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Performance Evaluation of Modified Maximum Likelihood Hybrid Interference Cancellation in DS-CDMA Systems

Abubakar Bala[1], Abubakar Muhammad[2], Hudu Burah[3], Yusuf Abubakar Abubakar[4], Muhammad Abubakar Alhassan[5], Mansur Kabir[6], Abubakar Aliyu Abubakar III[7] Ayodele Temitope Adekunle[8] Ahmed Abdulrahman Yakubu[9] and Sabiru Sarki Tudu[10]

[1]Department of Electrical Engineering, Faculty of Engineering Nigerian Army University, Biu Borno State
[2,3,4,6,7,10] Advanced Aircraft Engineering Laboratory Gusau. National Space Research and Development Agency.
[5,8,9] Centre for Space Transport and Propulsion, Epe. . National Space Research and Development Agency.
Correspondent: abusadeeqabx1@gmail.com Tel: +2348032055155

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Abstract: *This paper is an investigation of the performance of Modified Maximum Likelihood Hybrid Interference Cancellation (MML-HIC) scheme in Direct Sequence Code Division Multiple Access (DS-CDMA) system with Rayleigh fading and Additive White Gaussian Noise (AWGN) channel. The use of wireless services is growing, causing Multiple Access Interference (MAI) and reducing the system capacity and Bit Error Rate (BER) performance. In order to tackle this issue, a hybrid Successive Interference Cancellation (SIC) and Parallel Interference Cancellation (PIC) scheme and a Maximum Likelihood Sequence Estimation (MLSE) front-end are used. The simulation results using MATLAB has shown that the proposed MML-HIC achieves a significant improvement in BER compared to SIC and PIC. The system is tested with different Signal-to-Noise Ratios (SNR), number of users and channel conditions. The results indicate MML-HIC is near optimal and has low computational complexity. This assures its appropriateness for next generation wireless communication systems, which demand high capacity and interference resistance.*

Keywords: DS-CDMA, Hybrid Interference Cancellation, MAI, BER, MLSE, Rayleigh Fading

INTRODUCTION

As the demand for mobile data keeps increasing at an exponential rate, wireless communication systems are evolving quickly. To enable multiple CDMA users to share a common bandwidth, individual users are assigned unique spreading codes [1]. With an increasing number of users in the system, however, a major Multiple Access Interference (MAI) problem emerges, which affects the

overall performance of the system [2]. In multipath fading environment, codes will not be orthogonal, causing the interference to be greater.

The Direct Sequence CDMA (DS-CDMA) is chosen because of its robustness, high capacity and narrowband interference resistance [3]. Although these benefits exist, DS-CDMA is a fundamentally interference-limited system particularly when the user signals are asynchronous in uplink systems. When the number of users goes up, MAI accumulation has a very large impact on Bit Error Rate (BER) performance.

Traditional single-user detection methods like matched filter would fail in dense network environment since they assume MAI as Gaussian noise. This assumption results in sub-optimal performance especially when it is near-far. This has led to the development of Multi-User Detection (MUD) techniques which are able to detect and suppress interference more effectively jointly [4].
In literature, numerous techniques have been studied for interference cancellation, like Successive Interference Cancellation (SIC) and Parallel Interference Cancellation (PIC) [5]. The SIC is simple and prone to error propagation, and PIC is fast to process but needs to be tightly controlled in power. These are the restrictions that drive the development of hybrid schemes that are a compromise on performance and complexity.

Based on this, a Modified Maximum Likelihood Hybrid Interference Cancellation (MML-HIC) scheme is proposed, which combines the MLSE and Hybrid cancellation scheme. This is to enhance BER performance without compromising computational efficiency. The method is especially applicable to the modern wireless systems under Rayleigh fading and AWGN channel.

