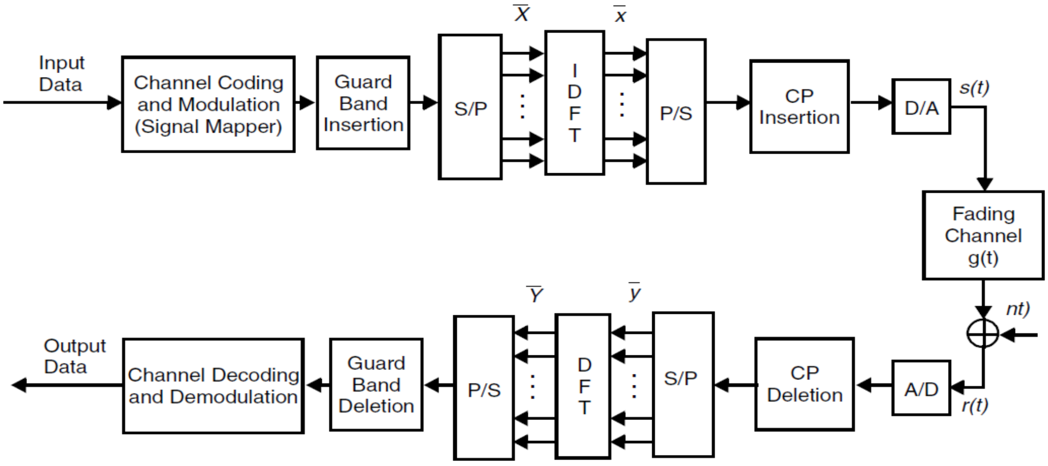

Fig.1 Block Diagram of Baseband OFDM System

The I/p data is in the binary form. This binary information is given to the signal mapper, in this the given data is divided into adjacent blocks of lengthN_u = 2N_a+1.Then the guard band N–N_u zeros is inserted. After that the$K$th block is inserted to a N-point IDFT (invers discrete fourier transform) block transforms a vector of N time-domain samples. An Ng-point CP (cyclic prefix) of time length TG is inserted to avoid interblock interference, intersymbol interference (ISI) and intercarrier interference (ICI). The resulting extended vector is transmitted over a discrete time multipath channel of order $L \le Ng$. The D/A converter contains low pass filter with 1/TS bandwidth, where TS is the sampling interval. The channel is modeled as an impulse response g(t) followed by the complex additive white Gaussian noise (AWGN) n(t), where αm is a complex values and 0 ≤ τmTS ≤ TG. We consider indoor communications applications (low mobility applications), the channel keeps approximately constant over short frames and denote by $h = [h(1), h(2), \ldots, h(L)]T$ the corresponding CIR vector.

At the receiver side, after passing through the A/D converter and the CP deletion, the N-point DFT is used to transfer the data back to frequency domain. At the O/p, the binary information data is obtained after the demodulation and channel decoding.Assume the timing and frequency acquisition has already accomplished at an earlier stage, the DFT of the k th received block takes in the form of

$$X(n,k) = c(n,k)H(n) + w(n,k) \qquad -N\alpha \le n \le N\alpha \qquad (1)$$

where$c(n, k)$ is the symbol transmitted onto the nth subcarrier,$w(n, k)$ is the background noise and any possible interference and, finally, H(n)is the channel frequency response, which is related to the CIR vector by

$$\mathrm{H}(n) = \Sigma L\ell{=}1h(\ell)e{-}j2\pi n(\ell{-}1)/N \qquad -N\alpha \le n \le N\alpha. \qquad (2)$$

