Noise Reduction for Optical OFDM Channel Estimation

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IN recent years, Orthogonal Frequency Division Multiplexing (OFDM) has been proposed for optical long-haul communications due to the ease of equalization of the dispersion-governed fiber optical channel [1]. The approaches pursued can be distinguished into two groups: First, there are coherent optical systems which use quadrature modulation at the transmitter and zero-IF (Intermediate Frequency) complex valued down-conversion using a local laser at the receiver [2], second, there exist incoherent approaches which use envelope detection at the receiver and thus are restricted to real valued modulation [3]. Since double sideband (DSB) modulation leads to undesired effects due to the phase properties of the fiber [4], single sideband (SSB) modulation is preferred, which can be accomplished by filtering in the bandpass domain [5] or by quadrature modulation [6]. However, the "compatible SSB" (CompSSB) approach presented in [6] is not a linear modulation scheme and therefore the end-to-end equivalent baseband channel, described in the electrical domain cannot be formulated [7]. This implies that there is no such thing as "perfect channel knowledge" in any CompSSB simulation. Usually, in these cases, the equivalent channel is modeled by an allpass with quadratic phase response, but in our paper we will show that by use of noise reduced [8] channel estimation, better results than with this approximation can be achieved.

The least squares OFDM channel estimation $\hat{H}(n) = \frac{Y(n)}{X(n)}, X(n) \neq 0, n = 0 \ldots N_{\mathrm{sc}} - 1$ with the received symbol $Y(n)$ on the n-th subcarrier being defined by the system equation $Y(n) = H(n) \cdot X(n) + N(n)$ yields a channel impulse response $\hat{h}(k)$ of length N_{sc} by application of the inverse FFT. This impulse response can be safely truncated to the length of the cyclic prefix, resulting in noise reduction of the frequency domain channel estimation $\hat{H}(n)$ [8]. Fig. 1 shows the average bit error rate (BER) of a 511 subcarrier optical OFDM system using electrical compatible SSB modulation, a cyclic prefix length of $1/4$ of the core symbol duration, quaternary phase shift keying (QPSK) with a bitrate of 42.8 Gb/s over 80km standard single mode fiber with a linearized receiver [9] and a carrier-to-sideband power ratio of approx. 12 over the optical signal-to-noise ratio (OSNR). A fiber bandwidth of 150 GHz was assumed and no optical filtering was performed. For the channel estimation, random QPSK training symbols were employed. It can be seen that the usage of only one training symbol (plotted in blue) leads to a significant OSNR loss at the interesting target BER of 10^{-3} compared to the case where the allpass model was used for equalization (plotted in black). The truncation of this channel estimation to $1/4$ improves system performance significantly (plotted in red), an additional gain can be observed when two channel estimations are averaged before truncation (cyan curve). At a BER of 10^{-3}, this channel estimation already performs slightly better that the allpass model, the inadequacy of this model becomes more apparent, when 16 independent channel estimations are averaged before truncation (magenta curve).

In our final contribution, we will describe the properties of the equivalent baseband channel, explain the noise reduction algorithm in more detail and also present results for different scenarios.

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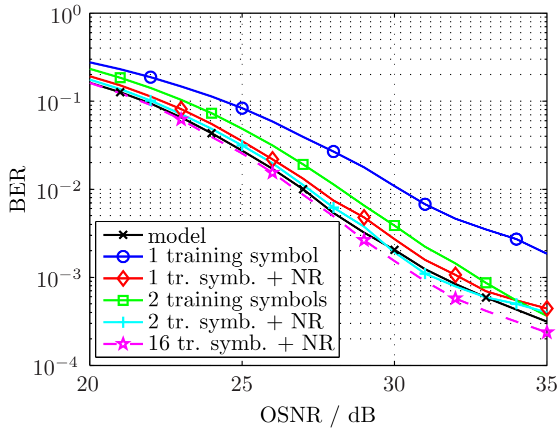

Fig. 1. Bit error rates with and without noise reduction

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