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Performance of Different Concatenated Coding Schemes for CDMA System

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ABSTRACT

In this paper different channel coding and interleaving schemes in DS/CDMA system over multipath fading channel were used. Two types of serially concatenated coding were presented. The first one composed of Reed-Solomon as outer code, convolutional code as inner code and the interleaver between the outer and inner codes and the second consist of convolutional code as outer code, interleaved in the middle and differential code as an inner code. Bit error rate performance of different schemes in multipath fading channel was analyzed and compared. Rack receiver was used in DS/CDMA receiver to combine multipath components in order to enhance the signal to noise ratio at the receiver.

Key Words: CDMA, concatenated coding, Reed-Solomon code, differential coding, a rake receiver.

تقييم الأداء باستخدام مصحح الأخطاء الأمامي إلى جانب التشفير المتسلسل في نظام النفاذ المتعدد بالتقسيم الشفري

زينب مجيد عبد
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كلية الهندسة- الجامعة المستنصرية

الخلاصة

في هذا البحث أستعمل تصحيح الأخطاء الأمامي إلى جانب التشفير المتسلسل في نظام النفاذ المتعدد بالتقسيم الشفري عبر قناة الخبو في المسارات المتعددة. وأستخدم نوعان من التشفير التسلسلي المتسلسل، أولهما يتألف من Reed-Solomon كرمز خارجي، والشفرات الالتفافية كرمز داخلي، والمداخل بين الشفرات الخارجية والداخلية، ويتألف الثاني من شفرة التفافية كقاعدة خارجية ورمز تفاضلي كقاعدة داخلية مع مداخل بينهما ، تم الاعتماد في تقييم الأداء للنظام على قيمة نسبة الخطأBER. وأستخدم مستلم الرف في نظام النفاذ المتعدد بالتقسيم الشفري للجمع بين مكونات المسارات المتعددة من أجل تعزيز نسبة الإشارة إلى الضوضاء عند المستلم.

الكلمات الرئيسية: CDMA، التشفير المتسلسل، تشفير Reed-Solomon، التشفير التفاضلي، المتلقي التجميعي

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1. INTRODUCTION

(DS-CDMA) Direct-sequence code-division multiple access is nowadays the subject of many types of research because it's one of the best multiple access techniques for third and fourth generations mobile communication systems. CDMA is a method by which many users simultaneously share the same higher bandwidth with little interference. In the DS-CDMA system, each bit is represented by multiple bits using spreading code. This spreading code spreads the signal across the wider frequency band. Spread Spectrum has a lot of advantages such as immunity from various noise and multipath distortion also can hide signals, the only receiver who knows spreading code can retrieve signal, **Khan,** and **Darda, 2012.**

Coded DS-CDMA system using BPSK over Rayleigh fading channel was simulated, to get low symbol error rate forward error correction and concatenated coding was used in which two error correcting codes are concatenated to get high coding gain over the uncoded system without increasing bandwidth but also (resist) frost both burst and random errors. In fact, using convolutional coding with Viterbi decoder as inner code and burst error resistant Reed-Solomon code as outer code can enhance the performance of DS/CDMA using low SNR, **Kim, et al., 1999.**
Also, the serial concatenated convolutional and differential codes are used in the DS-CDMA system, the differential encoder is the simplest type of convolutional code with a minimum number of states. The coding rate of the whole system the same as that of convolutional code because differential encoder does not (sacrifice) the transmission efficiency with a code rate of one, **Li Y,** and **Li K, 2002.**
Performance of DS/CDMA using concatenated coding in the multipath channel with different coding rates for both inner and outer codes was analyzed in **Wong,** and **Letaief, 2000.** In the receiver, many numbers of time-delayed versions of the originally transmitted signal were received by rake receiver which combines these time-shifted copies of the original signal in order to improve the signal to noise ratio at the receiver, **Bhalerao,** and **Zope, 2013.** The organization of this paper is as follows: Section (2) presents the system model used in the simulation, Section (3) presents the simulation results and Section (4) states the conclusions drawn from the paper.

