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PILOT SYMBOL PARAMETER OPTIMIZATION BASED ON IMPERFECT CHANNEL STATE PREDICTION FOR IMPROVED OFDM TECHNIQUES

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ABSTRACT

The optimization of pilot symbol parameters can improve the spectral efficiency of adaptive modulation for orthogonal frequency division multiplexing (OFDM) systems. Since pilot symbols impose an overhead on the system consuming power and bandwidth, an optimal pilot symbol assisted adaptive modulation (PSAAM) scheme for OFDM systems is proposed. The PSAAM scheme is used to maximize the spectral efficiency by adapting power and constellation size of each subcarrier based on employing imperfect channel state information (CSI) at the transmitter. The pilot symbol power and spacing is also optimized in this scheme. The optimality of minimum mean square error (MMSE) channel prediction for OFDM systems expressed in terms of a lower bound on spectral efficiency is approached. It is proved that the rectangular pilot pattern with equi-spaced and equal power pilot tones achieves the minimum Mean square error (MSE) of the channel prediction in addition to having the advantage of simplifying PSAAM design. Numerical results show the importance of optimal pilot parameter adjustment for rapidly fading channels.

Keywords: Orthogonal frequency division multiplexing (OFDM), adaptive modulation, channel prediction, imperfect channel state information, pilot symbol assisted modulation.

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. It has developed into a popular scheme for wideband digital communication. It is essentially a Frequency-Division Multiplexing (OFDM) scheme used as a digital multi-carrier modulation method. Optimum power and rate allocation based on a available imperfect channel state information at the transmitter in OFDM systems without considering the presence of pilot symbols adaptive resource allocation based on channel state information offers the potential of enhancing data rate while maintaining the quality of service in time varying wireless channel adaptive modulation where the transmission rate and powers are adapted according to perfect channel state information at the transmitter. Orthogonal frequency division multiplexing (OFDM) is an effective technique that compacts this effect by converting a frequency selective fading channel into a set of flat narrowband orthogonal fading channels the advantages of adaptive modulation schemes based on accurate channel state information were considered for multicarrier systems. It is not possible to have perfect channel state information at the transmitter due to time variation of the channel. The effect of imperfect channel estimation on the performance of adaptive modulation based on the perfect channel state information at the transmitter was analyzed and showed the high sensitivity of BER to both channel estimation error and the time variation of the channel estimation error and the time variation of the channel. an optimal pilot symbol assisted adaptive modulation (PSAAM)scheme for OFDM systems is proposed that maximizes spectral efficiency by adapting the power and constellation size of each sub carrier based on employing imperfect channel state information(CSI)at the transmitter.

The pilot symbol power and spacing is also optimized in this scheme. The optimality of minimum mean square error (MMSE) channel prediction for OFDM systems expressed in terms of lower bounds spectral efficiency is approached. It is proved that the rectangular pilot pattern with equal-spaced and equal power pilot tones achieves the minimum MSE of the channel prediction in addition to having the advantage of simplifying PSAAM design.

2 PROPOSED ADAPTIVE PSAM SCHEMES

The Adaptive PSAM OFDM System Under Consideration Is Depicted In Transmitted Frame Structure. A Pilot Insertion Block Inserts A Training Sequence Into The First OFDM Block, Referred To As the *P&D* (pilot and data) block, of each transmitted frame, and the $K-1$ remaining blocks, denoted *D* (data) blocks, of the frame are allocated to data.

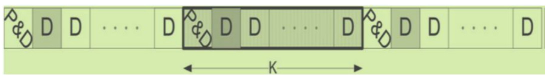

Fig.1 the transmitted frame structure.

Assuming the system parameters are chosen so that no inter-block interference (IBI) exists, we can describe the discrete time baseband equivalent model for the OFDM system as follows. Let $\mathbf{x}(n; k)$ denote the kth $N\times1$ time-domain block of the nth frame at the receiver. Where $\mathbf{w}(n; k)$ is an additive zero-mean white Gaussian noise vector having independent elements with variance equal to $N0/2$ per dimension, and N is the number of subcarriers. $\mathbf{H}$ is a circulant channel matrix with first column $[\mathbf{h}_T, 0, \cdots, 0]^T$ Where are transmitted data vectors in the frequency-domain, $\mathbf{F}^H$ denotes the unitary IDFT matrix, and $\mathbf{b}$ represents the pilot vector in the time domain that fulfills the power constraint $\mathbf{b}^H\mathbf{b}=S_P$. The channel frequency response of the mth subcarrier in the nth frame.It is straightforward to verify that the channel frequency response

$\boldsymbol{\Sigma}=E\ [\Delta\mathbf{h}\ \Delta\mathbf{h}]^H$, is a diagonal matrix and the MSE's of all predicted sub channels are identical. increasing the number of pilot tones greater than the channel length will not enhance the performance of the channel predictor. The MMSE of the channel prediction for rectangular pilot pattern with equi-spaced and equal power pilots. In addition to offering the minimum MSE for channel prediction, the rectangular pilot pattern with equi-spaced and equal power pilot tones has the advantage of decreasing computational complexity. Therefore, for the purpose of channel sounding, we insert $Np=Lh$ equi-spaced and equal power pilot tones in each *P&D* block to reduce the pilot overhead without loss in channel prediction performance and to obtain a low complexity power and rate adaptation algorithm.

