

Coordinate Change and SAG MCMA Equalizer in the Mobile Satellite Communication System

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Abstract— In this paper, we propose the coordinate change schemes for improving the performance of blind equalizer such as MCMA (modified constant modulus algorithm) and SAG (Stop-and-Go) MCMA which compensate for ISI channel effect. ISI (inter symbol interference) is generated due to user's movement in the mobile satellite communication environment. Satellite communication systems do not use pilot signals for channel estimation. Blind equalization techniques such as MCMA and SAG-MCMA are well known that it is possible to estimate and to compensate for channel without pilot signals. It is necessary to improve the blind equalizer performance. Therefore, we propose the coordinate change schemes. We confirm that this proposed method has better MSE performance than that of conventional MCMA and SAG MCMA.

Keywords- Blind equalizer, Coordinate change, MSE performance, MCMA; Stop and Go

I. INTRODUCTION

In digital communication system, it's important to transmit more information data. According to the given power, the amount of information is limited based on information theory. Channel noise and inter symbol interference (ISI) are main factors to limit amount of information. Conventional adaptive equalizations are using the training sequence to estimate the channel characteristic. Through the channel characteristic, we estimate the characteristic coefficient of reverse channel. After then, transmit signals are passed, have a characteristic coefficient of reverse channel, the filter. Using this method, we reduce the ISI and random phase rotation influence. Therefore, the equalization can improve overall performance. Training sequence is promised signal between transmitter and receiver. In other words, training sequence is additional information. So, Bandwidth efficiency is decreased.

In blind equalization method, bandwidth efficiency problem is partially solved because of transmitted signal does not use the training sequence. Many researches about blind equalization have been studied to compensate channel effect using only received signal without the training sequences. Blind equalization of 16-QAM signal through

coordinate change has already been studied [1]. We have to use the blind equalizer if receiver is in mobile status when there is no training sequence. In this blind equalization, it's very important to improve MSE performance to apply the blind equalization in mobile satellite communication system. Coordinate change is improved the equalization performance by reducing the modulus.

In the blind equalization, using the cumulative rate of received signal and using the constant modulus algorithm (CMA) is represented in a way. Inter symbol interference (ISI) and the phase rotation can be restored at the cumulative rate method. However, it requires high-level operation. So, high speed transmission may have a problem as equalization. In the CMA, ISI and phase rotation compensate is impossible at a time. However, this method has the advantage of reduces the amount of computation. CMA equalization method for updating the equalizer coefficients, using the LMS adaptive filtering algorithm the actual implementation is very simple. LMS method the Eigen value distribution of the correlation matrix of the input signal is large; the rate of convergence is slow. CMA blind equalization algorithm is one of the most used techniques.

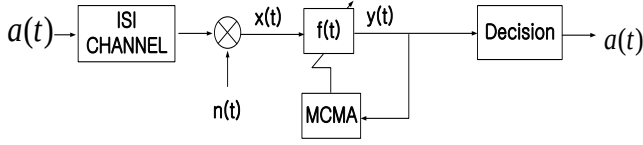
MCMA(modified CMA) can compensate phase rotation problem. The MCMA accomplishes the correction of phase error and frequency offset with the modified cost functions. But, the MCMA does not judge whether the adjustment of tap coefficients is correct or not. Picchi and Prati was define the SAG(Stop and go) algorithm[6]. SAG algorithm is comparing the received signal decision error with the Sato algorithm error. If two error sign is equal, tap coefficient is updated (Go). Another case, tap coefficient is not updated (Stop).

In this paper, we propose 16-APSK coordinate change method and 'stop and go' MCMA method. The propose method is to improve MSE performance because through the coordinate change reduces the modulus and error function. This paper is organized as follows. In section 2, the MCMA and the SAG MCMA are introduced. Section 3 describes the proposed method. Section 4 shows the simulations to evaluate the performance of the proposed system, and finally we can reach to the conclusions.

II. CMA ALGORITHM

A. MCMA algorithm

CMA algorithm is one of the most used algorithms [1]. The MCMA was proposed for correcting phase error based on CMA. Figure 1 shows a block diagram of MCMA.



Block diagram of MCMA blind equalization system.

$a(t)$ is the transmitted signal, $n(t)$ stands for the channel noise. $a(t)$ is the signal after passing equalizer determined.

