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ESTIMATION OF FAST FADING CHANNEL IN MIMO OFDM USING RANDOM WALK KALMAN FILTER

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Abstract- This paper focused with multipath channel estimation in multi carrier systems. In less complex per-path random walk kalman filter(RW-KF) solution is proposed to overcome the multipath fading effect is based on independent processing of the path. A single channel is designed and by using the least square estimator, error signal for single path is estimated. An error signal for each channel path is calculated with the least square criterion. Based on the error signal, kalman filter is applied to each path independently. This per path kalman filter solution explores the time-domain correlation of the channel, while the least square step exploits the frequency-domain correlation of the channel. The proposed per-path KF is shown to be efficient as the exact kalman filter (i.e. joint multipath kalman filter).

Index terms- OFDM, channel estimation, Kalman filter, least square estimation, Random walk model.

I. INTRODUCTION

Orthogonal frequency division multiplexing is widely applied in wireless communication due to its high bandwidth efficiency, high rate transmission capability and more robust to multipath delay. It is a multicarrier modulation technique which mitigates the effect of Intersymbol Interference. It uses a large number of parallel narrow-band subcarriers instead of a single wide-band carrier to transport information. Rapid fluctuation in amplitude and phase of the transmitted signal is called fading and multipath propagation leads to fading. When the signal is transmitted from transmitter to receiver, the signal can take any path to reach the destination is the basic concept of Random walk model. MIMO techniques are used with OFDM to increase the system performance. It is one of the emerging techniques which provide efficient communication with multicarrier modulation. In [1]-[3] the channel estimation can be performed by inserting pilot tones into each OFDM symbol i.e. in all subcarriers. Complexity is high in symbol by symbol scheme and amplitude and phase of the carrier varies in each symbol duration. In [4] improved channel estimation method over the multipath fading channels using pilot subcarriers is proposed and the algorithm is based on parametric channel model and it employs ESPIRIT (estimation of signal parameters by rotational invariance techniques) method. The proposed channel estimation algorithm had its improvement in mean square error over the nonparametric channel model. In [5] the flat fading Rayleigh channel with Jake's spectrum is estimated. The channel is approximated by a first-order autoregressive AR (1) model and tracked by a Kalman Filter (KF). But AR (1) pole estimation is not accurate for low SNR and low Doppler frequency. In [6] the paper addressed the problem of channel tracking and equalization for multi-input multi-output (MIMO) time-varying frequency-selective channels. A Kalman filter is used for tracking the channel and it employs a low order autoregressive model (AR) model and it offers good tracking behavior for multiuser fading channels. The Clarke model used in the paper does not provide such result. In [7] Expectation-Maximization (EM) algorithm is proposed which estimates the gain and carrier frequency offset jointly in the presence of high mobility. The proposed technique is more robust to delays and Doppler frequency. A method to approximate the fading process with an ARMA model is proposed [8] and tuning of the auto regressive (AR) coefficient minimize the variance in the output of kalman filter. In [9] the channel is estimated based on first order autoregressive model (AR1) combined with correlation matching(CM) and minimization of asymptotic variance (MAV) criterion to fix the AR1-CM and AR1-MAV criterion based on kalman filter. Mean Square Error performance of a kalman filter can be improved by switching from autoregressive model (AR) model to Random walk model (RW). In [10] complexity of implementation grows with the filter orders, precision of computation and real time realization of these kalman filters with desired level of accuracy is a challenging task. A second order random walk model is shown in paper. In this paper, the channel is estimated over flat fading Rayleigh channel with jake's Doppler spectrum. Simulation results show that there is a significant improvement over second order MAV approach compared to AR1-CM approach especially for slow fading variations. The third order random walk model (RW-3) is shown in [11]. The RW-3 KF is used to track slowly time varying parameters. Vector state scalar observation (VSSO) and vector state vector observation (VSVO) are the types of kalman estimators which is used for channel estimation over wide sense stationary uncorrelated scattering (WSSUS) channel. In [12] the proposed VSSO Kalman channel estimator performs better than the method of Barhumi's least-squares method. In [13] the comparison is performed between VSSO and VSVO method and the results showed that VSSO performs better than the VSVO method. In [14] the proposed method deals with multipath channel estimation for OFDM under slow to moderate condition. The proposed paper deals with multipath channel estimation for OFDM under fast fading condition.

II. PROPOSED METHOD

The proposed method deals with multipath channel estimation in multi carrier systems in fast fading channel. The advantage of multiple antenna transmission technique is to transmit or receive several signals carrying the same information to combat with the faded channel. Data rate can be increased by transmitting independent data streams through multiple transmit antennas. Due to multipath channel estimation, energy efficiency and SNR gets improved. Fading effect can be compensated for the replica of signals over different uncorrelated channels.

