Reduction of Computational Complexity in Adaptive Estimation of Multipath Non-stationary Channels

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ABSTRACT:
The operation of a wireless system depends on obtaining an accurate estimation of the channel. Moreover, the cyclical changes of the system resulting from a nonsyncronousness of the receiver and transmitter carrier frequencies can affect the operation of the estimator that is used to estimate channel parameters. The adaptive filters techniques are suitable for detecting this carrier frequency offset and channel changes in mobile communication receivers. Studies of the operation of adaptive filter algorithms to estimate the ability of non-stationary channel algorithms have always been a lively research area. This study uses QAM in analyzing MIMO-OFDM system operation to show that system operation has improved. A review of the results from simulations reveals that this procedure has significantly reduced computational complexity while having maintained system operation using low-pass filtering in time domain to reduce the effects of inter-symbol interference and noise in each cycle. Simulated results show that this is a very useful method to use in next generation wireless and modern cellphone (4G) systems.

KEYWORDS: MIMO, OFDM, inter-symbol interference, channel estimation, QAM modulation

1. INTRODUCTION

An increasingly high demand for wideband services such as access to high speed internet and HD voice and image transmission, wireless communication is complementing its third generation to upgrade to next generations that make wideband wireless communication possible. Several goals have been defined for such new systems including the design of smaller, cheaper cellphones, a frequency spectrum with high efficiency, an accepted standard at world level and user mobility. In fact, the final goal is to establish wideband communication anytime, anyplace. Due to their many transreceiver antennas, MIMO systems have a large spatial diversity. On the other hand, wireless systems are functionally limited since the signals sent by satellite are prone to propagation loss, fading in channel, multi-user interference (MUI) and limited ability in wireless equipment all creating a serious barrier against rate improvement. The effects of wireless media can be classified as path loss or attenuation, large-scale fading and small-scale fading [3]. Path loss indicates mean signal strength loss with an increase in the distance of the receiver from the transmitter. However, fading shows the fluctuations of the signal range transmitted along its path from the transmitter to the receiver. Large-scale fading shows signal range changes along longer distances, e.g. many kilometers. Such fading is a result of random appearing and disappearing of obstacles between transmitter and receiver which is why it is also referred to as shadowing effect. This effect is usually considered with normal logarithm distribution. This article studies the principles of flat fading in MIMO systems. OFDM is especially capable in reducing the multi-path effect. In the past decade, OFDM systems have been given much attention for their abilities in fast transmission of data. In OFDM, a wideband signal is divided into many parallel narrowband signals and then modulated on orthogonal subcarriers for transmission. An interesting, important characteristic of OFDM systems is their resistance against frequency selective channels. In an OFDM system, a frequency selective channel estimation and equalization simpler to a great extenct, i.e. an OFDM symbol includes a total of N modulated symbols for whose modulation methods such as QAM or PSK have been used [1], [2].

2. OFDM SIGNAL

When a wideband signal passes through a selective frequency channel, a large part of the signal is lost due to deep fading in the channel. But, when a wideband signal is modulated as OFDM, the frequency spectrum will be as a combination of the orthogonal narrowband signals shown in the figure. Therefore, when an OFDM signal passes through the selective frequency channel, only the narrowband signals will be affected at the fading spot, and it can be observed that each band signal experiences flat fading. In addition, in OFDM systems, the bandpasses of subcarriers may overlap each other due to orthogonality of subcarriers. This characteristic gives us the possibility to put subcarriers in a given spectrum band in a denser way and access to a higher spectrum gain. With today's advancements in processing digital signals, the OFDM system can be implemented to use IFFT for modulation and FFT for demodulation.