3 PERFORMANCE ANALYSIS OF THE SYSTEM

We going to analyze the spectrum efficiency and power distribution properties of OFDM system which will have initialization properties as block length of 64 subcarriers and cyclic prefix of length =16 where the carrier frequency is 2 *GHz* and the block length is 5 *µs*, which corresponds to a symbol rate of 16 . We assume a frequency selective and time varying coefficients are identically distributed, Gaussian processes, with mean zero and variance.

CHANNEL PREDICTION

The mean square error (MSE) of the channel predictor not only depends on the total pilot power and the frame length but also varies with the pilot pattern. Here, we show that the rectangular pilot pattern with equi-spaced and equal power pilot tones achieves the minimum value of $\sigma^2_{\Delta h}$. in addition to offering the minimum MSE for channel prediction, the rectangular pilot pattern with equi-spaced and equal power pilot tones has the advantage of decreasing computational complexity.

1. Under fixed pilot power constraint $\mathbf{b}^H\mathbf{b}=S_P$, the MSE of the linear MMSE channel predictor is a convex function in $\mathbf{B}^H\mathbf{B}$ and its minimum is achieved if the rectangular pilot pattern with equi-spaced and equal power pilot tones are transmitted. In addition to achieving the minimum MSE of channel prediction, one can show that the rectangular pattern with equi-spaced and equal power pilot tones exhibits the advantage that the predicted sub-channels have identical distributions for all subcarriers of each block therefore, the computational complexity decreases significantly in deriving optimal power and rate adaptation. In the following theorem, we establish the aforementioned advantage of the rectangular pattern.

2. Assuming rectangular pilot pattern with equispaced and equal power pilot tones with the number of pilot tones, Np, greater than or equal to the channel length, implies:The covariance matrix of the channel estimation error, channel whosbaseband equivalent has L=16. complex zero-mean Gaussian taps with normalized power delay profile.

Consider an OFDM system with a block length of 64 subcarriers and cyclic prefix of length $_p$=16 where the carrier frequency is 2 *GHz* and the block length is 5 *µs*, which corresponds to a symbol rate of 16 . We assume a frequency selective and time varying channel whose baseband equivalent has L=16. Complex zero-mean Gaussian taps with normalized power delay profile. Clarke's Doppler spectrum is chosen to model the time variation of the channel and we consider the delay =1 *ms*, for target BER equal to 10−6. The length of the channel prediction filter needs to be sufficiently large so that satisfactory channel prediction performance is obtained. The effect of increasing the predictor filter length on the spectral efficiency of the optimum PSAAM and equal power PSAAM is shown in by letting the mobile velocity range from 5 *km/h* to 150 *km/h*. In equal power PSAAM, which is shown here as a benchmark, α is set as $\alpha=N_K/(N_K +\ \ )$. As illustrated in the relative gain achieved by increasing is most notable at higher mobile velocities for which is relatively larger. Hence, channel predictors with more complexity are required at higher mobile velocities. Furthermore, it is obvious from Fig. 3 that satisfactory prediction is achieved with smaller predictor order (and therefore a more practical predictor length) in optimum PSAAM compared to the equal power PSAAM. This behavior can be explained by noting that the frame length obtained for the optimal PSAAM is much larger than that of the equal power PSAAM; therefore, filters with smaller prediction order can take enough past into account. According to the above discussion, we select a channel prediction filter of length =250.

In the spectral efficiencies of optimal power allocation (optimum PSAAM), equal power allocation between pilot and data symbols (equal power PSAAM), and the suboptimum design (suboptimum PSAAM) are plotted over a velocity range for SNR=25 *dB* and BER equal to 10−3 and 10−6. Also, Fig. 5 depicts the spectral efficiencies of these algorithms as a function of average SNR for mobile velocities *v*=10 *km/h* and *v*=107 *km/h*, which correspond to maximum Doppler frequencies =18 *Hz* and =200 *Hz*, respectively

4 SIMULATION RESULTS AND DISCUSSION

The relative gain achieved by increasing is most notable at higher mobile velocities for which fdt delay is relatively large. Hence, channel predictor with more complexity is required at higher mobile velocities. Furthermore, it is obvious from Fig. 3 that satisfactory prediction is achieved with smaller predictor order (and therefore a more practical predictor length) in optimum PSAAM compared to the equal power PSAAM. This behavior can be explained by nothing that the frame length obtained for the optimal PSAAM is much larger then that of the equal power PSAAM (see fig 6) therefore, filters with smaller prediction order can take enough past into account. According to the about discussion, we select a channel prediction filter of length =250.

