An iterative Channel Estimation for a *Hiperlan/2* OFDM System

Martin Feuersänger, Heiko Schmidt and Karl-Dirk Kammeyer

University of Bremen, FB-1, Department of Communications Engineering,
P.O. Box 33 04 40, D-28334 Bremen, Germany,
Fax: +49-421/218-3341, e-mail: feuersaenger@comm.uni-bremen.de
http://www.comm.uni-bremen.de

Abstract— ***In this paper we present a new iterative approach for channel estimation in an OFDM system under Hiperlan/2 conditions. The algorithm of the iterative estimation will be presented and the suitability in a slow fading environment will be proven by simulation. Additionally the system will be applied for the use of channel tracking in a faster fading environment as well as in an environment with a frequency offset.***

Keywords— ***Hiperlan/2, OFDM, channel estimation, channel tracking***

I. Introduction

Hiperlan/2 is a wireless indoor communications protocol standardized by ETSI. For the physical layer OFDM is used as transmission scheme. To accomplish various data rates *Hiperlan/2* makes use of different coherent modulation schemes like BPSK, QPSK etc. For a correct data detection these modulation schemes imply a channel estimation (CE) in order to equalize the amplitude and phase distortion of the received signal.

In a *Hiperlan/2* system short sequences of data (bursts) are transmitted. These bursts contain a certain number of OFDM symbols prefixed by a preamble including two symbols for training purposes. Four of the system's 52 active subcarriers are reserved for permanent transmission of known pilot symbols. Since standardization of *Hiperlan/2* is already completed a changing of these transmitter based parameters is not desirable. In order to improve the overall performance of the system it is most promising to look for more sophisticated receiver concepts.

This paper presents a CE that uses the redundancy of a FEC as proposed in [1]. Furthermore, an iteration over a variable length of OFDM symbols is introduced. This iterative channel estimation (ICE) is implemented in a standard *Hiperlan/2* environment as described in [2].

Of great interest is not only the improvement of the overall bit error performance but also the tracking behaviour under the influence of a frequency offset or at high Doppler frequencies which could open up new areas of employment for this standard.

In section II a motivation for a modified channel estimation in a slow fading environment is given. Section III describes the applied iteration algorithm. In section IV the simulation parameters are given and section V shows a performance analysis under various conditions.

II. Motivation

When estimating channel parameters in a mobile environment with overlaid additive white Gaussian noise (AWGN) by transmitting training data, it is inevitable that the estimation is also affected by noise. A received date $\tilde{d}_n(i)$ in the n^{th} subcarrier for time slot i is described as

$$\tilde{d}_n(i) = d_n(i) \cdot C_n(i) + N_n(i) \tag{1}$$

where $d_n(i)$ is the transmitted date, $C_n(i)$ the true channel coefficient and $N_n(i)$ the overlaid AWGN. Capitals denote the frequency domain.

Thus an estimation of a channel coefficient yields

$$\hat{C}_n(i) = \frac{\tilde{d}_n(i)}{d_{n,ref}(i)} = C_n(i) + N_n(i) \tag{2}$$

where $\hat{C}$ is the estimated coefficient for the time slot i and $d_{n,ref}(i)$ the reference date referring to

