Fast MIMO-OFDM Channel Gain Estimation for Mobile Velocity

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***Abstract*—This paper proposes a fast MIMO-OFDM channel gain estimation method using the Kalman filter with the colored driving source. The remarkable feature of the proposed method is the realization of the fast MIMO-OFDM channel gain estimation using only the Kalman filter without the concept of the AR system.**

I. INTRODUCTION

A Kalman filter based a MIMO channel gain estimation method consists of the two stages: (i) the parameter estimation of the AR (auto-regressive) system and then (ii) the channel estimation using Kalman filter algorithm [1]. However, this traditional method is greatly influenced by the estimation accuracy of the parameter of the AR system.

This paper, thus, proposes the robust MIMO-OFDM channel gain estimation method without the concept of the AR system for the mobile communication.

II. PROPOSED CHANNEL GAIN ESTIMATION METHOD

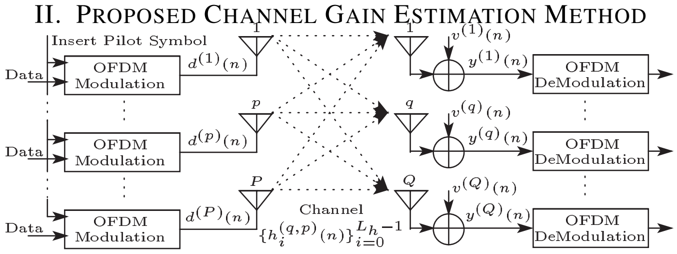

Fig. 1. MIMO-OFDM communication system

As shown in Fig. 1, the MIMO-OFDM channel gain estimation problem is to get the $QPL_h \times 1$ channel gain vector $\boldsymbol{h}(n)$ from the $Q \times 1$ received signal vector $\boldsymbol{y}(n) = [y^{(1)}(n), y^{(2)}(n), \cdots, y^{(Q)}(n)]^T$ [2]:

$$\boldsymbol{y}(n) = D(n)\boldsymbol{h}(n) + \boldsymbol{v}(n) \qquad (1)$$

where $D(n)$ denotes the $Q \times QPL_h$ MIMO-OFDM signal matrix and $\boldsymbol{v}(n)$ the $Q \times 1$ observation noise given by the AWGN.

The purpose of the proposed method is to achieve the channel gain estimation using the canonical state space models including (i) *a state equation* composed of the channel gain, and (ii) *an observation equation* composed of the MIMO-OFDM signal, the channel gain, and the AWGN.

When the $QPL_hL_p \times 1$ state vector is defined as $\boldsymbol{x}(n) = [\boldsymbol{h}^T(n), \cdots, \boldsymbol{h}^T(n-1), \cdots, \boldsymbol{h}^T(n-L_p+1)]^T$, we give *the state equation*:

$$\text{[The state equation]} \quad \boldsymbol{x}(n+1) = \Phi\boldsymbol{x}(n) + G\boldsymbol{\delta}(n+1) \qquad (2)$$

where the $QPL_hL_p \times QPL_hL_p$ state transition matrix Φ is lower shift matrix, the $QPL_hL_p \times QPL_p$ matrix $G = [I_{QPL_h \times QPL_h}, O_{QPL_h \times QPL_h(L_p-1)}]^T$, and the $QPL_h \times 1$ driving source vector $\boldsymbol{\delta}(n+1) = \boldsymbol{h}(n+1)$ is *colored signal*. (Here, I_A denotes the $A \times A$ unit matrix, and $O_{A \times B}$ the $A \times B$ zero matrix.)

The observation equation may be expressed from Eq.(1):

$$\text{[The observation equation]} \quad \boldsymbol{y}(n) = M(n)\boldsymbol{x}(n) + \boldsymbol{\epsilon}(n) \qquad (3)$$

where the $Q \times QPL_hL_p$ observation transition matrix $M(n) = [D(n), O_{Q \times QPL_h(L_p-1)}]$, and the $Q \times 1$ observation noise vector $\boldsymbol{\epsilon}(n) = \boldsymbol{v}(n)$.