2. SYSTEM MODEL

In coded DS/CDMA system firstly, the inner and outer codes must be chosen. The concatenated coding performance was made great by making the symbol size of outer code matched with the error pattern of inner code, **Saravanakumar,** and **Nagarajan, 2014.**

This system is considered over multipath fading channel with K users, symbol interleaver is put between the two encoders to alter the arrangement of transmitted symbols so that burst errors are minimized, **Saravanakumar** and **Nagarajan, 2014**. In DS/CDMA system message bits for each user was encoded by a concatenated coding and then BPSK modulated. It is then spread by each user unique code at the transmitter and transmitted through multipath fading channel, **Suchitra** and **Valarmathi, 2011.** The block diagram of system model used in this research is shown in **Fig.**1.

2.1 CDMA System

In code division multiple access (CDMA) many users can share the same higher bandwidth with little interference. A unique code sequence is assigned for each user in the transmitter, this code sequence is known by the receiver in order to recover the original data **Popa, 2011**. Walsh and Hadamard are the most commonly bipolar spreading codes that are used, in direct sequence CDMA systems for spectrum spreading, they exist only in form of 2^n and easy to generate and implement**.** The spreading code for user k is C_k must be unique for each user and they are orthogonal to one another, the spreading factor is J i.e. Eq. (1), **Seberry, et al., 2003.**

$$<C_i , C_k> = 0, \quad unless \quad i = k \qquad <C_i, C_k> = J, \quad if\ i = k. \qquad (1)$$

Block diagram of rake receiver is shown in **Fig.2** in a multipath channel, a direct signal with time-shifted copies of the original signal in DS-CDMA is received by rake receiver, several baseband correlators are used to individual process several signal multipath components. To improve communication performance, reliability and signal to noise ratio at the receiver the correlators are combined. Multipath diversity technique is used in a rake receiver, it is similar to rake which gathers the energy from the multipath propagated signal components. The rake receiver contains multiple of correlators in which received signals are multiplied by time-shifted versions of a locally generated code sequence, **Bhalerao,** and **Zope, 2013**.

2.2 Concatenated Coding

In concatenated coding system performance improvement of two or more codes is combined. **Fig.3** illustrates the general serial concatenated coding scheme which concatenates a high rate block code with short convolution code. Coding rate for the overall system is calculated from equation (2) with rate r1=k1/n1 inner code and rate r2=k2/n2 outer code, **Saravanakumar,** and **Nagarajan, 2014.**

$$k/n = k1/(k1+n2)=k1/(k1+n1/r2)=r1r2/(r1r2+1) \qquad (2)$$

The first system uses Reed Solomon (RS) code for the outer code to prevent burst errors that may be occurred in the inner code decoding and convolution code for inner code. In this system, data bits are converted to m-bits data symbols and encoded first by RS encoder. The most important parameters of RS code are (n, k, t), k is the number of input symbols, n is the length of code length and t is the minimum hamming distance. This encoder accepts a block of k data symbols and generates (n-k) symbols and then the output symbols from RS encoder are entered to symbol interleaver, **Saravanakumar,** and **Nagarajan, 2014.**

Interleaver is used to randomize data symbols because error-correcting codes have better performance in correcting random errors than a burst of errors. Two methods can be used in interleaving techniques one is symbol interleaving which works at the code symbol level, the other one is bit interleaving which works at the bit level, **Saravanakumar,** and **Nagarajan, 2014.** After that, these symbols are fed to convolution encoder which is specified as CC (n, k, and g), where k is the input bits count, n is the number of output bits, and g is the constraint length of the encoder, **Suchitra,** and **Valarmathi, 2011.** Then they are transmitted through a channel to the receiver. Data that is received is decoded first by the Viterbi decoder and then fed to RS decoder, **Saravanakumar,** and **Nagarajan, 2014.**

In second system the information bits for the desired user enters the convolutional encoder and the output is reordered by interleaver and then encoded by differential encoder after that encoded bit is spread, modulated by (BPSK) and transmitted. At the receiver, the received signal is despread and demodulated and then decoded. The differential encoder with code rate R=1 and generator [3, 1] is shown in **Fig. 4.** a_n and b_n are the nth information bit and a coded bit, **Li,** and **H., 2002.**

