

Improved Spread Sequence Design Mitigating Multipath Fading Effects

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ABSTRACT: In terrestrial radio communications systems, the signals reach the receiver via the direct path and the indirect paths as a result of reflections from objects that are adjacent to the main path leading to multipath fading. This can create problems with phase distortion and intersymbol interference degrading the performance of a wireless communication system mostly at cases where the data rate is as high as those systems beyond Long-Term Evolution Advanced (LTE-A). To combat this multipath-fading effects, CDMA schemes with Bit-Interleaved Coded Modulation (BICM) and Successive interference cancellation (SIC) schemes are introduced. The BICM scheme limits the loss of information under multipath fading and disperses the burst errors and maximizes the diversity order of the system. The Successive Interference Cancellation allows a receiver to decode packets that arrive at the same time, also estimates and cancels interference successively using feedback. As the user power gets more widely distributed, the relative performance of the successive scheme improves which in turn upgrades the system design. Also, comparisons in the performances using different spread sequences (Walsh, Gold and Kasami code) are analysed.

KEYWORDS: Multipath fading, CDMA scheme, Successive interference cancellation (SIC), Bit-Interleaved Coded Modulation (BICM).

I. INTRODUCTION

In wireless communications, multi-path effects arise as a result to signal fading. Multi-path effect can be explained as, when a signal transmitted from a transmitter it may have multiple copies due to traversing different paths to reach a receiver. At the receiver, the received signal is the sum of all the multipath signals. As the paths traversed by multipath signals are different, some are longer and some are shorter. Mostly the signal at the direction of light of signal (LOS) would be the shortest. Multipath signals interact with each other. If these signals are in phase, they would intensify the resultant signal otherwise, the resultant signal is weakened due to being out of phase. The aftermath of this propagation phenomenon is that the radio signals reach the receiving antenna by two or more paths and is called multipath fading. Multipaths, cause multipath interferences including constructive and destructive interferences, and also phase shifting of the signal. Usually, destructive interferences cause the effects of fading. In digital radio communications multipath leads to errors that affect the quality of communications.

A code-division multiple access (CDMA) scheme is introduced to reduce multipath fading effects. The CDMA scheme employs spread-spectrum technology and also a special coding scheme ie, each transmitter is allotted a code to allow multiple users to be multiplexed over same physical channel. All forms of CDMA utilizes the spread spectrum process gain to allow the receivers to partially discriminate the unwanted signals. Signals encoded with the specific PN sequence codes are received while the other signals with the different codes or same code with different timing offset appears as wideband noise reduced by this process gain. The main aim is to use an unique, simple, and effective method of finding optimum pseudo noise (PN) spreading and despreading sequences using a high signal-to-interference-plus-noise ratio (SINR) and channel state information (CSI). In addition to it, Bit Interleaved Coded Modulation (BICM) and Successive Interference Cancellation techniques are used to mitigate the effects of multipath fading.

In [1], the authors proposed a method of designing the spreading and despreading sequences so as to maximize the SINR and mitigate the effects of the frequency selective fading. Also the generated PN sequences are not made available to a jammer, in general, but only to the sources and destinations. In [2], joint transmitter-receiver adaptation is studied for the reverse links of a direct sequence-code division multiple access (DS-SS) system with that of the short signature sequences. Adaptive algorithms are derived, estimating the transmitter coefficients in the presence of multipath. In [3], the modification of an 'amplify and forward relay' transmission scheme where relays use random signatures to access the channel is proposed. The system has been studied in terms of spectral efficiency, mainly considering the asymptotic regime like: when the number of transmitted symbols together with the signature length grows without bound but with constant ratio, it is indeed possible to effectively remove the dependence on the realization of the spreading sequences.

In [4], the adaptive minimum mean square error (MMSE) detection together with the successive interference cancellation is considered. Through the theoretical analysis and the numerical examples, it is observed that the proposed detector gives a superior performance to the existing ones in the terms of the asymptotic multiuser efficiency (AME) and the bit error rate (BER). Also a better performance to a simple SIC and an adaptive MMSE detector even for the weakest user. Although the proposed detectors have relatively increased the complexities over a simple SIC and adaptive MMSE detectors, it seems to be quite promising in a near-far situation. In the paper [5], a design of iterative multi user detection (MUD) for BCIM signals in CDMA systems with multipath Rayleigh fading channels is explained. In [6], the performance of maximal-length, Gold and Kasami codes as spreading sequences in CDMA systems are evaluated.