Input vector is

$$x(t) = [x(t), x(t-1), \dots, x(t-N+1)]^T \quad (1)$$

Equalizer output signal $y(t)$ is as follows.

$$y(t) = f^T(t)x(t) \quad (2)$$

N-tap equalizer coefficients are defined as follows.

$$f(t) = [f_0(t), f_1(t), f_2(t), \dots, f_{N-1}(t)]^T \quad (3)$$

The cost function of MCMA can be expressed as

$$J(n) = E[(\text{Re}(y(n))|^2 - R_{2,R})^2] + E[(\text{Im}(y(n))|^2 - R_{2,I})^2] \quad (4)$$

The following is the error function of the MCMA.

$$\begin{aligned} e_R(t) &= y_R(t)(|y_R(t)|^2 - R_{2,R}) \\ e_I(t) &= y_I(t)(|y_I(t)|^2 - R_{2,I}) \\ e(t) &= e_R(t) + je_I(t) \end{aligned} \quad (5)$$

$s(t)$ is the transmitted symbol, the constant modulus of $R_{2,R}$

and $R_{2,I}$ are given by

$$R_R^2 = \frac{E[|a_R(t)|^4]}{E[|a_R(t)|^2]}, \quad R_I^2 = \frac{E[|a_I(t)|^4]}{E[|a_I(t)|^2]} \quad (6)$$

The tap coefficients are updated through the following equation (7).

$$f(t+1) = f(t) - \mu e(t)x(t) \quad (7)$$

μ is the step size value.

B. Stop-and-Go MCMA algorithm

The MCMA accomplishes the correction of phase error and frequency offset with the modified cost functions. But, the MCMA does not judge whether the adjustment of tap coefficients is correct or not. So we use the Stop-and-go method.

Error function is defined as follow:

$$\begin{aligned} e_R(t) &= y_R(t)(y_R(t)^2 - a_R(t)^2) \\ e_I(t) &= y_I(t)(y_I(t)^2 - a_I(t)^2) \end{aligned} \quad (8)$$

Stop-and-Go algorithm is used two flags, $\hat{f}_R$ and $\hat{f}_I$, to be controlled as follows.

$$\begin{aligned} \hat{f}_R &= \begin{cases} 1 & \text{if } \text{sgn } \hat{e}_R(t) = \text{sgn } e_R(t) \\ 0 & \text{if } \text{sgn } \hat{e}_R(t) \neq \text{sgn } e_R(t) \end{cases} \\ \hat{f}_I &= \begin{cases} 1 & \text{if } \text{sgn } \hat{e}_I(t) = \text{sgn } e_I(t) \\ 0 & \text{if } \text{sgn } \hat{e}_I(t) \neq \text{sgn } e_I(t) \end{cases} \end{aligned} \quad (9)$$

The tap coefficients are updated through the following:

$$f(t+1) = f(t) - \mu u(\hat{f}_R(t)e_r(t) + j\hat{f}_I(t)e_i(t))x(t) \quad (10)$$

III. COORDINATE CHANGE

A. Coordinate Change of 16-APSK

Coordinate change is proposed to be used for 16-APSK signal. 16-APSK is composed of inner circle and outer circle. Inner circle have four symbols and outer circle have twelve symbols. The ratio of the inner circle and outer circle is expressed as follows.

$$\gamma = \frac{R_2}{R_1} \quad (11)$$

γ of 16-APSK signal has a value of 2.85, each symbol has a value of $\{ \pm 1 \pm i, \pm 2.0153 \pm 2.0153i, \pm 2.7529 \pm 0.7376i, \pm 0.7376 \pm 2.7529i \}$. Change method can be seen in Table 1.

We need to obtain angular information before change the coordinate of the signal in the data values. Obtaining the angle is as follows.

$$\theta(t) = \tan^{-1}(y(t)) \quad (12)$$

TABLE I. COORDINATE CHANGE FOR 16-APSK

Original Coordinates	New Coordinates	Original Coordinates	New Coordinates
1+i	-1-i	1-i	-1+i
2.0153+2.0153i	1+i	2.0153-2.0153i	1-i
2.7529+0.7376i	1-i	2.7529-0.7376i	1+i
0.7376+2.7529i	-1+i	0.7376-2.7529i	-1-i
-1+i	1-i	-1-i	1+i
-2.0153+2.0153i	-1+i	-2.0153-2.0153i	-1-i
-2.7529+0.7376i	-1-i	-2.7529-0.7376i	-1+i
-0.7376+2.7529i	1+i	-0.7376-2.7529i	1-i

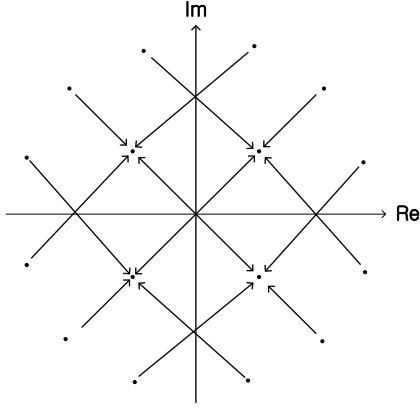
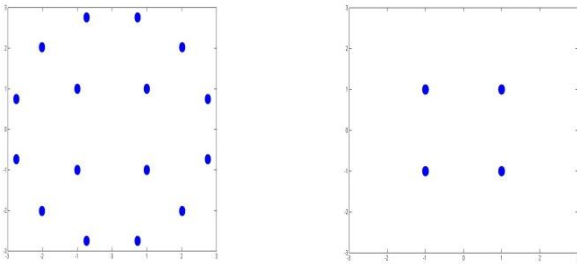


Figure 1. Coordinate change of 16-APSK.

