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Noise Power Estimation in Broadcasting OFDM Using Pilot Subcarriers

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Abstract: The aim of future wireless communication systems is to provide communication with extremely high data rates. For this to be achieved the most widely used technique is Orthogonal Frequency Division Multiplexing (OFDM), which is a modulation technique for transmitting large amounts of digital data over radio waves. Noise power estimation in wireless communication systems is the core issue nowadays. For noise power estimation in OFDM, each frame is appended with a preamble at the start of the frame during the broadcasting process. However the existing noise estimation schemes based on the preamble method do not provide noise variation accurately. A novel pilot-based noise power estimation method is proposed for OFDM systems which performs the evaluation of noise power for each data symbol. Pilot subcarriers are inserted in each data symbol for channel estimation. Pilot subcarriers transmit with a known data sequence. The proposed algorithm computes the circular convolution between the original signal and comb-type pilot sequence twice to generate noise power. In comparison with the conventional preamble based algorithm the proposed pilot-based noise power estimation provides good accuracy at various SNR values. This algorithm offers substantial decrease in Bit Error Rate (BER) over the conventional time domain estimator without much overhead of the preamble.

Index Terms: Bit Error Rate, Pilot-Subcarriers, OFDM System and Noise Power.

1. INTRODUCTION

In wireless OFDM system, noise variance increases the probability of receiving error bits. The vital measure of channel quality is noise variance and its estimation helps in adaptive modulation which optimizes the performance of wireless communication system. Similarly hand off algorithms and turbo coding depends on the variation of the noise statistics in the time varying channel. Thus from the precision and complexity of noise estimation, the performance and capacity of OFDM systems can be directly evaluated. In general there are two different classes of noise estimation algorithms –data-aided (DA), non data aided (NDA). In the first one, pilot or known training sequence is transmitted for noise power estimation at the receiver and in second class the noise is estimated blindly. Both these classes have their pros and cons in terms of estimation accuracy and complexity in computation.

Earlier reported noise estimation schemes belong to data-aided (DA) class and are based on the preamble based estimation method for channel estimation and synchronization. Pilot assisted channel estimation techniques are studied where the pilot symbol assisted modulation is used to mitigate the effects of fading in wireless communication systems. And another method, the superimposed pilot assisted modulation technique when compared with the earlier approach its bit error rate (BER) performance is reduced. Based on the wastage of bandwidth in the use of pilot assisted channel estimation techniques, blind channel estimation techniques have been reported later. Here the use of pilot symbols that use the channel capacity is avoided and the channel is instead estimated by using inherent information from the transmitted as well as the received signals statistical properties. Here the trained symbols are not employed in case of blind channel estimation where the complexity is reduced but the cost involved in transmission is relatively high. Preamble based channel estimation schemes were also reported in which the known symbols are appended at the start of a frame or they can be placed at isolated Fourier transform (FT) points throughout the frame. However the performance is degraded due to the mobility of the receivers in this approach.

To overcome this limitation improved preamble based noise estimation schemes are used where the comb type pilot is exploited and a low complication frequency domain noise estimation method is accomplished for the frequency selective fading channels. Using this method, the overloaded preambles are arranged with a certain number of null subcarriers, which are used to estimate the noise power. Likewise in low complexity time domain SNR estimation for OFDM systems, accessible time domain noise estimation for the frequency selective fading channel uses correlation of the received preambles for noise power estimation. And the results are obtained at the cost of preamble symbol and it also increases the overhead of OFDM broadcasting systems. And most of the useful communication systems now a day's adapt pilot based channel estimation. Channel estimation methods based on pilot estimation can be divided into two pilot models- Block pilot and Comb pilot. In the Block type model, the pilots are inserted into all the subcarriers of one OFDM symbol with a certain time period and this Block type model can be adapted for slowly fading channels. The Comb type pilot model consists of pilots positioned at some definite subcarriers in each OFDM symbol. Literature reveals that the estimation in time domain is not affected by loss of orthogonality which can occur due to carrier offset. Moreover the number of channel taps required for estimation in time domain are less, compared to that in frequency domain using number of FFT points for channel frequency response estimation.