A. PER-PATH KALMAN FILTER (KF)

The proposed methodology is less complex per-path Random Walk-Kalman Filter (RW-KF) solution which is based on independent processing of the paths. A single channel is designed first and by using the least square (LS) error estimator, error signal for single path is estimated. Then, a single channel is divided into sub channels and an error signal for each channel path is calculated with the least square (LS) criterion. Based on this error signal, kalman filter (KF) is applied to each path independently. This per path KF solution explores the time-domain correlation of the channel, while the least square step exploits the frequency-domain correlation of the channel. Finally, all the paths are joined together which is called joint multi-path kalman filter. The working principle of Per-Path Random Walk Kalman Filter is shown in fig.1. OFDM system model was designed based on fast fading channel with 128 subcarriers and after adding the pilot signals it is given to the least square estimator. The least square estimator is used to estimate the noise in the channel. The channel is divided into16 subcarriers and the least square estimator is used to estimate the noise in these sub channels.Based on the error signal, Kalman Filter (KF) is applied to each path independently. This per-path kalman filter solution explores the time domain correlation of the channel, while the least square step explores the frequency domain correlation of the channel. Finally, the link with joint multipath Kalman filter is established.

1) OFDM

OFDM system model was designed using fast fading channel with N subcarriers and a cyclic prefix length Ng. Let X_K be the sequence of transmitted symbols. The elements are modulated using pulse amplitude modulation (M-PAM) or quadrature amplitude modulation (M-QAM). After transmission over multipath channels, the received OFDM symbol is written as

$$Y_K=H_KX_K+W_K \quad (1)$$

where W_K be the noise vector and H_K be the diagonal values of the transmitted OFDM symbols. Then pilot signals are added. After calculating the Fourier transform of pilot symbols the output is calculated. The received pilot is calculated by using,

$$Y_P^K=\mathrm{diag}\{X_P^K\ F_P^K\ W_P^K\} \quad (2)$$

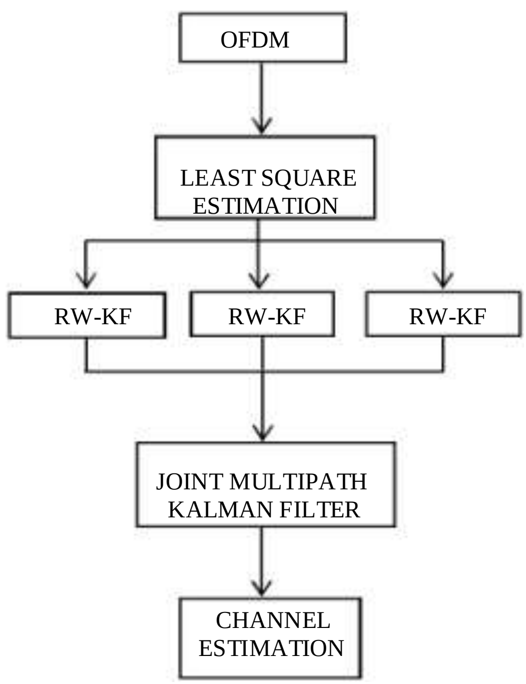

Fig.1 Block diagram of per-path kalman filter structure.

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Where XP,YP and WP corresponds to sent, received data symbol and the channel noise on pilot subcarriers. The pilot symbol is a symbol in which all or parts of its subcarriers are previously known. To obtain channel state information, pilot symbols are inserted in each OFDM symbol. OFDM is a high rate transmission technique that mitigates intersymbol interference (ISI) through insertion of cyclic prefix at transmitter and receiver. To track fast varying channel, pilot symbols are inserted to facilitate channel estimation.

2) LEAST SQUARE ESTIMATOR (LS)

After designing an OFDM system with fast fading condition, the least square estimator is used to estimate the noise in designed OFDM system. The Recursive Least Square filter (RLS) is used to estimate the LS criterion. Using the least square criterion, noise is calculated for a single channel. Then, the channel is divided into subcarriers and the noise is calculated for every sub channel using the least square criterion. The least square estimation is given as

$$\alpha^{(1)}{}_{LS(K)}= \alpha_K{}^{(1)}+W^{(1)}{}_{LS(K)} \text{ ....(3)}$$

Where $\alpha^{(1)}$ and $W^{(1}$ corresponds to complex amplitude and noise for the l paths. The advantage of dividing a channel into sub channel is data rate can be increased by transmitting independent data streams through multiple transmits antennas. The Recursive Least Square algorithm is used to estimate the least square criterion. It is an algorithm which minimizes the mean square error. This is in contrast to other algorithm the input signals are considered as deterministic and for LMS and other algorithms the signals are considered stochastic. Compared to many algorithms, the RLS exhibits fast convergence