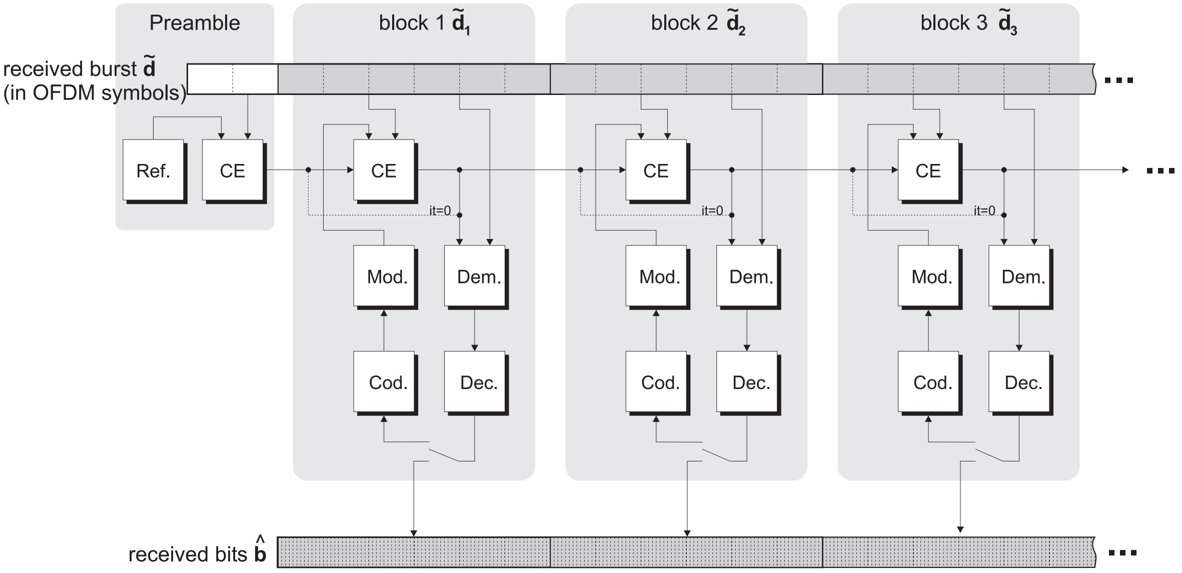

Fig. 1. Iterative channel estimation for a received burst

the i^{th} received date.

In slow fading environments the power of the overlaid AWGN can be decreased by taking the average out of a block containing n_s data. This yields

$$\bar{\hat{C}} = \frac{1}{n_s} \sum_{\mu=1}^{n_s} C_n(\mu) + N_n(\mu) = C_n + \bar{N} \tag{3}$$

and reducing the power of the noise by n_s.

However, this assumption is only valid when the channel can be assumed to be constant over those n_s data.

Since transmitting reference data is diminishing bandwidth efficiency, such data has to be limited to a small amount. In the *Hiperlan/2* system two OFDM symbols are provided for channel estimation. In this paper we present a method to construct an arbitrary number of training symbols using the FEC. Thus, the advantages of equation 3 can be exploited without the transmission of further training data.

III. Iterative channel estimation

As mentioned above the *Hiperlan/2* standard provides two OFDM symbols for training purposes preceding each burst of data transmitted. An initial channel estimation based on the evaluation of these two training symbols is needed as a starting value for the iterative component. The ICE is now implemented as an extension to the conventional CE.

The received burst $\tilde{\mathbf{d}}$ is split into n_{block} blocks $\tilde{d}_k$ containing n_s OFDM symbols. Now, the first block ($k = 1$) is equalized (with the initial estimation $\hat{\mathbf{C}}_{ini}$), demodulated and finally decoded. This leads to the received bits $\hat{\mathbf{b}}_{k,it}$. For the first iteration of the first block this leads to $\hat{\mathbf{b}}_{1,0}$. The received bits are used to reconstruct the n_s transmitted symbols by recoding and remodulating. The result of each iteration is a set of reconstructed transmitted OFDM symbols $\tilde{\mathbf{d}}_{k,it}$. These OFDM symbols can now be used as an expanded set of training symbols to generate a new channel estimation $\hat{\mathbf{C}}_{k,it+1}$ with a reduced influence of the AWGN power as described in the section above. The new channel estimation will be used in the next iteration.

This procedure is repeated once for each iteration it in the k-th block. After the final (n_{it}-th) iteration $\hat{\mathbf{C}}_{k,n_{it}-1}$ is passed on to the next ($k + 1$-th) block where it is used as $\hat{\mathbf{C}}_{k+1,0}$. The above strategy is illustrated in Fig. 1.