So it is more essential to have a time domain noise estimation scheme in which the noise variation can be tracked symbol by symbol instead of at the start of the frame using a preamble symbol. It has been observed from the literature that none of the time domain noise estimators exploit the pilot subcarriers reserved for channel estimation for signal as well as noise power estimation. In this proposed work, the noise power is evaluated by utilizing the data symbol that uses pilot subcarriers with the guard bands.

2. PROPOSED PILOT BASED METHOD

In this method for pilot based time domain noise power estimation, the guard band subcarriers are placed at the end of each OFDM symbol. In Pilot-based channel estimation the channel information is estimated by locating the impulse response of all sub-carriers from pilot. The OFDM system can be described using Fast Fourier Transform (FFT) and Cyclic Prefix (CP) and performance of the channel estimation is described using two methods known as block type pilot and comb type pilot.

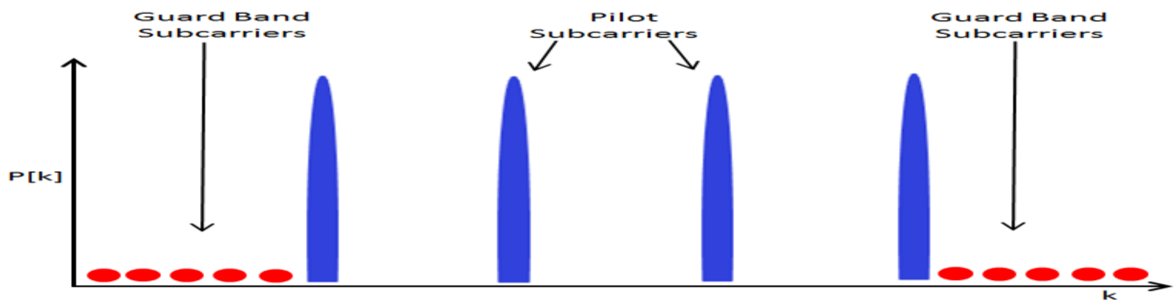

Figure 1: Data symbol containing pilot subcarriers with guard band in the proposed method.

In the prearrangement of block type pilot, the performance of channel estimation is analyzed with estimators based on three different algorithms such as Least Square(LS) algorithm, Linear Minimum Mean Square Error(LMMSE) algorithm and Singular Value Decomposition(SVD) algorithm. For Comb type pilot arrangement, three methods of interpolation are introduced such as linear interpolation, second order interpolation and cubic spline interpolation. At the end results are presented using MATLAB simulation. Bit error rate (BER) is compared for different schemes using MATLAB.

3. BLOCK DIAGRAM FOR PILOT BASED METHOD

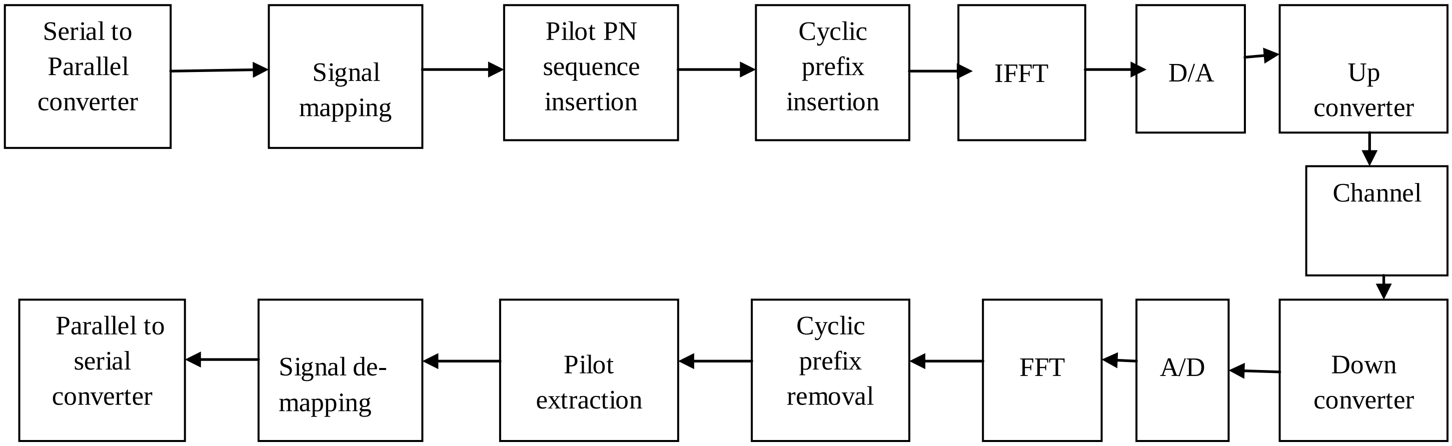

Figure 2: Block diagram of the proposed method.