3. SIMULATION RESULTS

Results of the simulated system were discussed. The RS (255,223) code, a (1/2) rate convolutional code with constraint length (7) and generator polynomial [171 133] is used by all users in the transmitter. At the receiver, Viterbi decoder is used, bit error rate performance of the proposed concatenated coding DS/CDMA is observed for an AWGN channel with a number of users varying from 1 to 6. Hadamard transform of size (8) and (16) are used for spreading, BPSK modulation is used. In **Fig. 5,** the relation between BER and SNR for a different number of users in AWGN is shown, as the number of users in CDMA increased the SNR requirement of (10^{-3}) is also increased. For (6) users the BER of (10^{-3}) is achieved at very high SNR.

In **Fig. 6**, the relation between BER and SNR for a different number of spreading factor in AWGN channel is shown. It can be seen that if the greater spreading factor is used, the received signal has a few errors. In **Fig.7,** the performance of coded and uncoded DS/CDMA system for (6) users with spreading factor (8) was investigated the results show that to achieve (10^{-3}) BER, SNR of about (8 dB) in uncoded system is needed, while in a coded system about (3 dB) is needed then a coding gain of about (5 dB) can be got when using concatenated coding with DS/CDMA system.

In **Fig. 8.B,** the performance of different concatenated coding schemes is shown. Two types of schemes are shown in **Fig. 8. A**, they are channel coding 1 and channel coding 2. The concatenated coding can be seen with bit interleaver offering good performance than the same code with symbol interleaving because interleaving at bit level is strong than interleaving at the symbol level. Randomization of errors is better in bit interleaver.

In **Fig. 9,** the performance of changing error correcting capability of outer RS code is investigated and fixing the code rate and constraint length of the inner convolutional code. The results show that increasing error correcting capability from 16 to 64 improving the system performance.

In **Fig. 10,** the RS (255,223) code is considered, and the investigation the performance of the coded system when changing constraint length of convolutional code from 7 to 9. It can be seen that increasing the constraint length is a good method for reducing the system BER.

In **Fig. 11,** bit error performance with and without using rake receiver in DS/CDMA system is shown. Using a rake receiver will improve performance and this improvement increase with increasing SNR. At 8 dB SNR, the error decreases from 10^{-1}(without Rake) to 10^{-3} (with a rake). In **Fig. 12,** RS (255, 223) and (1/2) convolutional concatenated code DS/CDMA are considered. The performance of the coded system in the multipath channel with 6 users is investigated. Each user has 3 multipath, one path is the direct one and two paths have different delays. It is assumed that all users have the same delay. Rake receiver with three fingers is used for each user to compensate with three paths channel. Bit error is decreased when rake receiver is used, at bit error 10^{-1} there is approximately 3 dB advantage of using coding.

In **Fig. 13,** a serial concatenated convolutional and differential code DS/CDMA are considered and the performance of the coded system in a multipath channel is investigated. It can be seen that the performance of bit error is improved at 11 dB SNR while in **Fig. 12** the performance gets better at 7 dB. From these results, it can seen that concatenated RS and convolutional code gives an improvement of about 4 dB in SNR for the same error in the concatenated convolutional concatenated code.

4. CONCLUSIONS

In this paper, two concatenated coding schemes for DS/CDMA system are simulated, the first one uses RS code as the outer and convolutional code as the inner code. From the simulation results, it can be seen that the performance of concatenated RS and convolutional code in AWGN is better than the uncoded system and 3dB SNR improvement is achieved than the uncoded system at BER (10^{-3}). Numerical results show that bit interleaving can improve the performance by orders of magnitude compared with symbol interleaving. Also, simulation results show that the performance of the same coding system in the multipath channel in two cases first one without using rake receiver in CDMA and the second with using a rake. Rake receiver technique is used in the CDMA system rather than the conventional receiver to reduce error due to multipath interference. From the results, this improvement could be seen.

The second scheme uses the convolutional code as the outer code and differential code as the inner, it can be seen that the performance is getting better at 11 dB SNR while the performance of RS code and convolutional code get better at 7 dB SNR, this gives an indication that the first scheme is better than the second.