4.1 CHANNEL PREDICTION FILTER LENGTH =80,250,500.

The mobile velocity range from 5 *km/h* to 150 *km/h*. In equal power PSAAM, which is shown here as a benchmark, α is set as $\alpha=N_K/(N_K + \ )$. As illustrated in the relative gain achieved by increasing is most notable at higher mobile velocities for which is relatively larger. Hence, channel predictors with more complexity are required at higher mobile velocities. Furthermore, it is obvious from Fig. 3 that satisfactory prediction is achieved with smaller predictor order (and therefore a more practical predictor length) in optimum PSAAM compared to the equal power PSAAM. This behavior can be explained by noting that the frame length obtained for the optimal PSAAM is much larger than that of the equal power PSAAM; therefore, filters with smaller prediction order can take enough past into account. According to the above discussion, we select a channel prediction filter of length =250.

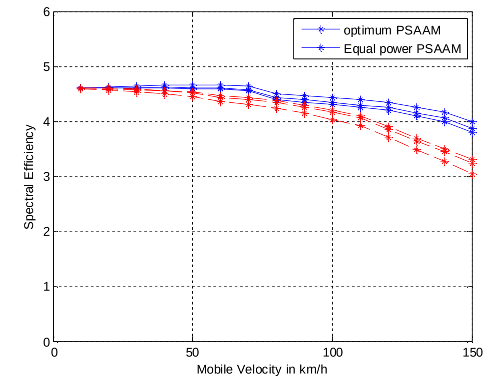

Fig. 2. Channel prediction filter length =80,250,500

4.2 THE SPECTRAL EFFICIENCY RESPONSE FOR SNR=25DB AND BER EQUAL TO AND .

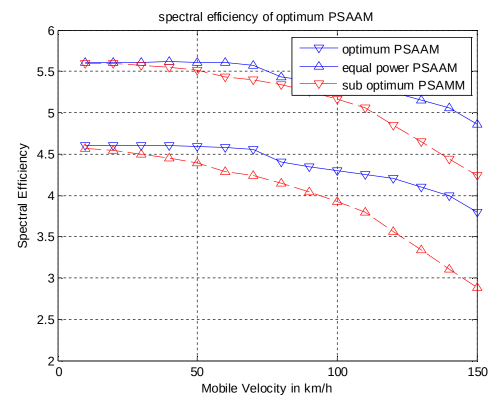

Fig. 3. Signal to noise ratio 25 dB and BER equal to and .

In the spectral efficiencies of optimal power allocation (optimum PSAAM), equal power allocation between pilot and data symbols (equal power PSAAM), and the suboptimum design (suboptimum PSAAM) are plotted over a velocity range for SNR=25 *dB* and BER equal to 10−3 and 10−6.

4.3 PSAAM FOR DIFFERENT MOBILE VELOCITIES

The spectral efficiencies of these algorithms as a function of average SNR for mobile velocities *v*=10 *km/h* and *v*=107 *km/h*, which correspond to maximum Doppler frequencies f_d=18 *Hz* and f_d=200 *Hz*, respectively. This is shown in below figure.

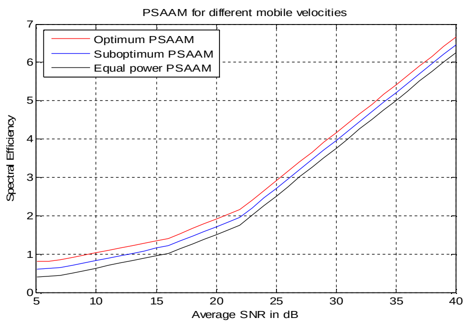

Fig.4. The spectral efficiency of optimum PSAAM, suboptimum PSAAM and equal power PSAAM.

5 CONCLUSION

In this paper, we have proposed an optimal pilot symbol assisted adaptive modulation (PSAAM) scheme for OFDM systems that maximizes spectral efficiency, and optimizes pilot parameters including power and spacing at the same time. The optimality of the MMSE channel predictor in terms of a lower bound on spectral efficiency has been proved for OFDM systems. Furthermore, we have proved that the rectangular pilot pattern with equal-spaced and equal power pilot tones not only achieves the minimum MSE of the channel prediction but also has the advantage of impelling PSAAM design.

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