The coherent detection of the transmitted data requires knowledge of the channel response H =[(−Na),H(−Na + 1), . . . , H(Na)]T over all modulated subcarriers. Assume that P pilot symbols{(p, k); 1 ≤ p ≤ P} with constant energy $\sigma 2s$ = |$a(p, k)$|2are inserted into one or more OFDM blocks to assist the channel estimation process. We collect the pilot subcarrier indices into a set *Jp= {np; 1 ≤ p≤ P}* and call *X(k) = [x(n1, k),x(n2, k), . . . , x(np , k)]T*the DFT output at the pilot positions during the *k*th OFDM block, for convenience. Then, from (1) and (2) it follows that

$$\mathrm{X}(k) = \mathrm{A}(k)\mathrm{Fh} + \mathrm{w}(k) \qquad (3)$$

Where$\mathrm{A}(k) = \mathrm{diag}\{a(p,k); 1 \le p \le P\}$, F is a $P\times L$matrix with entries

$$[\mathrm{F}]p{,}\ell = e{-}j2\pi np(\ell{-}1)/N1 \le p \le P, 1 \le \ell \le L \qquad (4)$$

and*w(k) = [w(n1, k), w(n2, k), . . . , w(np , k)]T* is the disturbance vector. Following [15], the entries of *w(k)* are assumed to be Gaussian distributed with zero mean and unknown variance σ*2(np)* = σ*2w*+ σ*2l(np),* where σ*2w*is the thermal noise contribution.

The average NBI power is represented by □ (□□). The NBI power is assumed to be constant over the observation period. The NBI Gaussian distribution is adopted only for mathematical convenience. The random variables (□□, □) are treated as statistically independent for different values of □□ and □. Some correlation is expected between the interference contributions over closely spaced subcarriers when applied thermal noise.

Consider w(□) =[□(□1, □), □(□2, □), . . . , □(□□ , □)]□ as a Gaussian vector with zero mean and a diagonal covariance matrix C =diag{□2(□□); 1 ≤ □ ≤ □}. To formulate our estimation problem, we denote by {H, σ2} the set of unknown parameters, with □2 = [□2(□1), □2(□2), . . . , □2(□□)]□, and rewrite (2) in matrix notation as

$$\mathrm{H} = \mathrm{Gh} \qquad (5)$$

Where G is an $N_u \times L$ matrix with entries

$$[\mathrm{G}]n{,}\ell = e{-}j2\pi(n{-}N\alpha{-}1)(\ell{-}1)/N\ 1 \le n \le Nu, 1 \le \ell \le L. \qquad (6)$$

Then, from equation (5) it follows that an estimate of the channel frequency response can be obtained as

$$\hat{}\mathrm{H} = \mathrm{G}\hat{}\mathrm{h} \qquad (7)$$

Where ˆh is the corresponding CIR estimate. In practical OFDM systems $N_u \ge L$, the equation (7) has the advantage of reducing the number of unknown parameters compared to the direct estimation of H. For this purpose, we aim at estimating h and eventually use the relation (7) to compute ˆH. Our approach is based on ML methods and relies on a set of observations X = [XT(1),XT(2), . . . ,XT(k)]T collected over K adjacent blocks.

IV. MAXIMUM LIKELIHOOD CHANNEL ESTIMATION

The equation of Maximum Likelihood Estimation (MLE) is

$\hat{h}_{MLE} = \arg\ max\ \hat{h}\{\phi(\hat{h})\}$ (1)

The CIR estimation is possible while the number of pilot symbols in each block is not smaller than the channel order.

$E\left\{\left|\left|\hat{H}_{MLE} - H\right|\right|^2\right\} \geq \frac{1}{k\sigma_\xi^2} \cdot tr\{G(F^H C^{-1} F)^{-1} G^H\}$ (2)

V. ITERATIVE CHANNEL ESTIMATION

5.1 The Expectation-Maximization Algorithm

In the EM formulation, the observed measurements X are replaced with some complete data. From that data an original measurements can be obtained by using a many-to-one mapping. There are two steps in this algorithm.