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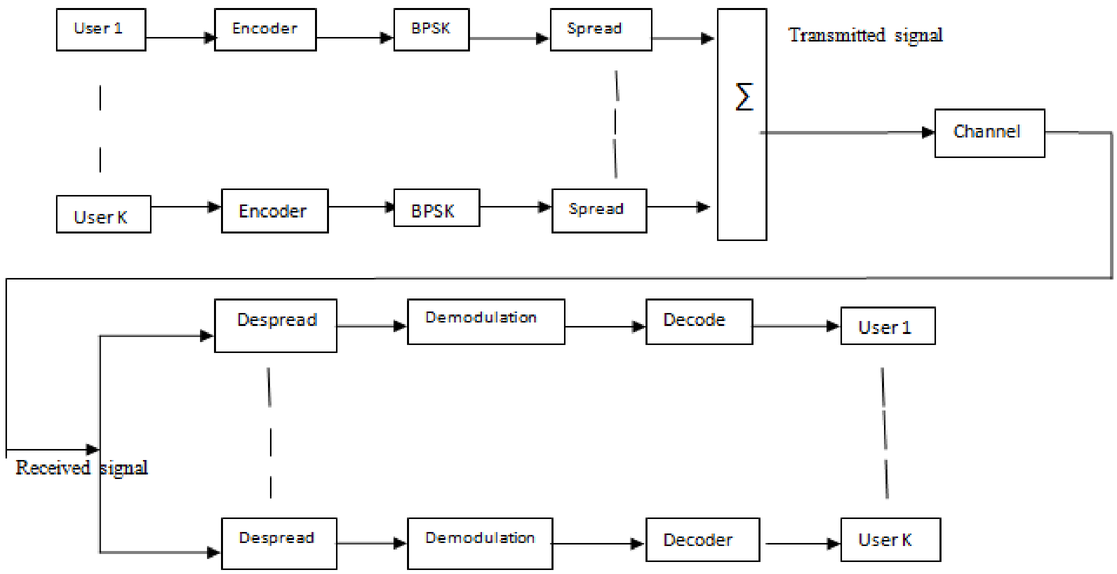

Figure 1. System model of transmitter and receiver.

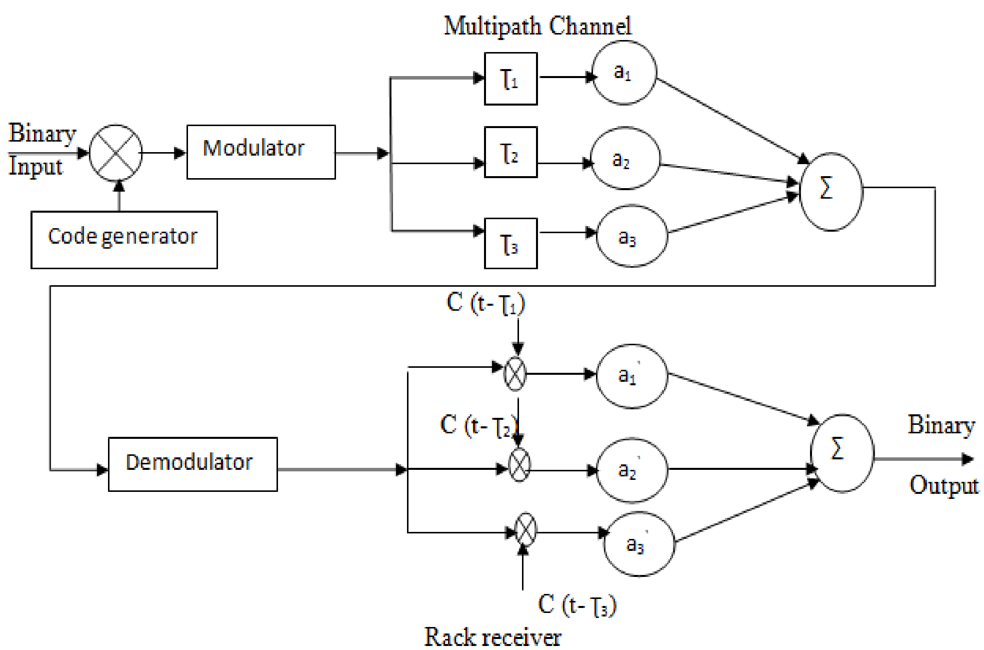

Figure 2. Principle of the rake receiver.