When deciding on the maximum number of iterations two measures can be taken into account. Either the number of iterations will be controlled by a threshold determining a minimum difference between the current and the previous channel estimation $\hat{\mathbf{C}}$ or limited to a fixed number. The latter alternative though not necessarily yielding the best result could be limiting the process time of the ICE.

IV. Simulation Parameters

In this paper the ICE is compared to the conventional CE which is only evaluating the two provided training symbols. Furthermore, both the conventional CE and the ICE were combined with a noise reduction (NR) proposed in [1] and [3] which is based on the knowledge of the length of the impulse response of the mobile radio channel. Since *Hiperlan/2* uses a FFT length of 64 and makes use only of 52 subcarrier on some subcarriers no data is transmitted. This has been taken into account when performing the noise reduction by using a modification to the NR introduced in [4]. In the following examinations the supposed impulse response length has been limited to the length of the *Hiperlan/2* systems OFDM guard interval being 16 samples resp. 0,8 μs. The system was simulated using a mobile radio channel model with a delay spread of 100 ns. All further parameters were were adjusted according to the *Hiperlan2* standard as described in [2].
Simulations were performed at a data rate of 27 Mbit/s using 16QAM. In order to evaluate the time needed for simulations, parameters were fixed to a burst time of 400 μs yielding 100 OFDM-symbols. The number of OFDM symbols in a block (n_s) was fixed to 20 which implies $n_{block} = 5$. The number of iterations n_{it} was limited to 2.
The simulation results were obtained by Monte Carlo simulations of up to 7000 runs. In each simulation of the channel impulse response 10800 bits were transmitted.

V. Performance Analysis

In this section the performance of the *Hiperlan/2* system described above is analysed. As already mentioned in the introduction we concentrate our interest not only on the overall bit error performance but also evaluate the performance in a system with a frequency offset and investigate the behaviour in a faster fading environment. In the latter two cases the ability of the ICE as a tracking mechanism is of great interest.

A. Bit error performance

In this section an ordinary analysis of the overall bit error performance is conducted. In **Fig. 2** the bit error rate is shown at 27 Mbit/s for the Hiperlan/2 conditions given above. A velocity of $v_0 = 3$m/s between base station and mobile unit is assumed. This is the maximum velocity proposed by the *Hiperlan/2* specifications. For channel estimation we used conventional CE and ICE. Those two channel estimations were once again combined with the above described NR. The conventional CE combined with NR and the ICE without NR yield approximately the same gain of about 2 dB at a BER of 10^{-3}. Combining the ICE with NR shows optimal performance and closes in to the bit error curve of the ideal known channel. The distance of the two curves is 0.5 dB at a BER of 10^{-3}.