E-step, Expectations are calculated

$$Q(\hat{h}|\hat{h}_i) = E_{\sigma^2}\{\ln[p(X|\sigma^2, \hat{h})]p(X|\sigma^2, \hat{h}_i)\} \quad (1)$$

M-step, here we maximize the expectation w.r.t unknown parameters

$\hat{h}_{i+1} = \arg\max \hat{h}\{Q(\hat{h}|\hat{h}_i)\}$ (2)

The channel frequency response is computed as

$\hat{H}_{EMCE} = G\hat{h}_J$ (3)

5.2 The Jacobi- Newton algorithm

The Jacobi- Newton based channel estimator (JNCE) is calculated by

$\hat{h}_{i+1} = \hat{h}_i + \frac{1}{t_r\{\hat{c}_i^{-1}\}} F^H \hat{c}_i^{-1}(Y - F\hat{h}_i)$ (4)

After J iterations, the channel frequency response is obtained as

$\hat{H}_{JNCE} = G\hat{h}_J$ (5)

Table 1: Number of Flops Per Iteration Required By The Proposed Algorithms

	No. of flops
EMCE	P (4L+6K-1+10$log_2 P + 16L^2$)
JNCE	P (9+6K+10$log_2 P$)

VI. SIMULATION RESULT

In this work the channel estimation is simulated by using MATLAB. The system parameters are compliant with the IEEE802.11g standard for a WLAN operating in the 2.4 GHz frequency band.

The OFDM has the IDFT/DFT units of length N=64, Bandwidth=20MHz, sampling period=50ns,CP of length Ng=16. The CIR is composed by 8 channel taps.