3.1 Serial To Parallel Converter

The serial data input stream in the form of words for transmission, for example two bits per word for QPSK and will be shifted into parallel format. Then parallel data transmission occurs by assigning one data word to one carrier.

3.2 Signal Mapping

Mapping defines the relationship between logical and physical inputs and outputs. That is assignment of physical inputs to logical inputs and logical outputs to physical outputs is called mapping. Each bit is mapped to a signal.

3.3 Pilot Sequence Insertion

Pilot sequences are the un modulated data used for synchronization and channel estimation. To improve the channel capacity, channel estimation is the main parameter that is required. To increase the channel capacity more number of pilots are needed. But this will increase the overhead too. Therefore there should be a tradeoff between pilot symbols and spectral efficiency. These pilots are generated using a pseudo random binary generator block. As the PN sequences have good auto and cross correlation properties, they are the simplest choice for pilot sequences. The term cyclic prefix refers to the prefixing of a symbol with repetition at the end. To serve the objective, cyclic prefix should have length of at least equal to the length of multipath channel.

3.4 Fast Fourier Transform And Inverse Fast Fourier Transform

These are used to convert the signal from time domain to frequency domain and vice versa. FFT rapidly computes the transformations using DFT matrix by factorization.

3.5 A/D & D/A converters

A/D converters are used to split the physical or analog quantity into discrete form and are then converted to digital values. D/A converter perform the reverse operation.

3.6 Parallel to Serial Converter

In contrast to serial-parallel conversion, a stream of multiple data elements are converted into a stream of data elements, transmitted in time sequence i.e one at a time.

3.7 Noise Estimation

Noise power can be determined by the evaluation of least squares and averaged estimates of the noise. From the get pilot estimate subsystem, the noisy least squares are estimated and from the pilot average subsystem, noise averaged pilot symbol estimates are obtained which will provide an indication of the channel noise. Simply alluring the difference between these two estimates results in a noise level for the least squares channel estimates at pilot symbol locations.

$$\tilde{HP}(k) = \frac{YP(k)}{XP(k)} = HP(k) + noise$$

Averaging the rapid channel estimates over the smoothing window, we have

$$\widetilde{HPavg(k)} = \frac{1}{|S|}\sum_{m=S} HP(m)\widetilde{\sim HP(k)}$$

Where *S* is the set of pilots in the smoothing window and |*S*| is the number of pilots in *S*. Thus, an estimate of the noise at a particular pilot can be formed using:

$$\widetilde{noise} = \mathbf{HP(m)\text{-}HPavg\ (k)}$$

In practice, it is not possible to remove all the noise using averaging. Because it is only possible to reduce the noise, only an estimate of the noise power can be made.

4. RESULTS

This section presents the results and analysis of the proposed pilot-based noise power estimator with preamble scheme. The Bit Error Rate and Mean Square Error Performance of the Preamble and proposed schemes are illustrated in the graphs shown below.

