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Prediction method for fading channels based on the diagonal slice of the fourth-order cumulant

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Abstract: In a communication system, to implement adaptive transmission, the channel state information must be available at the transmitter. This paper presents a new algorithm to estimate and predict the state information of fading channel based on the diagonal slice of the fourth-order cumulant. Theoretical analyses and simulation results show that the method proposed can be used to achieve better results than MMSE.

Key words: prediction; communication; cumulant
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基于四阶累积量切片的衰弱信道预测方法

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摘要: 在通信系统中, 为实现自适应传输, 发送端必需知道信道状态信息。本文我们研究一种基于四阶累积量切片的估计和预测衰弱信道状态信息的方法。理论和仿真实验表明其相对于最小均方误差算法有更好的效果。

关 键 词: 预测; 通信; 累积量
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1 Introduction

In a mobile wireless communication system, due to the fast channel variation, signal fading degrades performance severely and imposes high power requirements. It is mainly caused by multipath propagation and Doppler frequency shift[1]. Since the channel changes rapidly, the transmitter and receiver are not generally optimized for current channel conditions, and thus fail to exploit the full potential of the wireless channel, resulting in low bandwidth and power efficiency. In the future, high-speed data transmission will be supported in the third generation wireless communication system, for example the speed of the transmitting data is up to 2 Mbits/s. Bandwidth efficiency is becoming more and more important. Recently, some adaptive modulation and coding methods have been investigated. To implement adaptive transmission methods in practice, the channel state information (CSI) must be available at the transmitter. If

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the channel state information can be precisely predicted at the transmitter, the capacity of fading channel can be achieved by adapting the transmission parameters to the exact fading level. Adaptive transmission[1-2], without sacrificing the bit error rate (BER), can provide high bandwidth efficiency by transmitting signal at high speed when the channel condition is favorable, and reduce the transmission rate when the channel condition is poor. In addition, reliable prediction is necessary for adaptive transmitter diversity techniques, reliable power control and so on. Alexandra Duel-Hallen and others have investigated adaptive long-range prediction algorithm[3-6]. But when SNR is low, the result is unacceptable. Here we proposed a new prediction algorithm based on the diagonal slice of the fourth-order cumulant, the simulation result shows that it is effective.

2 The fading channel model

In this paper, we concentrate on flat fading signals which result from interference between several coherent scattered components. The complex envelope of the flat fading signal at the receiver is given by the sum of N Doppler shifted signals[7].

$$c(t) = \sum_{n=1}^{N} A_n e^{j(2\pi f_n t + \varphi_n)}, \tag{1}$$

where N is the number of scatters, and for the nth scatter, A_n is the amplitude, f_n is the Doppler frequency, and φ_n is the uniform phase. The parameters A_n, f_n, φ_n vary much slower than the actual fading signal. Moreover, the Doppler frequency is given by

$$f_n = f_c\left(\frac{v}{c}\right)\cos\alpha_n, \tag{2}$$

where f_c is the carrier frequency, v is the speed of the mobile, c is the speed of the light, and α_n is the incident angle relative to the mobile's direction. Since we consider short term fading, we assume the parameters in (1) are approximately constant or change very slowly for the duration of the data block.

A deterministic Jakes model is used as a standard model in computer simulation. Using Jakes model, the theoretical Doppler spectrum of the fading channel can be accurately approximated by a summation of a relatively small number of sinusoids (usually less than nine).

The discrete-time system model at the output of the matched filter and sampler is given by:

$$y_k = c_k b_k + z_k, \tag{3}$$

where c_k is the flat fading signal sampled at the symbol rate, b_k is the binary phase shift keying (BPSK) data sequence, and z_k is the complex discrete AWGN process.

In defining the SNR, it is assumed that $E[|b(k)|^2] = 1$, and here suppose b_k is known, and $b_k = 1$. We also assume the average channel power $E[|c(k)|^2]$ is normalized to one.

In the results below, we have:

$$y_k = c_k + z_k, \tag{4}$$

3 Prediction of the fading channel

To predict the fading signals, first, we compute the diagonal slice of the fourth-order cumulant of the received samples,

$$C_{4y}(m, m, m) = C_{4c}(m, m, m) + C_{4z}(m, m, m), \tag{5}$$

where

$$C_{4y}(m_1, m_2, m_3) = cum(y^*(n), y^*(n+m_1), y(n+m_2), y(n+m_3)), \tag{6}$$

Because z_k is Gaussian noise, so

$$C_{4z}(m, m, m) = 0, \tag{7}$$

Then we can get[8]

$$C_{4y}(m, m, m) = C_{4c}(m, m, m) = -\sum_{k=1}^{N} |A_k|^4 e^{j2\pi f_k m}, \tag{8}$$

After this, we use linear prediction (LP) method to predict the channel coefficient. The LP method of the future channel coefficient C_n based on p previous numbers

$C_{n-1}, \Lambda, C_{n-p}$ is given by

$$\hat{C}_n = \sum_{j=1}^{p} d_j C_{n-j}, \quad (9)$$

where p is the AR model order, and the optimal coefficients d_j are determined by the orthogonal principle as

$$\underline{d} = \underline{R}^{-1}\underline{r}, \quad (10)$$

where $\underline{d} = (d_1, \Lambda, d_p)^T$, $\underline{R}$ is the autocorrelation matrix $(p \times p)$ with coefficients $R_{ij} = E[C_{n-i}C^*_{n-j}]$, and $\underline{r}$ is the autocorrelation vector with the coefficients $r_j = E[C_n C^*_{n-j}]$. Now we extend one-step prediction in (9) to a general channel prediction problem as follows. The objective is to find the MMSE estimate of a future sample $C(\tau)(\tau > 0)$ by p previous values at and prior to time zero. The predicted value

$$\hat{C}(\tau) = \hat{C}_v = \sum_{j=0}^{p-1} d_j C_{-j}. \quad (11)$$

The comparison of the MSE for prediction with the diagonal slice of the fourth-order cumulant is shown in Fig. 1, were we choose $p = 40$, $f_{dm} = 100$ Hz, the sample rate is 25 Kb/s, and $m = 200$.

The performance of the method for prediction based on the diagonal slice of the fourth-order cumulant is good, particularly for low-to-moderate SNR. The reason is that the fourth order cumulant can reduce the AWGN. The fault of this method is that the computational speed is very slow.

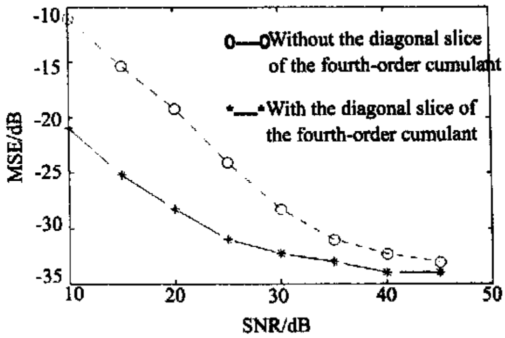

Fig. 1 Prediction MSE performance comparison

4 Conclusion

A new prediction method for fading channel is discussed in this paper. It is shown that the prediction performance for the flat fading channel can be significantly improved when the new method based on the diagonal slice of the fourth-order cumulant is used.

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