The block diagram of a general OFDM system structure is shown in the figure. It can be seen in the block diagram that the set of input datais modulated using certain modulation techniques such as PSK or QAM and then, the modulated signal, X(k) (where k=0,…,N; N being the number of subcarriers) is transformed to parallel signals and passes through the IFFT block. The IFFT operator modulates the parallel signals on orthogonal subcarriers. The signals of the narrowband output will be as follows:

$$x(k)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}X(n)e^{\frac{j2\pi}{N}},0\le k\le N-1 \qquad (1)$$

When an OFDM signal passes through the channel, what signal will experience ISI and ICI. The ISI effect is a result of channel delay spread while ICI happens through a removal of the orghogonality of subcarriers due to channel's frequency response. In order to limit the ISI and ICI effects, a cyclic prefix as long as NCP is added in front of the signal, NCP being longer than the channel order, giving the signal a final general length of N+NCP. This cyclic prefix is removed from the end of the signal and added to its beginning. Finally, to retrieve data in the receiver, the reverse of the above operation is done. The result is, that symbol length will be larger by time N than the carrier signal having the same symbol length.

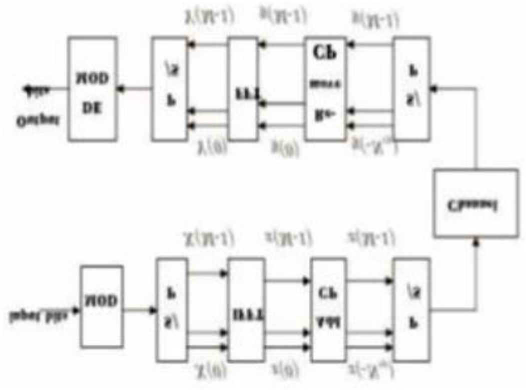

Fig.1. MIMO-OFDM system model

OFDM has been used in IEEE802.16a LAN/MAN and IEEE802.11a LAN [7]. In IEEE802.20a standards, too, OFDM has been used to maintain users bandwidth while moving at 60 mi/h. In reality, as well as in IEEE802.11a LAN, the raw data rate is 54 Mb/s of the total 20 MHz channel width; therefore, OFDM has resulted in bandwidth economy [6].

3. MIMO-OFDM SYSTEM MODEL

ODFM systems are a useful technology in the physical layer owing to their high spectrum efficiency and low computational complexity. On the other hand, MIMO systems can, depending on how the system is implemented, improve capacity, coverage or communication reliability. Thus, it is evident that combining OFDM with MIMO will improve a system's operation and output. Figure 1 shows a sample MIMO-OFDM system. This system includes Mt, transmitter antenna, and Mr, receiver antenna. During the time t, a block of binary input data is modulated, coded after passing through MIMO, and Mt data length is produced in several antennas for transmission. Each of the Mt data lengths is classified in blocks measuring N in length, and then OFDM is employed for transmission in MIMO channels. The signal received in each antenna will be a combination of all the signals in different paths plus noise. The noise process is a white, Gaussian noise with zero mean and (σn2) variance. Let's suppose that signal and noise are independent of each other. This is a possible supposition used in most works [4], [5].

4. MODEL PRESENTATION

This article supposes that the OFDM signal in each antenna is obtained from IFFT and FFT. The MIMO-OFTM symbol received with the nth subcarrier and mth OFDM symbol from ith receiver antenna after FFT can be written as follows:

$$x(k)=\sum_{j=0}^{N}H_{i,j}[n,m]\,A_j[n,m]+W_i[n,m] \qquad (2)$$

Where AJ[n,m] is the transmitted symbol with the nthcarrier and mth OFDM symbol, wi[n,m] the effect of noise increase in the ith receiver antenna for the corresponding symbol in the frequency domain, and Hj[n,m] the channel coefficient in the frequency domain in the jthantenna of the receiver. Channel coefficients in frequency domain have been calculated using linear combinations of channel diffraction.