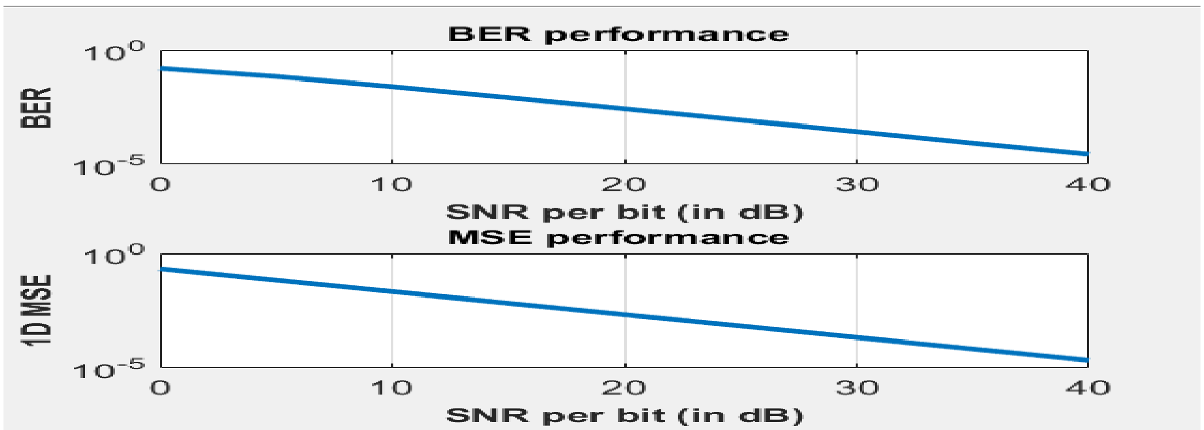

Figure 3: Output for preamble method.

Table 1: BER and MSE values of preamble method for different SNRs.

SNR	BER	MSE
0	0.1574	0.2162
5	0.0694	0.0684
10	0.0252	0.0216
15	0.0083	0.0068
20	0.0027	0.0022
25	$8.5625e^{-04}$	$6.8333e^{-04}$
30	$2.7425e^{-04}$	$2.1614e^{-04}$
35	$8.3103e^{-05}$	$6.8264e^{-05}$
40	$2.7515e^{-05}$	$2.1596e^{-05}$

Table 2: Input values of preamble method.

Channel length	10
Number of frames	10000
CP_num	19
Data size	512
Preamble length	256

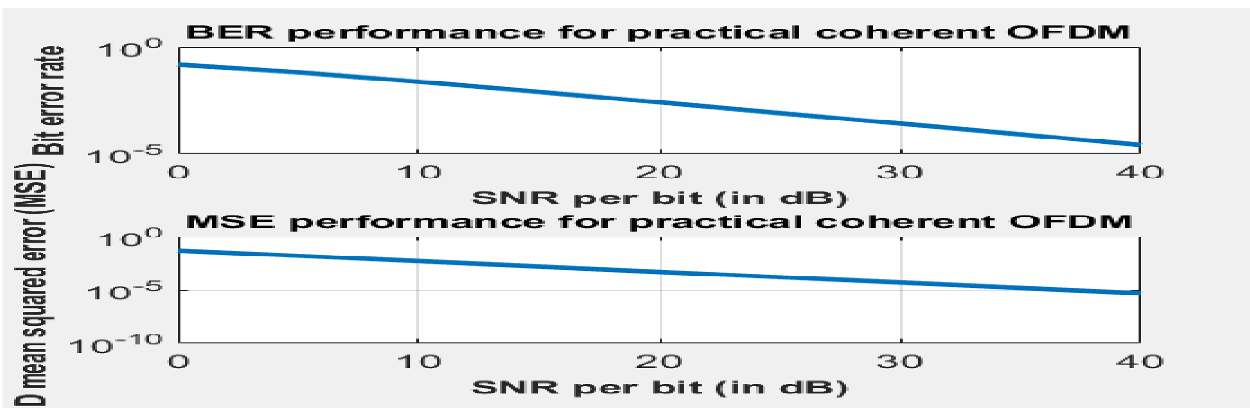

Figure 4: Output for pilot method.

Table 3: BER and MSE values of Pilot method for different SNRs.

SNR	BER	MSE
0	0.1491	0.0488
5	0.0654	0.0154
10	0.0237	0.0049
15	0.0079	0.0015
20	0.0025	$4.8823e^{-04}$
25	$8.0521e^{-04}$	$1.5432e^{-04}$
30	$2.5696e^{-04}$	$4.8838e^{-05}$
35	$8.0850e^{-05}$	$1.5444e^{-05}$
40	$2.5342e^{-05}$	$4.8796e^{-06}$

Table 4: Input values of Pilot method.

Channel length	10

Frame size	1024
CP_num	9
Data size	512
Pilot_num	512

It is observed that for a particular value of SNR, the Bit Error Rate (BER) and Mean Square Error (MSE) values of the proposed method are better than the existing method. For different levels of SNR, the BER and MSE values for the existing and proposed system are compared as shown in the above tables.