Paper is organized as follows. Section II describes the related work in which SIC and BICM techniques are explained to overcome the multipath fading effects. Section III presents the experimental results showing the comparison in performances of different spreading codes: Walsh, Gold and Kasami codes. Finally Section IV presents the conclusion.

II. RELATED WORK

To combat the deleterious effects of multiple-access interference (MAI) the system designed uses CDMA scheme with techniques like Successive Interference Cancellation (SIC) and Bit Interleaved Coded Modulation (BICM) achieving better performance. No direct links between the sources and the destinations because their distances are far away, and the received signal strengths are too weak to use, compared with signals from relays. The relay operates in a half-duplex mode and it is assumed that all channels undergo frequency-selective fading.

The technique of SIC is based on the explanation that if in a system where multiple signals are interfering with each other and each signal is estimated individually serially, then the interference effects of an estimated signal can be eliminated from the signals that is yet to be estimated, increasing the reliability of remaining signals. The linear MMSE filter detection method is mostly used within the process to estimate the symbols. The order in which a SIC processing cancels the estimated signals can make a huge difference to the overall error rate performance of the detection algorithm. If the signal being estimated has a greater effect of interference than others, if the signal being estimated has a high level of interference, then the symbol estimate has a greater chance of being inaccurate. If the inaccuracy generated is used for cancellation in the algorithm this may lead the other signals to also be estimated incorrectly known to be error propagation. To reduce this effect, we order the signals by the greatest associated channel power first and then weakest last. Also it ensures that signals with better SINR are estimated first. Finally the interferer with highest power is cancelled first to improve the SINR of the remaining signals to come. The ordering by channel power is called as Ordered SIC or the VBLAST algorithm.

BICM is considered as a highly influencing technique for coded modulation in fading channels. BICM, makes use of bit-wise interleaving at the encoder output and an appropriate metric at the decoder. By doing so it can achieve a better performance Based on the maximum a posteriori (MAP) decoding rules the received BICM signals are demodulated and decoded. The decoder outputs are not only used to cancel both multiple access interference (MAI) and intersymbol interference (ISI) but also to demap the high order modulation symbols.

In this paper we consider the design of iterative Multi-User Detection (MUD) for BCIM signals in coded CDMA systems with the multipath Rayleigh fading channels. The BCIM increases the bandwidth efficiency at the expense of higher power consumption which can be overcome by iterative processing. This can be explained in two loops, the outer loop consisting of SIC and MMSE filter to eliminate MAI and ISI and the inner loop consists of a demapper, a deinterleaver and a decoder. As the number of iterations increase, so does the reliability and hence the system performance.

The spread sequence design using SIC and BICM schemes are checked for different spreading codes; Walsh, Kasami and Gold codes & their performance comparisons are studied.

III. EXPERIMENTAL RESULTS

Figure 1 plots different code Signal-to-Noise ratio (SNRs) to Bit Error Rate (BER) for uplink through a Rayleigh channel. It is observed that Gold code (line coloured blue) is having the best signal strength with comparatively less BER compared with Walsh (line coloured red) and Kasami (line coloured magenta) Codes.

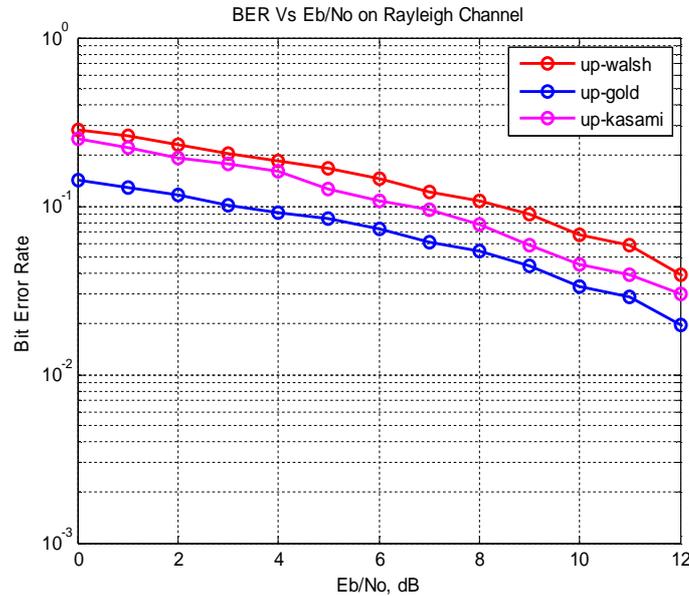


Fig.1 SNR for Walsh, Gold and Kasami codes Vs BER for up-link

Figure 2 plots different code Signal-to-Noise ratio (SNRs) to Bit Error Rate (BER) for downlink through a Rayleigh channel. It is observed that Gold code (line coloured green) is having the best signal strength with comparatively less BER compared with Walsh (line coloured black) and Kasami (line coloured yellow) Codes.

