An Adaptive Blind Channel Estimation of OFDM System by Worst Case H_∞ Approach

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Abstract

The aim of this paper is to estimate the Channel characteristics of OFDM communication system by using worst case H_∞ approach and comparing the result with existing Kalman [6] *and H_∞ channel estimators* [8]. *This estimation criterion is different from kalman filter. These two algorithms fail because of more updation parameters like V, W and Q. In order to estimate the signal without updating factors, we are proposing this worst case H-infinity approach in which V and W are considered as worst case values (maximum). In this approach V and W are updated only once for entire recursive estimation process. This method improves the performance even for high data rate also.*

Keywords: *Kalman Filter, H_∞ approach, Updation parameters*

1. Introduction

The high demand for a large volume of multimedia services in wireless communication systems requires high transmission rates [1]. However, high transmission rates may result in severe frequency selective fading and inter symbol interference (ISI), when the Bandwidth of the transmitted signal is large compared to the coherence bandwidth of the channel. Orthogonal frequency division multiplexing (OFDM) has been proposed to combat these types of channel disturbance. A proper channel estimation algorithm for the OFDM systems should capture both the time and frequency domain characteristics. This channel estimation is done in time domain by considering the channel fading factors.

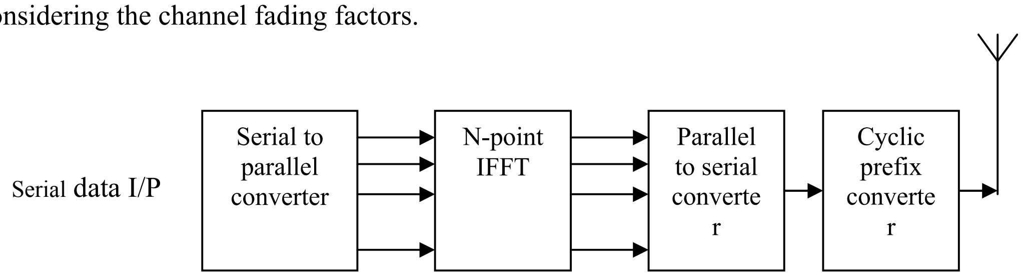

Figure 1. Basic Transmission Section of OFDM

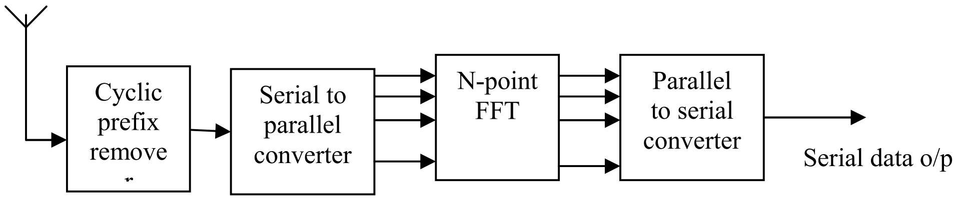

Figure 2. Basic Receiving Section of OFDM

2. Overview of OFDM communication system

OFDM is multicarrier transmission technique, where the spacing between two adjacent carriers is identical to the inverse of the symbol period. To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required based on the input data. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. Finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components, does this. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. OFDM has several advantages like less inter symbol interference, simplicity of channel equalization, efficient use of spectrum, etc.

3. Introduction to channel estimation procedures

The channel estimation procedure considers a Radio communication system in which training sequences are sent periodically to form data based estimates of the channel. The channel is assumed to be invariant over the time span of the training sequence being sent over the channel. This, in general is undesirable since any such increase would result in more waste of channel bandwidth, which is better utilized for sending data rather than training information. The channel estimation algorithm presented in this section improves on the data based estimate without decreasing channel throughput. Impairments in a wireless channel are unknown and most likely time-variant. Methods that do not depend on precise knowledge of the channel characteristics should be more effective and robust for performing the channel. In the designs of channel estimators in which the estimator gains are optimized using a minimum error variance criterion [6] (the Kalman filtering approach) and a minimum estimation error spectrum criterion [8] (the mod H_∞ filtering approach) are presented. The Kalman approach is a covariance minimization problem while the mod H_∞ approach is a minimization problem where the maximum “energy” of the estimation error of overall disturbances is minimized.