3) RANDOM WALK MODEL BASED KALMAN FILTER

In this, less complex per-path RW-KF structure is used that is based on independent processing of the paths. Random walk model is first designed for three orders such as RW-1, RW-2 and RW-3. A kalman filter for a single path is proposed to filter the noise using LS estimator. Based on this, the global per-path KF for the L path is calculated. The equation of joint multipath kalman filter is given as

$$Y_P{}^{(K)}=F_S\alpha^{(K)}+W_P{}^{(K} \text{ ………………………..(4)}$$

Where Fs=FpS and S is the selection matrix. The basic concept of Random walk model in OFDM is when the signal is transmitted from transmitter to receive the signal can take any path to reach the destination. There is no limit for the signal to be transmitted. Filtering is a desirable factor and it is an effective method in radio communication system. As wireless signals are often corrupted with noise, a good filtering algorithm is necessary to remove the noise. The Kalman filter is an effective method to remove the impurities in linear systems. It is also used to estimate the past, current and future states. It is a mathematical equation which provides an efficient computation to estimate the state of a process.

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4) JOINT MULTIPATH KALMAN FILTER

After removing the noise based on random walk-kalman filter (RW-KF), all the paths are joined which is called joint multipath kalman filter. The comparison is done between per-path kalman filter and joint multipath kalman filter.

5) CHANNEL ESTIMATION

The main objective of this work is to estimate a channel. Channel estimation is an important part in communication system. It is simply defined as the process of characterizing the effect of the physical channel on the input sequence. If the channel is linear, the channel estimate is simply the estimate of the impulse response of the system. A good channel estimate is one where some sort of error minimization criteria is satisfied (e.g. MMSE).Here, fast fading channel is estimated with a minimum amount of error.

III. RESULTS AND DISCUSSION

In this section, the performance of the proposed method will be evaluated by signal to noise ratio (SNR) versus Mean square error (MSE) in different scenarios. We assume a scenario with the following settings: The number of subcarriers Ns = 128, pilot signals Np=16.

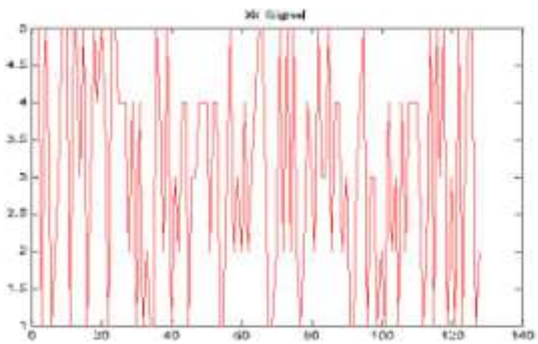

Fig.2.Input signals of OFDM systems

The input signal of OFDM system is shown in fig 2. The input signal is generated randomly with 128 subcarriers and step size is calculated corresponding to the input signal

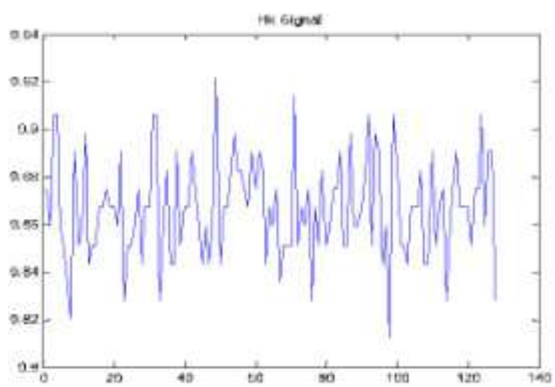

Fig.3.Fast fading channel signal

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The fast fading channel signal i.e. Hk signal is shown in fig 3. The output signal is generated by modulating the generated input signal.

The output signal is shown in fig 4 by applying convolution to the input signal with the modulated signal. From the graph, it is shown that output signal is generated with 128 subcarriers.

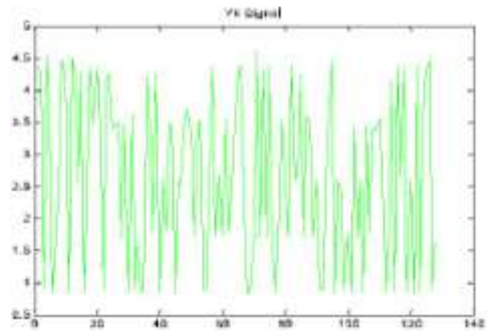

Fig.4. Output signal

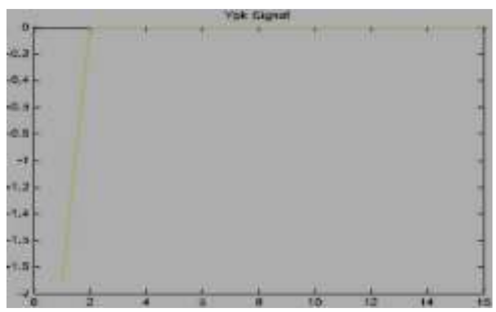

Fig.5. Output of OFDM system after adding the pilot signals.