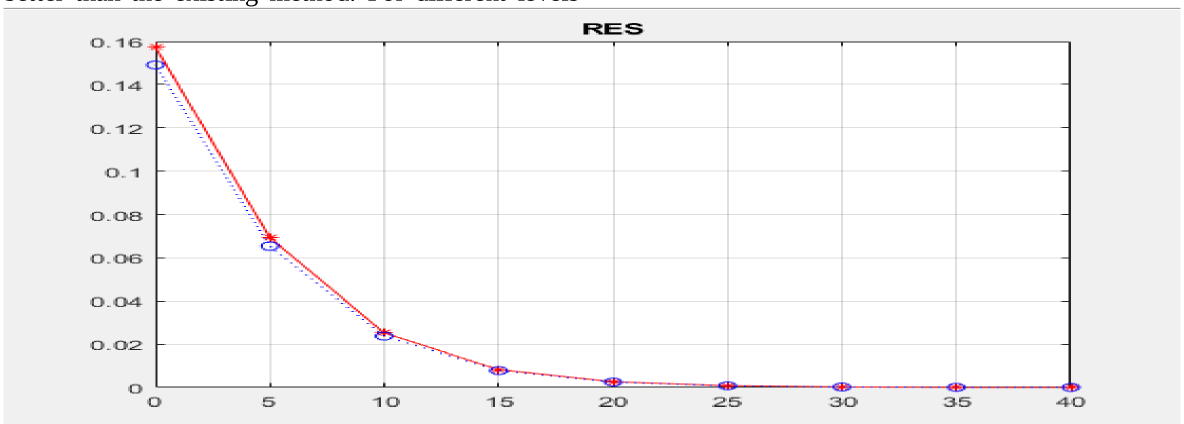

Figure 5: Comparison of BER for existing and proposed methods.

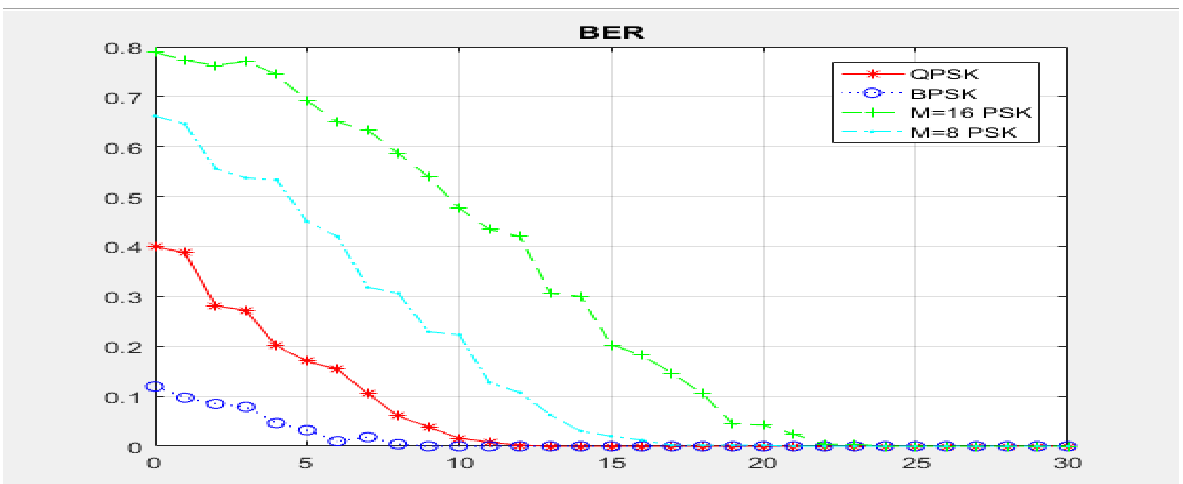

Figure 6: Estimation of BER for different techniques.

5. CONCLUSION

In this paper, noise estimation algorithm using pilot subcarriers for broadcasting OFDM system is presented. Pilot subcarriers are used for estimating the noise power symbol by symbol. The simulation results have shown the betterment of NMSE of this method over other methods. The proposed method is less sensitive to tracking errors, reduces channel overhead and the number of complex multiplications required is also less due to usage of circular correlation when compared to the conventional method.

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