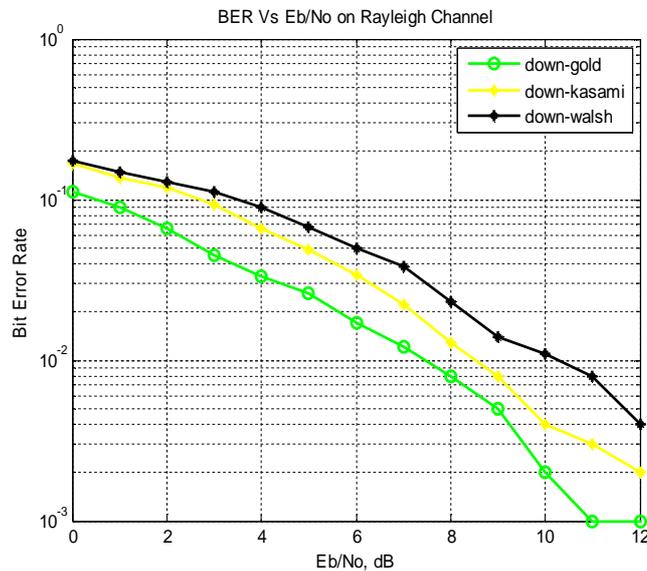


Fig.2 SNR for Walsh, Gold and Kasami codes Vs BER for downlink

Figure 3 plots the performances of different codes w.r.t their code lengths. It is observed that Gold code (line coloured red) is having a better performance compared with Walsh (line coloured green) and Kasami (line coloured blue) Codes. Also Kasami codes are next to Gold codes performance wise.

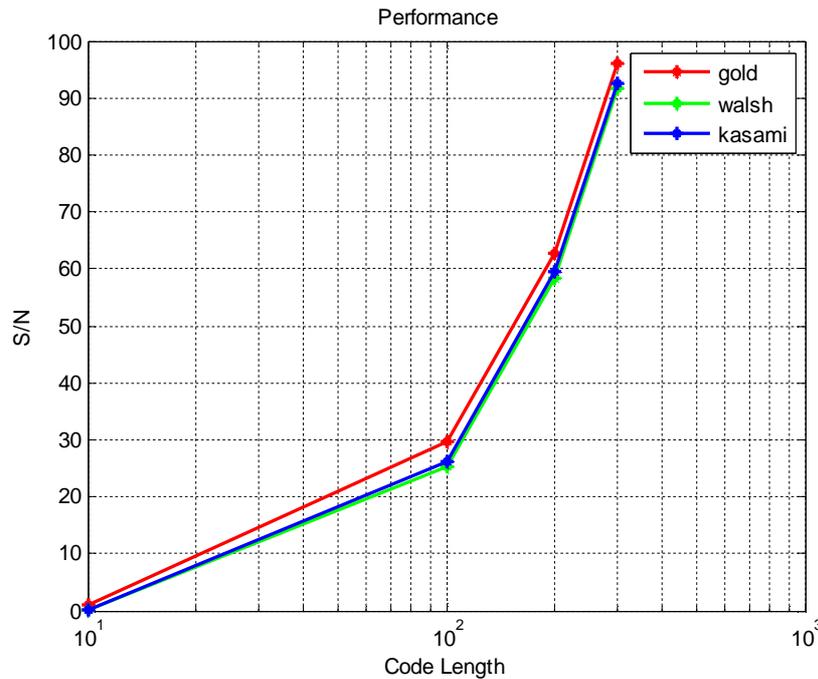


Fig.3 Comparison between the performances of Walsh, Gold and Kasami codes

IV. CONCLUSION

To nullify the signal quality degrading effects due to multipath fading, the SIC and BICM schemes allow the receiver to decode the packets that arrive and, also estimates and cancels the interferences successively using feedback. The relative performance of the successive scheme improves which in turn upgrades the system design when the user power gets more widely distributed. A comparison between different codes in their performances using these schemes is also done. As per the performances analysed it can be concluded that Gold code and Kasami codes are good for CDMA applications. It may also be stated that Gold codes are better when compared with Kasami codes.

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