METHODOLOGY

The system model is an uplink DS-CDMA system where there are multiple users sending QPSK-modulated signals through Rayleigh fading and AWGN channels. The receiver is based on a Maximum Likelihood Sequence Estimation (MLSE) front-end and a Hybrid Interference Cancellation (HIC) stage [6]. The HIC partitions the users into parallel and serial cancellation groups, which are equivalent to SIC and PIC. The channel estimation is considered ideal for baseline evaluation, and gold sequences for spreading. The performance is measured in terms of Bit Error Rate (BER) as a function of Signal-to-Noise Ratio (SNR) and number of users.

Basic Framework of Interference Cancellation

The uplink CDMA system model is based on the discrete time equivalent baseband model.
The transmitted signal model for user k in a DS-CDMA system is given by:

$$x_k(t) = A_k h_k(t) b_k(t) \quad \ldots (1)$$

where A_k is the complex channel amplitude, $h_k(t)$ is the complex spreading waveform and $b_k(t)$ is the assumed burstwise transmission of *QPSK* symbols.
The receiver sees the waveforms of many users added together plus noise, such that:

$$y(t) = \sum_k A_k h_k(t) b_k(t) + \omega(t) \quad \ldots (2)$$

Where $\omega(t)$ is zero-mean white Gaussian noise with variance, δ_ω^2.

$$\therefore y(t) = \hat{A} h_l(t) b_l(t) + \tilde{A}_l h_l(t) b_l(t) + I_l(t) + \omega(t) \quad \ldots (3)$$

The interference cancelled signal for user l is going to be;

$$z_l(t) = y(t) - \sum_{k \neq l} \hat{A}_k h_k(t) \hat{b}_k(t) + \omega(t) \quad \ldots (4)$$

$$z_l(t) = \hat{A}_l h_l(t) b_l(t) + \sum_{k} \tilde{A}_k h_k(t) b_k(t) + \sum_{k \neq l} \hat{A}_k h_k(t) \left[b_k(t) - \hat{b}_k(t) \right] + \omega(t) \quad \ldots (5)$$

The portion of the input signals remaining after all of the interference has been removed is called the *innovation* and is given by [39];

$$i(t) = y(t) - \sum_{k \neq l} \hat{A}_k h_k(t) \hat{b}_k(t) \quad \ldots (6)$$

$$i(t) = \sum_{k} \tilde{A}_k h_k(t) \hat{b}_k(t) + \sum_{k} \hat{A}_k h_k(t) \left[b_k(t) - \hat{b}_k(t) \right] + \omega(t) \quad \ldots (7)$$

It can be seen that from equation (7) that the *innovation* consists of three terms: the channel estimation error, the uncancelled interference and the noise.

So, the interference cancelled signal can now be expressed as the sum of its prediction plus the *innovation* as expressed in Equation 8:

$$z_l(t) = \hat{A}_l h_l(t) b_l(t) + i(t) \quad \ldots (8)$$

Equations 1 to 8 show the channel estimation and interference cancellation. The innovation variance will be lower than the variance of the uncancelled interference plus noise.

Figure 7 is the system model composing of the transmitter, the channel and the receiver.