3.1 Briefing about kalman filtering

The kalman filter is a tool that can estimate the variables of a wide range of processes. In mathematical terms we would say that a kalman filter estimates the states of a linear system. The kalman filter not only works well in practice, but it is the one that minimizes the variance of the estimation error. In order to use a kalman filter to remove noise from a signal, the process that we are measuring must be able to be described by a linear system. Kalman filter is an optimal recursive linear estimator. It processes all available measurements, regardless of their precision, to estimate the current value of the variables of interest with use of knowledge of the system noises, measurement errors and any available information about initial conditions of the variables of interest.

Estimation of a random vector *Y* based on all observations at once, it is often beneficial to estimate ***Y*** from a subset of the observations and then update the estimator with new observations. This is done recursively with observation random vectors $\boldsymbol{X_0}$, $\boldsymbol{X_1}$, $\boldsymbol{X_2}$… An initial linear estimator for ***Y*** is based on $\hat{X}_0$; this initial estimator is used in conjunction with $\boldsymbol{X_1}$ to obtain the optimal linear estimator based on $\hat{X}_0$ and $\hat{X}_1$; and this procedure is recursively performed to obtain linear estimators for ***Y*** based on $\boldsymbol{X_0}, \boldsymbol{X_1} \dots \boldsymbol{X_j}$, for j= 1, 2… It is used in the recursive estimation of time varying signals

3.2 Briefing about H-Infinity filtering process

A robust H-infinity channel estimation algorithm is proposed to estimate the channel fading in the time domain. The H-infinity approach differs from the traditional approach such as the Kalman estimation in the following two respects.

- No a prior knowledge of the noise source statistics is required. The only assumption is that the noise has finite energy.
- The estimation criterion is to minimize the worst possible effect in the estimation error (including channel modeling error and additive noise).

3.3 Equations related to the H-infinity and kalman filter

Let us recall that the Kalman filter estimates the states x of a linear dynamic system [4], defined by the equations

$$x_{K+1} = Ax_k + Bu_k + w_k \quad \dots\dots (1)$$

$$y_K = Cx_k + z_k \quad \dots\dots. (2)$$

Where A, B, and C are known matrices; k is the time index; x is the state of the system (unavailable for measurement); u is the known input to the system; y is the measured output; and w_k and z_k are noise. The two equations represent what is called a discrete time system, because the time variable k is defined only at discrete values (0, 1, 2…). We cannot measure the state ***x*** directly; we can only measure ***y*** directly. In this case we can use a Kalman filter to estimate the state ***x***. The state equations of kalman filter given as follows:

$$K_k = AP_kC^T\left(CP_kC^T + S_z\right)^{1} \quad \dots\dots. \quad (3)$$

$$\hat{x}_{k+1} = \left(A\hat{x}_k + Bu_k\right) + K_k\left(y_{k+1} \; C\hat{x}_k\right) \dots (4)$$

$$P_{k+1} = AP_kA^T + S_w \; AP_kC^TS_z^{1}CP_kA^T \dots (5)$$

Where $\mathbf{S_w}$ and $\mathbf{S_z}$ are the covariance matrices of w and z, K is the Kalman gain, and P is the variance of the estimation error. The Kalman filter works well, but only under certain conditions. First, the noise processes need to be zero mean. The average value of the process noise, w_k, must be zero, and the average value of the measurement noise, z_k, must also be zero. This zero mean property must hold not only across the entire time history of the process, but at each time instant, as well. That is, the expected value of w and z at each time instant must be equal to zero. Second, we need to know the standard deviation of the noise processes. The Kalman filter uses the S_w and S_z matrices as design parameters (these are the covariance matrices of the noise processes). That means that if we do not know Sw and Sz, we cannot design an appropriate Kalman filter. The attractiveness of the Kalman filter is that it results in the smallest possible standard deviation of the estimation error.

3.4 Channel estimator (objective function of H-infinity approach)

The problem formulation of H_∞ approach will start as $\min_x \max_{W,V} J$ where J is some measure of how good our estimator is. We can view the noise terms w and v as adversaries that try to worsen our estimate. Think of w and v as manifestations of Murphy's Law: they will be the worst possible values. So, given the worst possible values of w and v, we want to find a state estimate that will minimize the worst possible effect that w and v have on our estimation error. This is the problem that the H infinity filter tries to solve. For this reason, the H infinity filter is sometimes called the minimax filter; that is, it tries to minimize the maximum estimation error. We will define the function J as follows:

$$J = \frac{ave\left\|x_k \quad \hat{x}_k\right\|_Q}{ave\left\|w_k\right\|_W + ave\left\|v_k\right\|_v} \quad \ldots\ldots (6)$$