The output signal of OFDM system is shown in fig.5. The Fourier transform for pilot signal and the diagonal value of input signal is calculated. By taking the Fourier transform of pilot signal and by reshaping the diagonal value of these signal the graph is generated

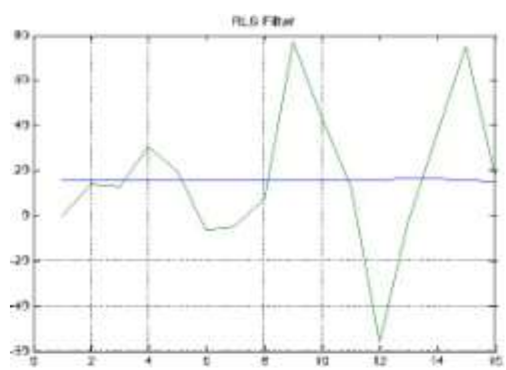

Fig.6 Output of least square estimation

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The output of least square estimation is shown in fig.6. The graph is plotted for the generated output signal (Ypk signal) with 16 subcarriers. The curve indicates the least square estimated signal

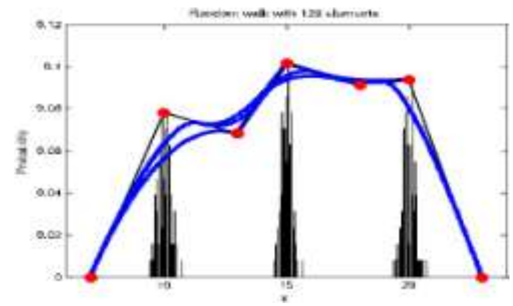

Fig.7.Output of Random walk model

The Random walk model output is shown in fig.7. The random walk model is used in three orders. The dot indicates the position where kalman filter has to be applied and error metric has to be calculated within this bounded region. The curve indicates the random walk pathway

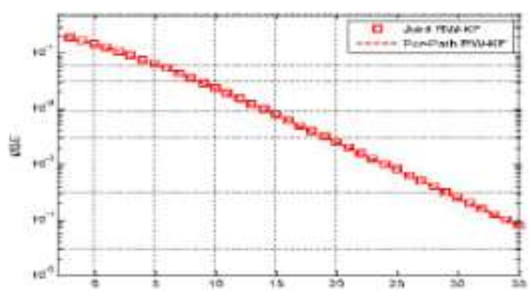

Fig.8.Output of per-path and joint random walk kalman filter

The comparison of per-path and joint random walk kalman filter is shown in fig 8.From the figure it is shown that the output of both per-path and joint RW-KF remains same. This shows the efficiency of Per-path kalman filter

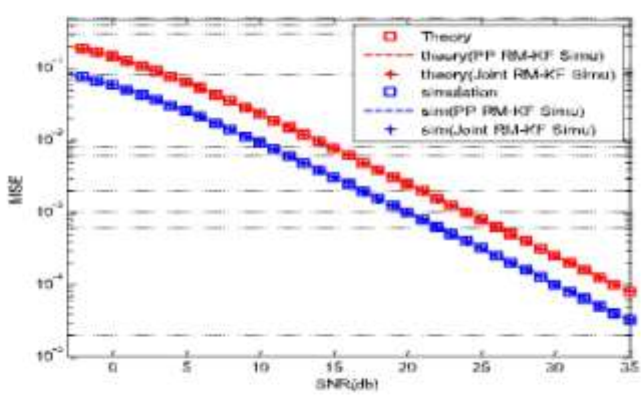

Fig.9. MSE of per-path RW-KF versus joint RW-KF for theoretical versus simulation.

The output of per path and joint multipath kalman filter for theoretical versus simulation is shown in fig 9. From the figure, it is shown that the noise ratio is greatly reduced in simulation value compared to theoretical graph.

IV. CONCLUSION

This paper proposes the use of per-path random-walk kalman filter (RW-KF) in OFDM system. In this work, multipath channel estimation for OFDM under fast fading condition is proposed. The use of per path KF solution explores the time-domain correlation of the channel, while the Least Square step exploits the frequency-domain correlation of the channel. The proposed per-path KF is shown to be efficient as the exact kalman filter (i.e. joint multipath kalman filter). Simulation results show that the output of per-path kalman filter is almost as same as joint multipath kalman filter. This result shows that the efficiency of per-path kalman filter.

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