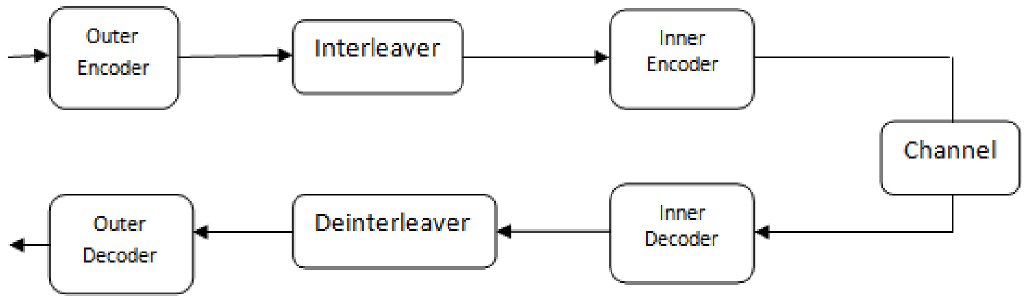

Figure 3. General concatenated coding model.

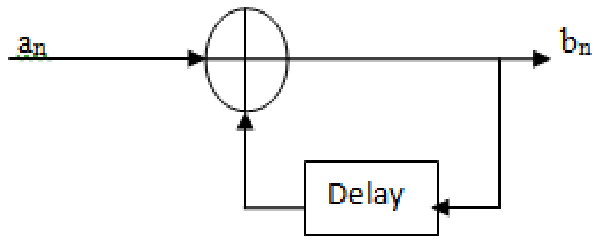

Figure 4. Differential encoder structure.

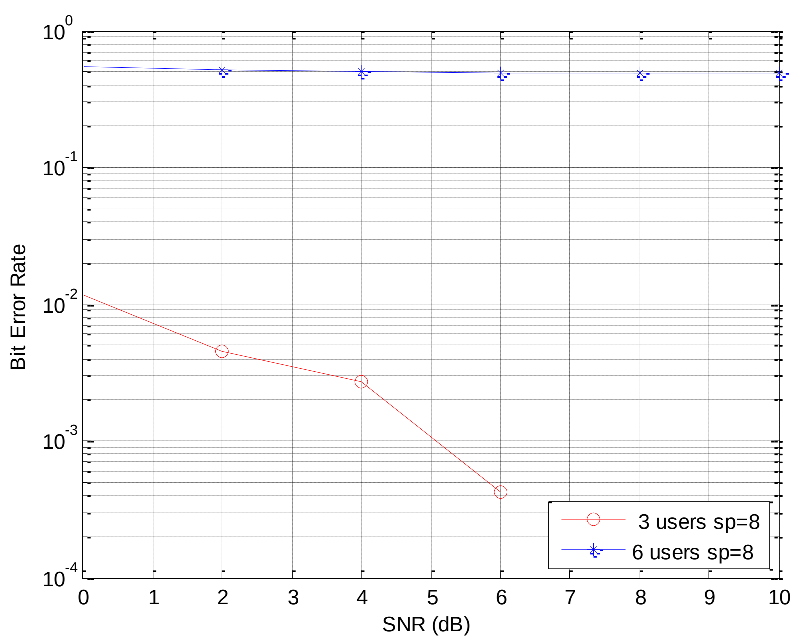

Figure 5. Performance of uncoded DS/CDMA with a different number of users.