$$H[n,m] = \sum_{i=0}^{I-1} h_i[m] e^{\frac{-j2\pi\tau_i n}{T}} \quad (3)$$

$$n = 0,\ldots,N-1$$

Where I is the channel split number in time domain, and [m]h is modeled as zero mean independent. The impulse response of the channel with Rayleigh fading can be expressed as follows:

$$h(t,\tau) = \sum_{j=0}^{I-1} h_i(t)\delta(\tau - \tau_i(t)) \quad (4)$$

Where hi is split gain, and τi is the delay for the ith split. This delay can be considered variable with time. The channel impulse response is supposed static along one OFDM symbol. ‘TCHANNEL=T+T where T is OFDM symbol delay and ‘T is cyclic prefix duration. This relates to the slower changes of the channel where coherence is longer than the channel symbol time. This supposition prevents inter-carrier interference (ICI) of the channel. Channel matrix, H, is an NxM matrix related to the nth subcarrier and mth OFDM symbol.

$$\bar{H}[n.m] = \begin{bmatrix} & H_{1,1}[n,m] & H_{1,2}[n,m] & \\ & \ldots & H_{1,N}[n,m] & \\ H_{2,1}[n,m] & H_{2,2}[n,m] & \ldots & H_{2,N}[n,m] \\ \vdots & \vdots & \ddots & \vdots \\ H_{M,1}[n,m] & H_{M,2}[n,m] & \ldots & H_{M,N}[n,m] \end{bmatrix} \quad (5)$$

5. PROPOSED METHOD ANALYSIS

Considering the data symbols received from all antennas, the data symbol expression can be shown as the following matrix:

$$\bar{R}[n,m] = \bar{H}[n,m]\bar{A}[n,m] + \bar{W}[n,m] \quad (6)$$

Where the matrix Ā[n,m] is shown as:

$$\bar{A}[n,m] = [A_1[n,m] \quad A_2[n,m] \ldots A_N[n,m]]^T \quad (7)$$

And the matrix Ṛ[n,m] is shown as:

$$\bar{R}[n,m] = [R_1[n,m] \quad R_2[n,m] \ldots R_M[n,m]]^T \quad (8)$$

In the above equations, Nx1 and Mx1 are transmitted and received symbols. In order to calculate the transmitted symbols in (5), the following equation called the MIMO-OFDM equation must be solved first [5].

$$\bar{A}[n,m] = \bar{H}[n,m]^{-1} \quad (\bar{R}[n,m] + W[n,m] \quad (9)$$

This equation works well with low noise and in total absence of ISI and ICI. When ISI and ICI are present in the received signal, the following equation can be used:

$$\begin{aligned} \bar{R}[n,m] &= \sum_{j=1}^{N} R_{j,i}^{U}[n,m] \\ &+ \sum_{j=1}^{N} R_{j,i}^{ICI}[n,m] \\ &+ \sum_{j=1}^{N} R_{j,i}^{ISI}[n,m] \\ &+ W\ [n,m] \\ &= C(K) + I(K) \end{aligned} \quad (10)$$

Where (c)K equals

$$\sum_{j=1}^{N} R_{j,i}^{U}[n,m] \quad P_U = E[|C(K)|^2] \quad (11)$$

Showing the transmitted MIMO-OFDM signal. (K)I indicates the effect of interference in signal. The effective power and interference power are expressed as

$$P_I = E[|I(K)|^2] \quad (12)$$

The results from BER operation simulation in the proposed method of MIMO-OFDM receiver is shown by simulating a 2*2 system with two transmitter and two receiver antennas. Data bits are modulated in each transfer cycle with convolution rate ½ coding and length limitation G=[133-171] as QAM, and the coding after prefix up to 48 data carrier and from 64 points of OFDM system is written according to IEEE and a802.11 standards.