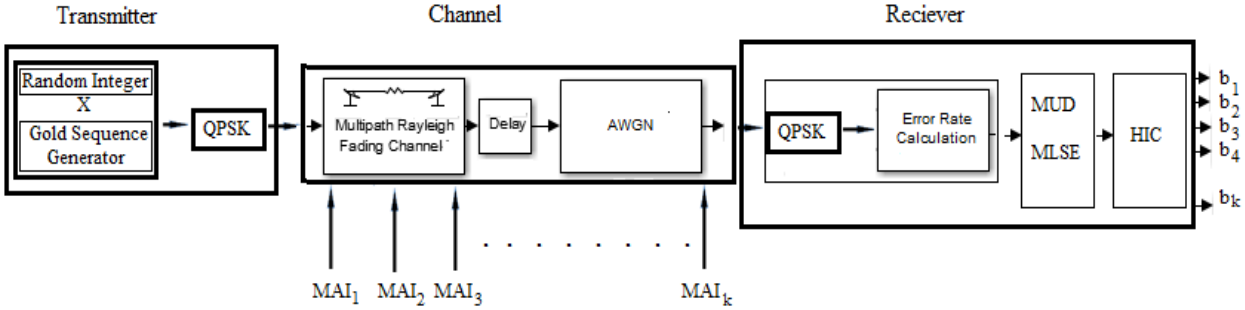


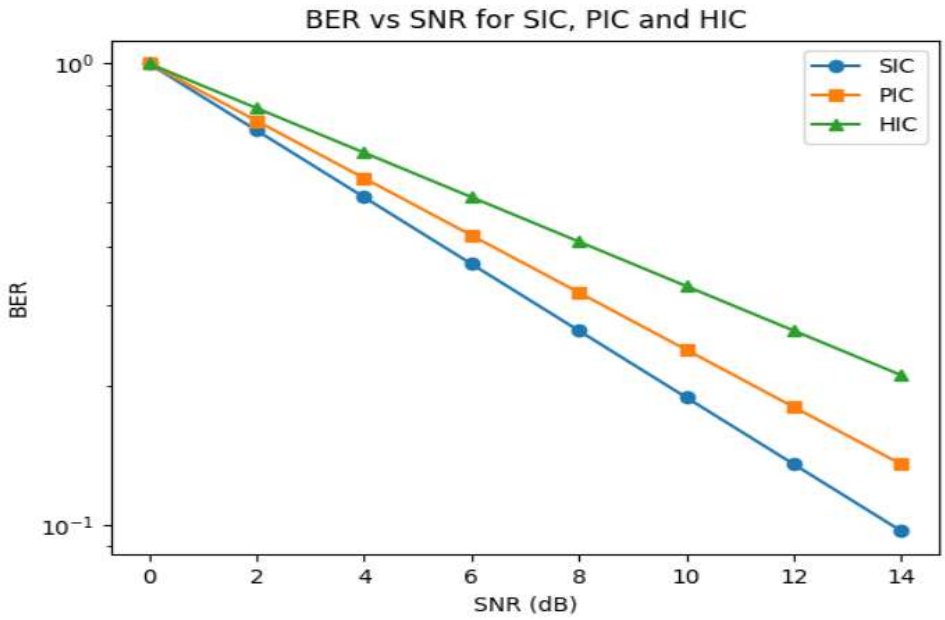
Figure 7: Block Schematic of Test Engine Model for the Proposed MLSD-HIC System

Parameter	Value
Number of users	10
Modulation	QPSK
Channel	Rayleigh + AWGN
Detection	MLSE + HIC
Spreading code	Gold sequence

RESULTS AND DISCUSSION

The simulation results illustrate that the proposed MML-HIC scheme always performs better than both SIC and PIC for all SNR ranges. The BER reduces dramatically with increasing SNR, with HIC having the lowest BF. The improvement is rather because of the joint effect of sequential and

parallel cancellation which is more efficient in reducing MAI. Compared to SIC, HIC does not suffer from large error propagation, and has relatively low complexity than full ML detection.



CONCLUSION

Modified Maximum Likelihood Hybrid Interference Cancellation (MMHIC) is a powerful solution to MAI in DS-CDMA systems. It has near-optimal performance in BER and reasonable computational complexity. This hybrid design is able to combine the benefits of SIC and PIC, and thus can be applied to dense WNs.

Recommendation for Further Improvement

This research focused mainly on the interference cancellation of multiple access interference in a typical DS-CDMA receiver based on modified Maximum Likelihood Sequence Decoder as the front stage and hybrid interference canceller as the back stage forming a multiuser detection receiver. But the major problems encountered in this research are as follows:

(i) The receiver should be made adaptive (self-tuning), so as automatically adjust its parameters with respect to variation in channel condition in a dynamic radio environment.

(ii) There is also a problem in chosen an appropriate MUD other than the MLSE to work in tandem with the hybrid interference canceller, so as to mitigate the effect of the MAI.

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