CHANNEL ESTIMATION BY EXPLOITING SUBLAYER INFORMATION IN OFDM SYSTEMS

Maik Bevermeier, Tobias Ebel, Reinhold Haeb-Umbach

Department of Communications Engineering
University of Paderborn, Germany
{bevermeier, haeb}@nt.uni-paderborn.de

ABSTRACT

Algorithms used to estimate the influence of the medium on the transmitted data signal in an OFDM system typically incorporate one or more known symbols, called preamble, in front of each data stream [1]. An estimate of the channel transfer function is most easily obtained by $\hat{H}_m(k_{\text{Pre}}) = Y_m(k_{\text{Pre}})/X_m(k_{\text{Pre}})$, where $Y_m(k_{\text{Pre}})$ and $X_m(k_{\text{Pre}})$ are the received signal and the transmitted data of the preamble at the m-th subcarrier. An equalization of the received data of a packet-oriented transmission is then carried out by using these instantaneous estimates on all following payload symbols $\mathbf{Y}(k)$, where k is the symbol counter.

The performance of this kind of equalization is quite limited, if the channel transfer function changes considerably during the transmission of the payload, be it because of high terminal velocities or long payloads. Therefore semiblind channel estimation has been suggested, where the initial estimates obtained from the preamble are further improved on the payload.

We examined the possibility to use additional existing known data of the physical layer of a Wireless LAN system, like IEEE 802.11a, for channel estimation [2], [3]. Under consideration of the coding process at the transmitter we propose to use the so-called "Tail-Bits" and the "Pad-Bits", which finalize the data unit of the physical layer, for channel estimation. Generating a postamble in this way would allow for estimating the channel transfer function for each symbol of the payload by Wiener interpolation between the known pre- and postamble [4], [5].

To be able to do so, however, several issues have to be addressed. The coding process contains a scrambler, convolutional coder, puncturer and an interleaver. The preamble of a WLAN system has constant energy for all subcarriers and has the advantage not being coded. By contrast the last payload bits are passed through the coding process. For a complete OFDM symbol at the end of the payload to be known, not only the source bits of the symbol need to be known but also the N_{CL} preceding ones, where N_{CL} is the contraint length of the convolutional code. We propose to decrease the payload and insert "Zero-Bits" in front of the tail-bits as needed to obtain a completely known postamble symbol. This entails a much smaller loss of efficiency than the insertion of a postamble symbol just for the purpose of channel equalization. For some data rates and a special choice of transmitting bits it is sufficient to reduce the payload length only by N_{CL} bits and replace them by known bits. The price to pay is, however, that the value of the postamble is not a design parameter which can be chosen such that channel estimation performance is maximized.

Another important issue is the random initialization sequence of the scrambler. The sequence has to be known to recalculate the reference symbol for the postamble. A simple way to get the sequence is to use the instantaneous channel estimate obtained on the preamble to equalize and then detect the first payload symbol, the so-called "Service field", which is used to synchronize the descrambler. Now that the postamble is completely known, we are able to estimate the instantaneous channel coefficients at the end of the payload.

Let $\hat{H}_m(k_{\text{Pre}})$ and $\hat{H}_m(k_{\text{Post}})$ denote the instantaneous channel estimates of the m-th subcarrier obtaind on the pre- and postamble, respectively. We propose to use a Wiener Filter to interpolate the channel coefficients

in time direction for each OFDM symbol k of the payload by applying the Wiener-Hopf equation

$$\tilde{H}_m(k) = \begin{pmatrix} r(k - k_{\text{Pre}}) & r(k - k_{\text{Post}}) \end{pmatrix} \begin{pmatrix} r(0) + \sigma^2_{\text{Pre},m} & r(k_{\text{Post}} - k_{\text{Pre}}) \\ r(k_{\text{Pre}} - k_{\text{Post}}) & r(0) + \sigma^2_{\text{Post},m} \end{pmatrix}^{-1} \begin{pmatrix} \hat{H}_m(k_{\text{Pre}}) \\ \hat{H}_m(k_{\text{Post}}) \end{pmatrix},$$

with $r(k) = J_0(2\pi f_d T_S k)$. The noise variances $\sigma^2_{\text{Pre},m}$ and $\sigma^2_{\text{Post},m}$ account for the different signal-to-noise power ratios of the subcarriers of pre- and postamble.