In order to improve the operation of the receiver, the length of the cyclic prefix is selected higher than all the frequencies and, additionally, more than 10 consecutive OFDM symbols taken as equal to 474 bits of information in each codeword. Carrier frequency and velocity in medium are set at 5.2 GHz and 50 km/h respectively leading to a maximum Doppler frequency of 240 Hz. The Rayleigh channel has been selected as the fading model. The common characteristics of wireless networks, such as noise, multi-path fading and cut-off can be studied by simulating the channel. a simple noise has been simulated by adding random data to transmitted signals. Multi-path simulation is done by adding weaker and delayed editions of signals transferred to the main text. Although OFDM successfully prevents ISI, it does not suppress channel fading. Transmitted data are carefully protected using symbol division techniques and programming in frequency and time domains. This will improve through other advanced techniques, such as adaptive modulation and power allocation. The following diagram shows the carrier signal domain – interference ratio in a 2*2 (MIMO-OFDM) system.

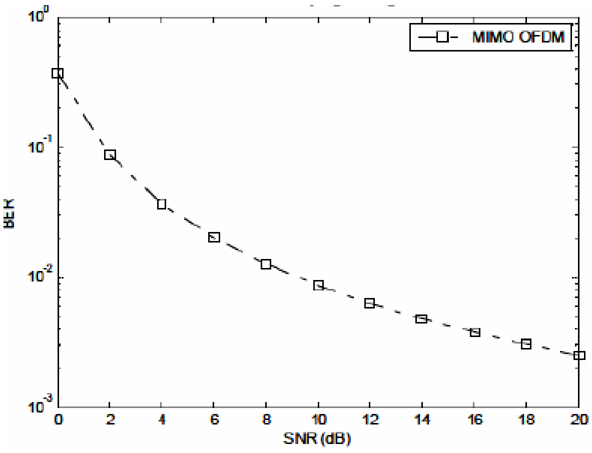

Fig. 2. BER diagram in 2*2 MIMO-OFDM system with Rayleigh fading

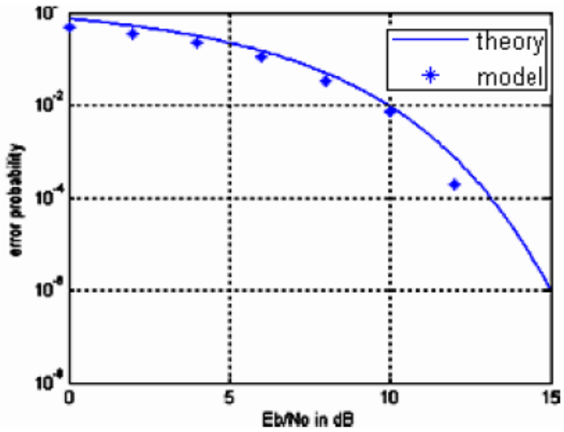

Fig. 3. Error probability in proposed model

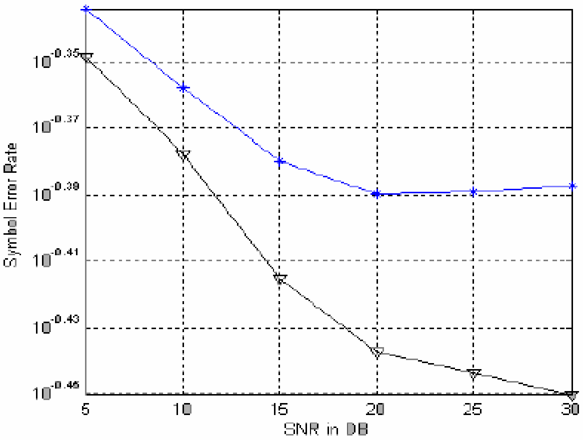

Fig. 4. SER comparison in proposed model

6. CONCLUSION

A new model of MIMO-OFDM has been offered and simulated. In wideband wireless systems, using OFDM technology significantly reduces receiver complexity. A combination of MIMO and OFDM is an attractive way for future wireless wideband systems.

It has recently been shown that the MIMO-OFDM technology offers a large potential to achieve very high data rates. This article analyzes the MIMO-OFDM system operation using QAM in channel with Rayleigh fading. The results from simulations show that the system offered in this study has less final errors compared to previously offered systems. Also, the computations of this system are simpler than previously modeled systems and the answer is found faster.

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