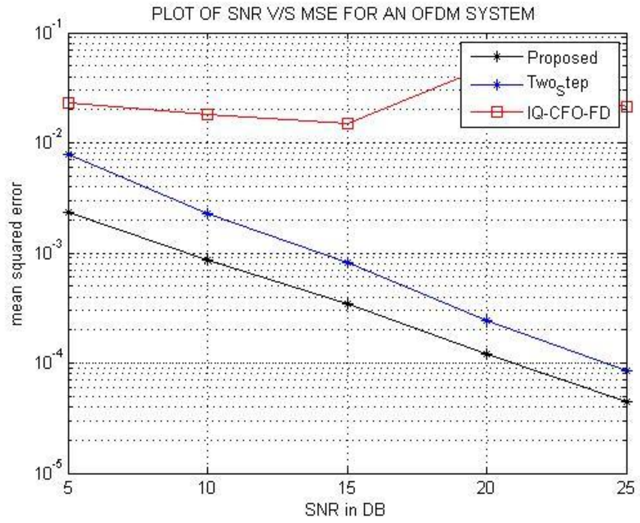

Fig. 3. Plot of SNR v/s MSE for an OFDM System

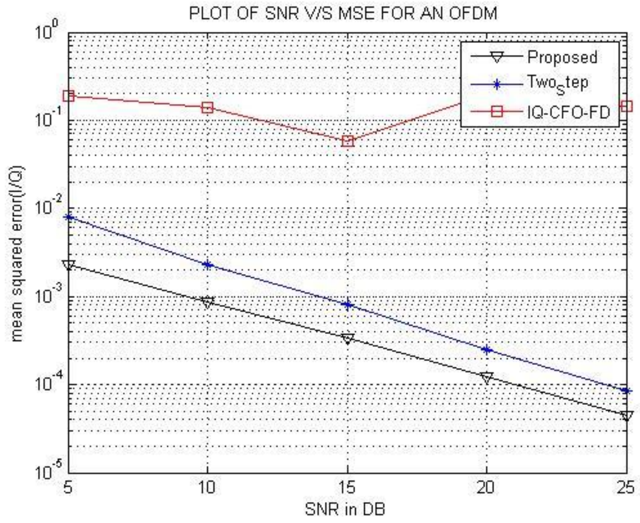

Fig. 4. Plot of SNR v/s MSE for an OFDM

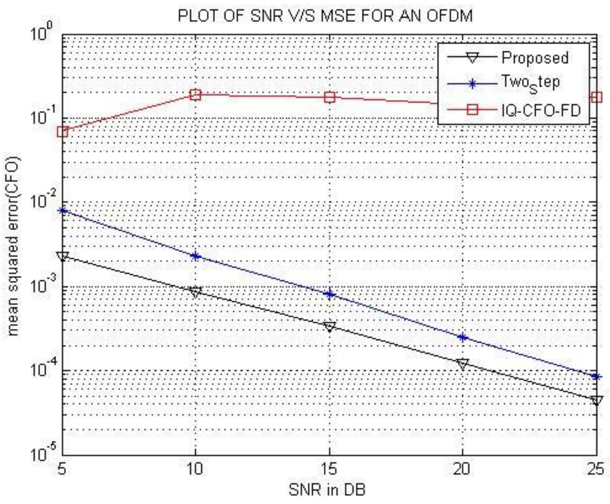

Fig. 5. Plot of SNR v/s MSE for an OFDM

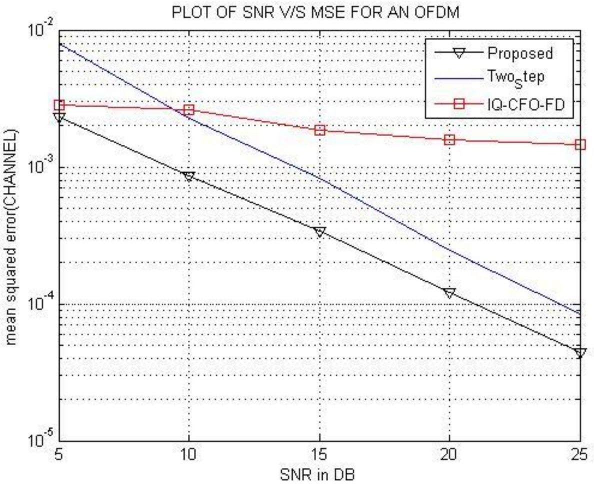

Fig. 6. Plot of SNR v/s MSE for an OFDM

VII. CONCLUSION

Here we have presented two schemes for OFDM channel estimation in presence of narrow band interference. The latter is modeled as a Gaussian process. By using an inverse gamma distribution its power is averaged out from the likely hood function. The Expectation-Maximization or Jacobi-Newton algorithm have been adopted to circumvent the maximization of the likelihood function over the multidimensional domain. The resulting scheme EMCE and JNCE uses the dedicated pilot subcarriers and proved channel estimates. Simulations indicate that the proposed methods are inherently robust to NBI.

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REFERENCES

[1] Marco Moretti and Michele Morelli, “Channel Estimation in OFDM systems with Unknown Interference” IEEE Transactions on wireless communications, vol. 8, no. 10, october 2009.

[2] J. A. C.Bingham, “Multicarrier Modulation for data transmission an idea whose time has Come” IEEECommun. Mag., vol 28,pp 5-14, May 1990.

[3] M. Morreli and M. Moretti “Robust Frequency Synchronization of OFDM based cognitive radio syastem,” IEEE Trans. Wireless Commun.,vol. 7, part 2, pp. 5346-5355, Dec. 2008

[4] M. Hann, T.Yu, J.Kim, K.Kwak, S. Lee, S. Han, and D. Hong “OFDM channel estimation with jammed pilot detector under narrowband jamming” IEEE Trans. Veh.Technol., vol. 57,pp. 1934-1939, May2008.

[5] D. Cabric, I. D. O’Donnel, M. S.-W. Chen, and R. W. Brodersen,“Spectrum sharing radios," IEEE Circuits and Systems Mag., vol. 6,pp. 30-45, 2006.

[6] C. S. Patel, G. L. Stuber and T. G. Pratt, "Analysis of OFDM/MCCDMA under imperfect channel estimation and jamming" in Proc.IEEE Wireless Commun. Net. Conf., vol. 2, pp.954-958, Mar. 2004.

[7] ETSI, "Radio Broadcasting Systems; Digital Audio Broadcasting to mobile, portable and fixed receivers" pr. ETS 300 401. NOV 1994.

[8] Y. Le, "Pilot-symbol-aided channel estimation for OFDM in wireless systems," IEEE Trans.Veh. Technol., vol.48,pp,1207-1215,July 2000.

[9] A. P. Dempster, N. M. Laird, and D. B. Rubin, "Maximum likelihood from incomplete data via the EM algorithm," J. Royal Stat. Soc., pp.1-38, Dec. 1997.

[10] J. Wang, A. Dogandžic, and A. Nehorai, "Maximum likelihood estimation of compound- Gaussian clutter and target parameters," IEEE Trans.Signal Processing, vol. 54, pp. 3884-3898, Oct. 2006.