The complexity of this channel estimation method is quite small since the autocorrelation matrix and crosscorrelation vector do not change over time. Fig. 1 presents some results obtained with the proposed method using a payload, which contains 126 symbols, and assuming a terminal velocity of 30 km/h. The bandwidth is chosen to 20 MHz in the 5 GHz Band, 96 data bits are distributed on 48 data subcarriers at a coding rate of 1/2, and the modulation employed is 16-QAM.

As shown, the performance of a channel estimation based on this Wiener interpolation outperforms a Kalman Filter (KF), which operates solely on the preamble in time domain, for E_b/N_0 greater than 11 dB. This threshold value will be lower for higher terminal velocities. Perfectly knowing the scrambler initialization sequence leads to a smaller mean square estimation error (MSEE) obtained by the Wiener filter (WI-KS) compared to detecting it on the data (WI-ES) only for low E_b/N_0 values, where detection errors may occur. Generally, the quality of the proposed interpolation justifies the decreased effective data rate due to the insertion of a few known bits. For example, for a data rate of 24 MBits/s and a PSDU (*Physical Sublayer Service Data Unit*) length of 490 bytes (42 symbols) one extra pad byte has to be inserted resulting in a loss of data rate of $1/490 \approx 0.2\%$ compared to about 2.4% if a complete extra postamble symbol were to be inserted for channel estimation only.

A detailed examination of computational complexity and robustness will follow in the final paper.

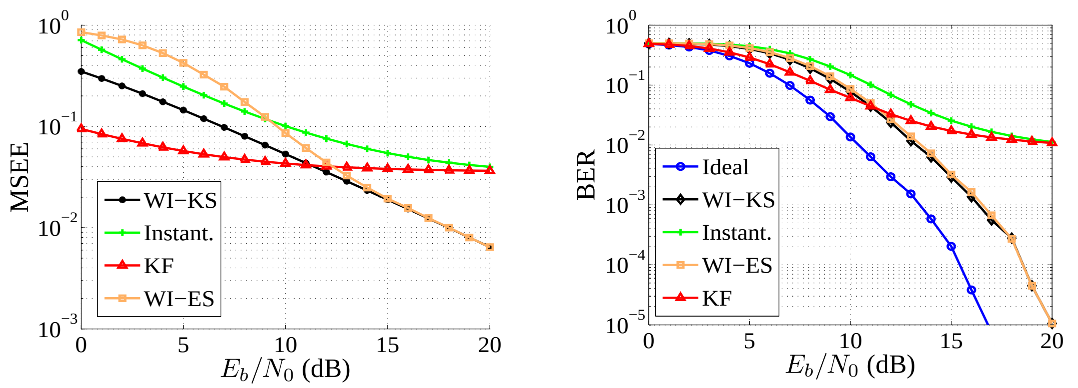

Fig. 1. Wiener interpolation in time direction by assistance of a pre- and generated postamble: channel model with six propagation paths of $[-6.5, -7.6, -8.7, -9.8, -10.9, -12.0]$ dB and delays of $[0, 50, 100, 150, 200, 250]$ ns.

REFERENCES

[1] Z. Wang and G. Giannakis, "Wireless multicarrier communications", *IEEE Signal Processing Magazine*, Vol. 17, no.3, pp. 29-48, May 2000.

[2] IEEE Std 802.11a-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications - High-speed Physical Layer in the 5 GHz Band".

[3] B. O'Hara and A. Petrick, "IEEE 802.11 Handbook - A Designer's Companion, *Standards Information Network IEEE Press*, 2001.

[4] K.-D. Kammeyer, "Nachrichtenuebertragung", *Teubner*, Ed. 3, Nov. 2004.

[5] K.-D. Kammeyer, "Berichtigungen und Ergaenzungen zum Buch Nachrichtenuebertragung", http://www.ant.uni-bremen.de/pub/books/nue/correction/index.html.