TABLE I. Parameters for simulation.

Number of transmitting antennas	$P = 2$
Number of receiving antennas	$Q = 2$
Subcarrier modulation scheme	QPSK
OFDM Symbol Duration	$T_F = 3.2[\mu s]$
Guard Interval Length	$0.8[\mu s]$
Carrier Frequency	$f_c = 5$[GHz]
Number of Subcarrier	$K = 64$
Fading Model	Rayleigh Fading[3]
Number of Delay Path	$L_h = 2$
AR Model Oder	$L_c = 2$
The length of $\boldsymbol{x}(n)$	$L_p = 2$
Number of Trials	20
SNR	$0, 2, \cdots, 20$[dB]

TABLE II. No. of arithmetic operations for the conv. and the prop. methods.

Procedure	Conv.	Prop.
1.	$2Q^2P^2L_h^2L_c^2$	0
2.	$Q^3+Q^3PL_hL_c$ $+2Q^2P^2L_h^2L_c+Q^2PL_h$	$Q^3+Q^3PL_h+$ $Q^2P^2L_h^2+Q^2PL_h$
3.	$Q^2PL_hL_c+QPL_h(L_c+1)$	Q^2PL_h
4.	0	0
5.	$Q^3P^2L_h^2L_c^2+Q^2P^2L_h^2L_c$	$Q^3P^2L_h^2+Q^2P^2L_h^2$
Total	$Q^3(P^2L_h^2L_c^2+PL_hL_c+1)$ $+Q^2(2P^2L_h^2L_c^2+3P^2L_h^2L_c$ $+PL_hL_c+PL_h)$ $+Q(PL_hL_c+PL_h)$	$Q^3(P^2L_h^2PL_h+1)$ $+2Q^2(P^2L_h^2+PL_h)$

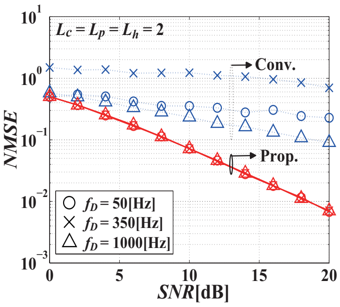

Fig. 2. SNR v.s. NMSE for the conv. and the prop. methods.

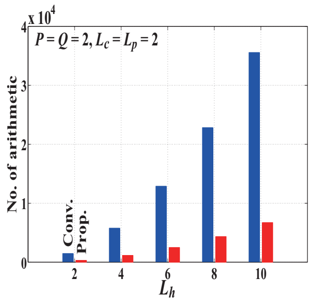

Fig. 3. Computational complexity in arithmetic operations.

III. SIMULATION RESULTS

We compare the proposed method with the conventional method which is a modification of [1] for performance of the MIMO-OFDM channel gain estimation under the condition of TABLE I.

Fig. 2 shows the NMSE (normalized mean square error) [4] of the conventional and the proposed methods for the maximum Doppler frequency $f_D = 50, 350,$ and 1000[Hz] (corresponding to mobile velocity of $10, 75,$ and 216[km/h] respectively). It is seen that the NMSE of the propose method is better than that of the conventional method over all range of SNR and mobile velocity.

TABLE II shows the computational complexity to calculate each procedure for both the conventional and the proposed methods. Fig. 3 also compares the complexity of each method for the delay path L_h. It is clear from TABLE II and Fig. 3 that the proposed method requires less computational complexity compared to the conventional method.

IV. CONCLUSION

This paper has presented the fast MIMO-OFDM channel gain estimation method using only the Kalman filter with the colored driving source. It is clear that the proposed method realizes simple and practical MIMO-OFDM channel gain estimation for various mobile environments.

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