Coordinate change data can be obtained using angle information. Conversion equations are as follows.

$$\begin{aligned}
 & \text{if } ((0 < \theta(t) \leq 30 \parallel (150 < \theta(t) \leq 180)) \& \& |X| \geq 2.13 \\
 & Y = [X_r - 1.7529 \text{sign}(X_r)] + i[X_i - 1.7376 \text{sign}(X_i)] \\
 & \text{elseif } ((0 < \theta(t) \leq 30 \parallel (150 < \theta(t) \leq 180)) \& \& |X| < 2.13 \\
 & Y = X \\
 & \text{elseif } ((30 < \theta(t) \leq 60 \parallel (120 < \theta(t) \leq 150)) \& \& |X| \geq 2.13 \\
 & Y = [X_r - 1.0153 \text{sign}(X_r)] + i[X_i - 1.0153 \text{sign}(X_i)] \\
 & \text{elseif } ((30 < \theta(t) \leq 60 \parallel (120 < \theta(t) \leq 150)) \& \& |X| < 2.13 \\
 & Y = X \\
 & \text{elseif } (60 < \theta(t) \leq 120) \& \& |X| \geq 2.13 \\
 & Y = [X_r - 1.7376 \text{sign}(X_r)] + i[X_i - 1.7529 \text{sign}(X_i)] \\
 & \text{elseif } (60 < \theta(t) \leq 120) \& \& |X| < 2.13 \\
 & Y = X
 \end{aligned} \quad (13)$$

Figure 3 shows the signals of 16-APSK applying (13).



(a) Constellation of 16-APSK. (b) Constellation of 16-APSK after coordinate change.

Figure 2. Coordinate change of 16-APSK.

B. Proposed MCMA algorithm

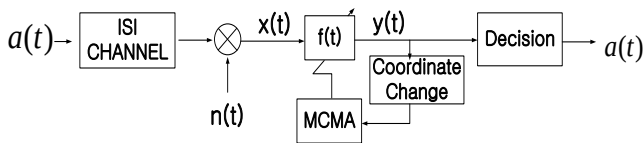


Figure 3. Block diagram of the proposed scheme in MCMA.

Coordinate change of R'^2 is defined as follows.

$$R_R'^2 = \frac{E[|a_R'(t)|^4]}{E[|a_R'(t)|^2]}, \quad R_I'^2 = \frac{E[|a_I'(t)|^4]}{E[|a_I'(t)|^2]} \quad (14)$$

The output signal of the equalizer is

$$y(t) = f^T(t)x'(t) \quad (15)$$

The proposed error function is

$$\begin{aligned}
 e'_R(t) &= y'_R(t)(|y'_R(t)|^2 - R'_{2,R}) \\
 e'_I(t) &= y'_I(t)(|y'_I(t)|^2 - R'_{2,I}) \\
 e'(t) &= e_R(t) + je_I(t)
 \end{aligned} \quad (16)$$

Cost function of the proposed CMA is as follows.

$$J'_{CMA}(f) = E\{e'(t)^2\} \quad (17)$$

The tap coefficients are updated through the following equation.

$$f(t+1) = f(t) - \mu u(f_R(t)e'_R(t) + jfi(t)e'_I(t))x(t) \quad (18)$$

μ means the step size.

C. Proposed SAG MCMA algorithm

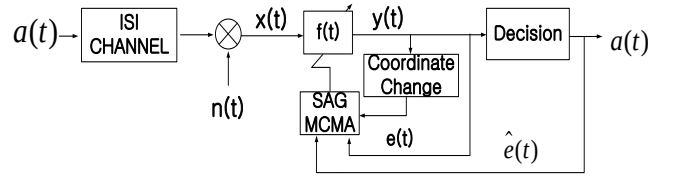


Figure 4. Block diagram of the propose scheme in SAG-MCMA.