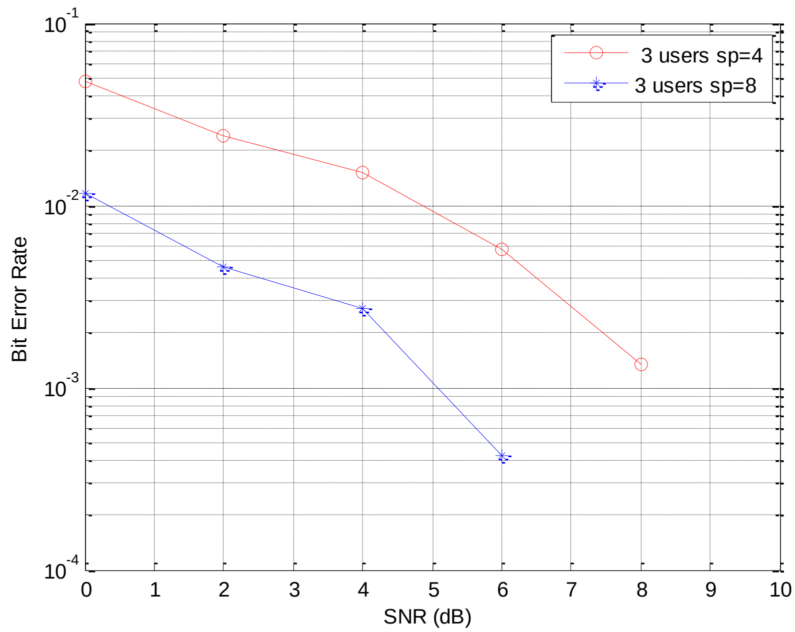

Figure 6. Performance of uncoded DS/CDMA with a different number of spreading factors.

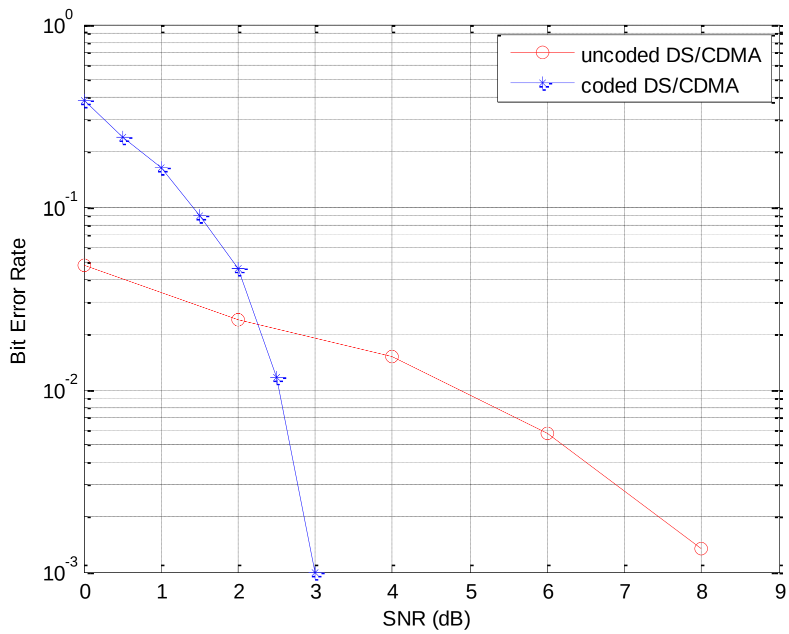

Figure 7. Performance of uncoded and coded DS/CDMA in AWGN channel.

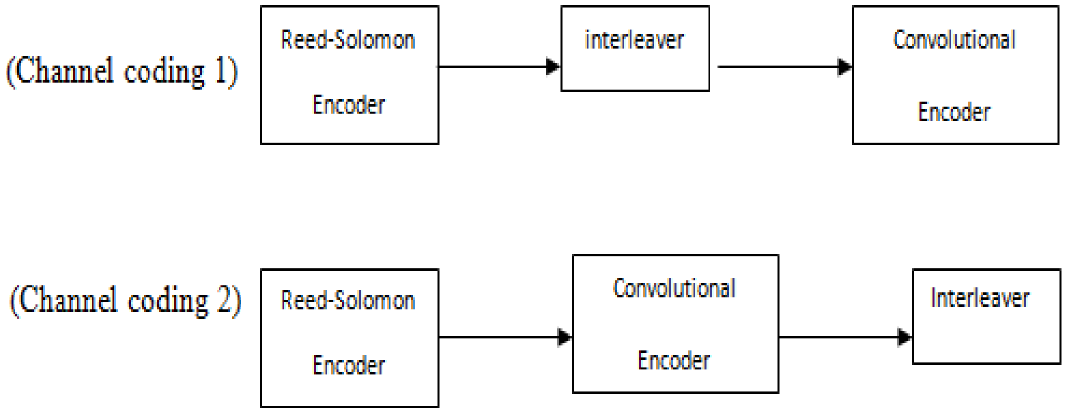

Figure 8.A Types of concatenated coding schemes.