Where the averages are taken over all time samples k. In other words, we want to find that minimizes *J*, so we want to find that is as close to x as possible. But nature tries to maximize *J*, so we want to find noise sequences **W** and **V** that cause our estimate to be far from the true state x. The previous equation is the statement of the H infinity filtering problem. Our task is to find a state estimate that makes *J* small even while noise terms that make *J* large. The **Q**, **W**, and **V** matrices that are used in the weighted norms in *J* are chosen by designer, to obtain desired trade-offs. For example, if we know that the **W** noise will be smaller than the **V** noise, we should make the **W** matrix smaller than the **V** matrix.

3.5 Worst case channel estimator (objective function of H-infinity approach)

The cost function generally defined for H_∞ is given as (6). In this so many tuning parameters are observed like **Q**, **W** and **V**. For every time, we need to update these tuning parameters which is complicated for high data transmission. So, the denominator of H_∞ cost function is approximated with worst case values of **V** and **W**. These are considered as $\mathbf{V^1}$ and $\mathbf{W^1}$ instead of average values. Then the worst case cost function becomes

$$J_{Opt} = \frac{ave\left\|x_k - \hat{x}_k\right\|_Q}{\left\|w'\right\|_W + \left\|v'\right\|_v} \quad \ldots. (7)$$

This process repeats like 3.4 for k number of samples. Always equation (7) gives better performance than (6) because we are considering worst case values initially without updation every time. At any time, for any sample $J_{opt} < J$. With this worst case designing better optimum estimation is obtained.

4. Design approach

The design flow for implementing ODFM and estimation of OFDM was realized on MATLAB environment starting with random input data as input. High data rate signals should be passed through OFDM system analyze this data rate compatibility for different channel estimation algorithms mainly concentrate towards worst case H_∞, how best estimate the characteristic of channel and the performance is compared with existing Kalman filter and H_∞ filter. So with this proposed worst case H-infinity approach better result will be obtained, so, enhanced H-infinity approach cost function J is varied according to given data rate.

The simulation shown is evaluated with variation in channel noise strength and varying the fading strength in the channel. The system is evaluated keeping the SNR low and high with the increase in fading strength and decreasing in the fading strength. In this result analysis is evaluated for 2 cases by using Effect of Input SNR, Effect of BER.

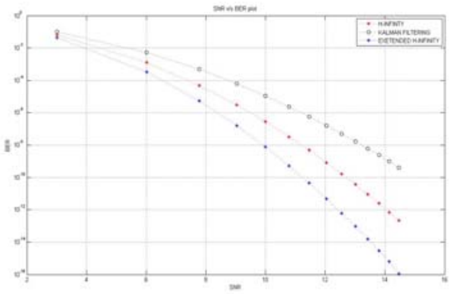

Figure 3. SNR v/s BER Plot

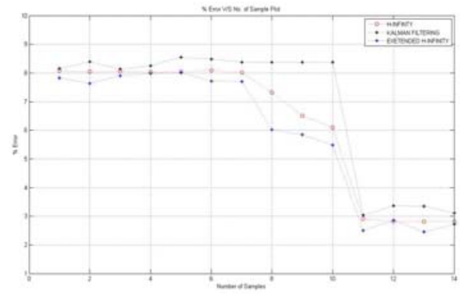

Figure 4. % error v/s samples

Table 1.

SNR Value	BER of kalman	BER of H_∞	BER of extended H_∞
At 6 db	$10^{-2.5}$	10^{-3}	$10^{-3.5}$
At 10 db	10^{-5}	$10^{-6.5}$	10^{-8}
At 12 db	10^{-7}	10^{-9}	10^{-11}

Table 2.

Number of samples	%error of kalman	%error of h-infinity	%error of extended h-infinity
At 2	8.5	8.1	7.7
At 8	8.25	7.4	6
At 14	3.2	2.9	2.7

5. Conclusion

In the result analysis 2 cases are studied, in each case simulation results gives analysis between % error vs. No. of samples and BER vs. SNR. All the cases are analyzed by effect of input SNR and channel noise characteristics. From the simulation results we can conclude that

1. With an increase in input SNR, the mean-square-error performance of worst case H_∞, H_∞ and Kalman estimation algorithms improves.
2. The worst case H_∞ estimation algorithm outperforms the Kalman and H_∞ estimation algorithms over all the SNR range is considered.

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