Coordinate change of R'^2 is defined as follows.

$$R_R'^2 = \frac{E[|a_R'(t)|^4]}{E[|a_R'(t)|^2]}, \quad R_I'^2 = \frac{E[|a_I'(t)|^4]}{E[|a_I'(t)|^2]} \quad (19)$$

The output signal of the equalizer is

$$y(t) = f^T(t)x(t) \quad (20)$$

The proposed error function is

$$\begin{aligned}
 e_R(t) &= y_R(t)(y_R(t)^2 - a_R(t)^2) \\
 e_I(t) &= y_I(t)(y_I(t)^2 - a_I(t)^2)
 \end{aligned} \quad (21)$$

Cost function of the proposed CMA is as follows.

$$J'_{CMA}(f) = E\{e'(t)^2\} \quad (22)$$

The tap coefficients are updated through the following equation.

$$f(t+1) = f(t) - \mu u(f_R(t)e'_R(t) + jfi(t)e'_I(t))x(t) \quad (23)$$

IV. SIMULATION RESULTS

In this paper, we like to compare the MCMA method with the Stop-and-Go MCMA method. We can find a better MSE performance by coordinate change. We consider Table

2 for analyzing the MSE performance. In the simulation, the ISI channel was used. SNR is 30dB. Equalizer has 21 taps.

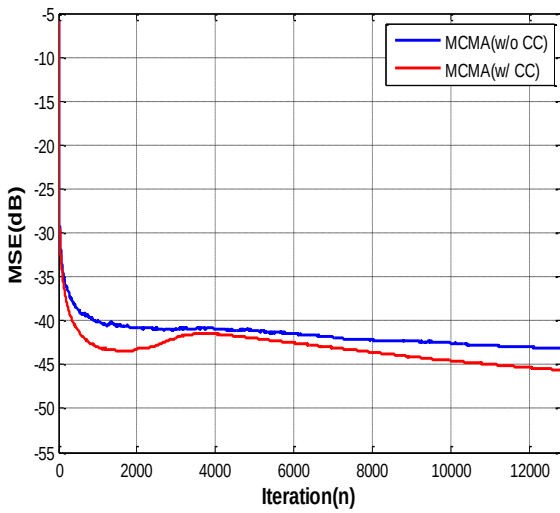
We calculate the MSE by (24) [3].

$$MSE = (h_s - CW) * (h_s - CW) \delta_s^2 + W * W \sigma_w^2 \quad (24)$$

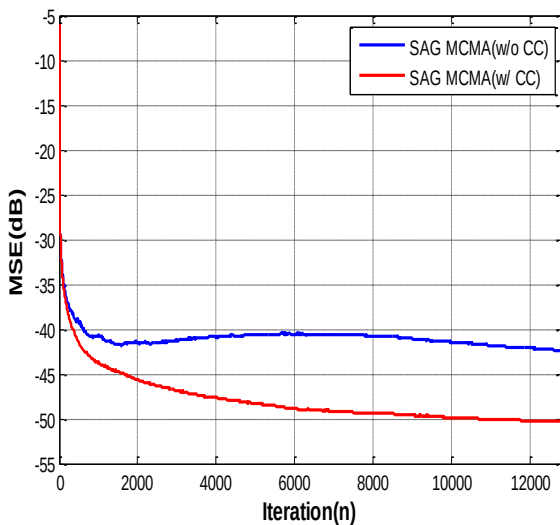
TABLE II. SIMULATION PARAMETERS.

Modulation	16-APSK
Step Size	0.00005
Channel	ISI Channel [0.8, 0.3, 0, 0.2+j0.2, 0, 0]

Figure 5 shows the MSE performance of the proposed method and conventional CMA.



(a) MSE performance of MCMA



(b) MSE performance of SAG MCMA

Figure 5. Comparison of the MSE performances.

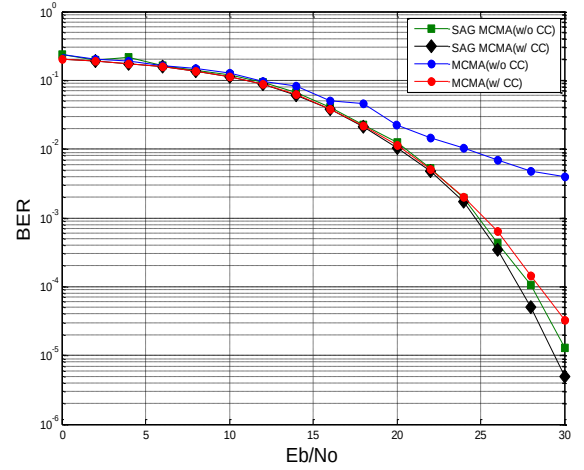


Figure 6. BER performance of the SAG MCMA and the MCMA

V. CONCLUSIONS

In this paper, we propose the Stop-and-Go MCMA algorithm and the coordinate change method to improve MSE performance in 16APSK system. We confirm that the proposed scheme achieves the MSE performance enhancement, compared with that of conventional MCMA blind equalization system at SNR=30dB. SAG-MCMA has better BER performance than MCMA. The proposed scheme has a little error function because modulus value is decreased by using coordinate change. So, SAG-MCMA and MCMA with coordinate change has better receiver performance than that of SAG-MCMA and MCMA without coordinate change.

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