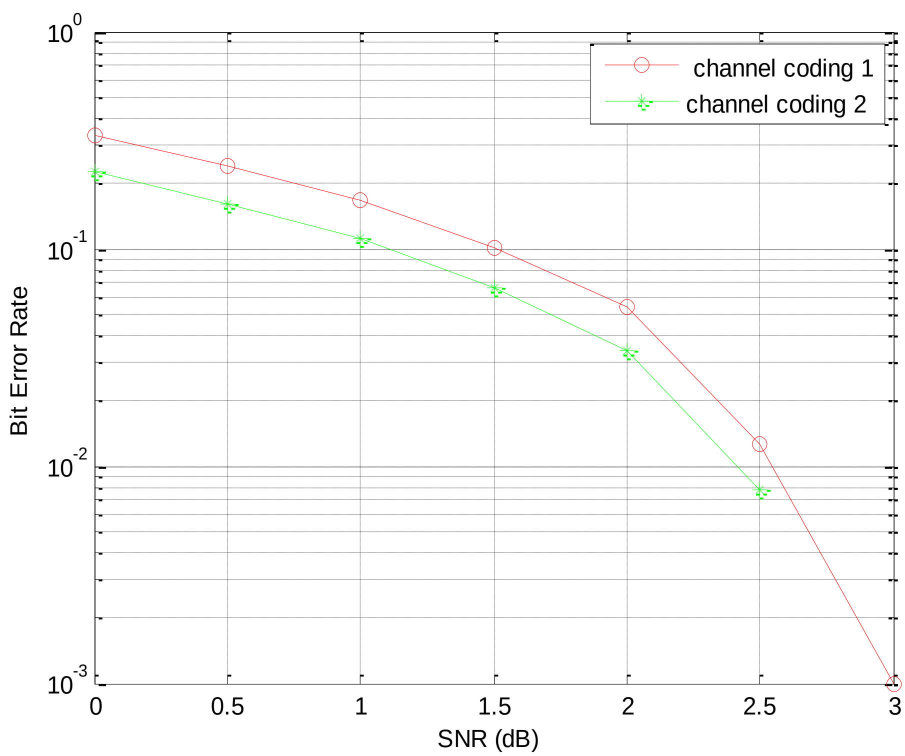

Figure 8. B Performanceof DS/CDMA with different concatenated coding.

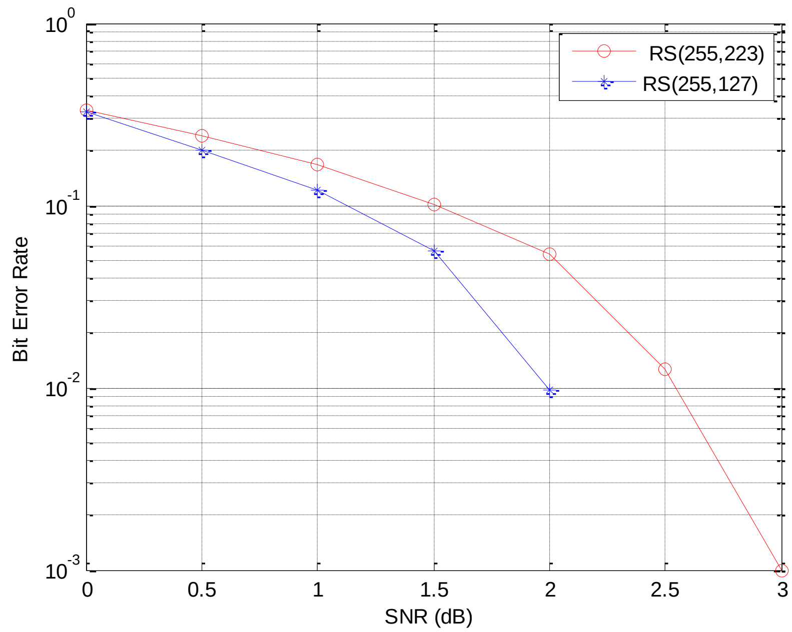

Figure 9. Performance of coded DS/CDMA system with different RS code rates and fix convolutional code rate.