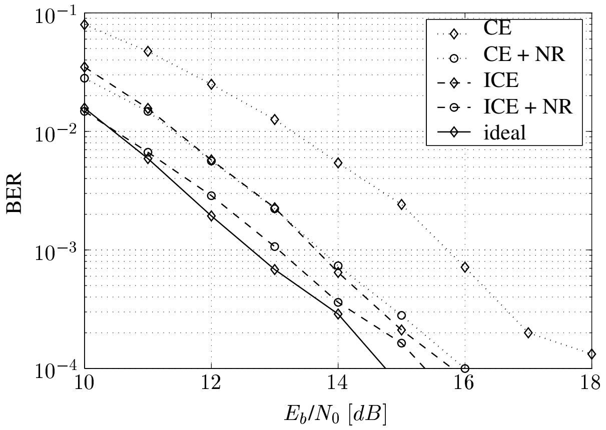

Fig. 2. Simulation results: BER Hiperlan/2 conditions

B. Frequency offset

As mentioned above, the ICE can not only be employed to reduce the noise of the channel estimation. A second use is the tracking of the channel coefficients. **Fig. 3** shows a system at 27 Mbit/s with the influence of a constant frequency offset Δf at a E_b/N_0 ratio of 13 dB. Using the pilot carriers of the system to track the channel shows the best results in ensuring a transmission. However an ICE ($n_s = 2$) not evaluating the pilot carriers manages as well to sustain a receptible transmission up to a Δf of 2000 Hz (considering a BER of 10^{-2} as a tolerable limit for decent reception). This is a realistic frequency offset the system has to handle after performing a pre-synchronisation. Fig. 3 makes clear that reducing the effects of noise and tracking channel parameters are two opposed purposes. A larger n_s yields a low BER when there is no or minimal offset, however no tracking can be performed at higher offset rates since the channel is changing too much within one block. To the contrary a small n_s permits tracking but starts at a much higher BER when offset effects are still low.

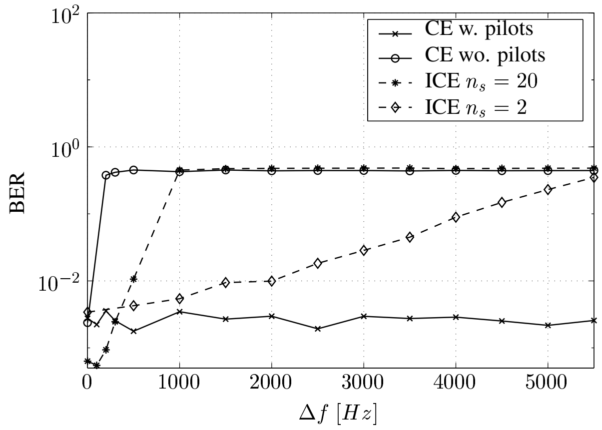

Fig. 3. Simulation results: frequency offset

C. *Fast fading environments*

Finally, **Fig. 4** shows the same scenario as in Fig. 3 but now with the influence of a Doppler spread caused by a velocity up to $v_0 = 50\,m/s$. In such an environment a conventional CE with pilot carriers fails to track the channel since such an interference is arbitrary for each subcarrier so a conclusion from one subcarrier to the other is not valid. To the contrary the ICE (with a block length of $n_s = 3$ OFDM symbols) is able to track the channel. A limiting factor to this mechanism is the block length. For the tracking to work the channel may only change to a certain extend between two blocks since the last estimation of one block is used for the initial equalisation of the next one.

VI. Conclusions

In this paper an iterative channel estimation for a slow fading environment has been presented. In section II the motivation for a modified channel estimation using an extended set of training data generated in the receiver has been given. In section III we presented the algorithm to perform the iterative channel estimation. A performance analysis was done in section V with a system described in section IV. It has been shown that an iterative channel estimation can be used to reduce the noise of the estimated channel coefficients in a slow fading environment as well as to track the channel in faster fading environments or in a system with a frequency offset. Both aspects of the ICE are mutually exclusive since noise reduction requires a long block length and channel tracking can only be performed with a shorter block length of OFDM symbols.

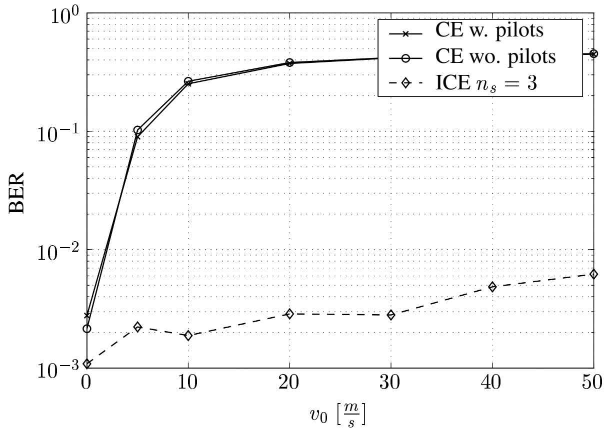

Fig. 4. Simulation results: Doppler frequency

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