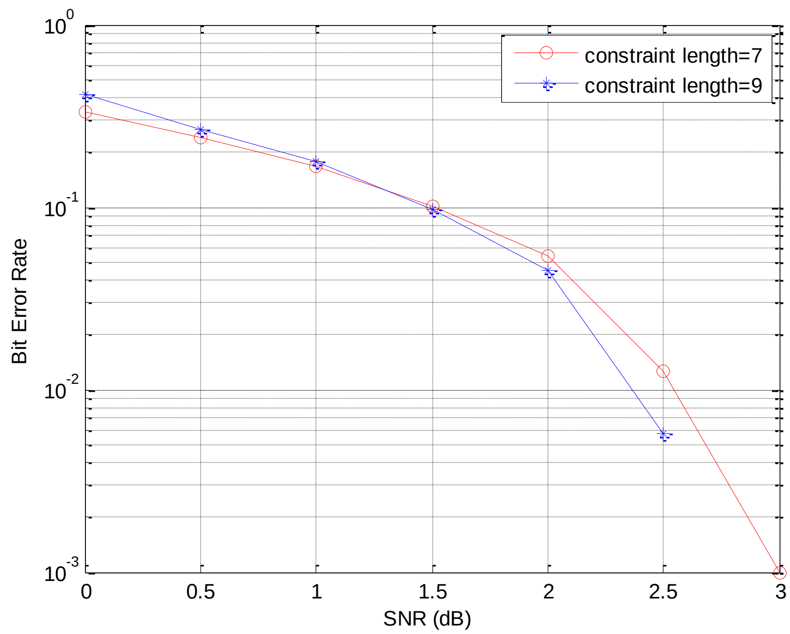

Figure 10. Performance of coded DS/CDMA system with different constraint lengths of convolutional code and fixed RS code rate.

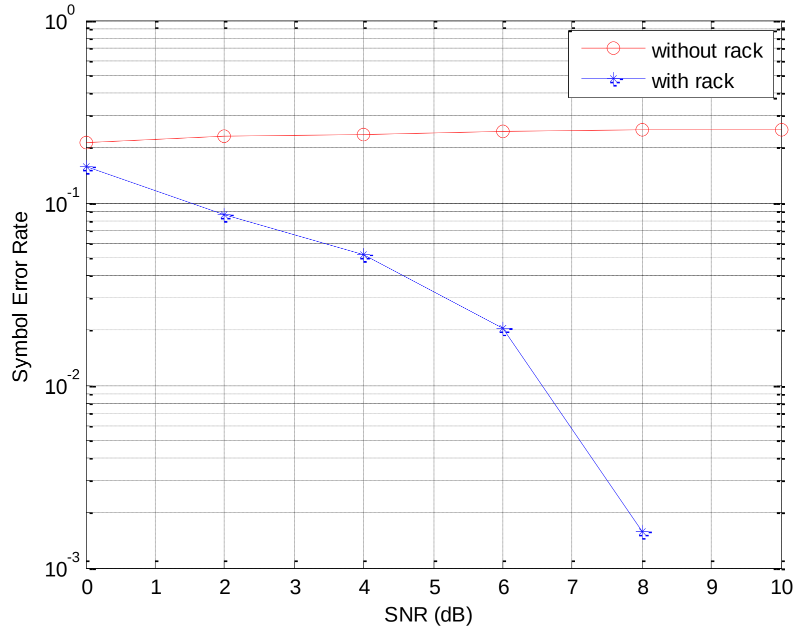

Figure 11. Performance of DS/CDMA system with a rake and without rake in a multipath channel.

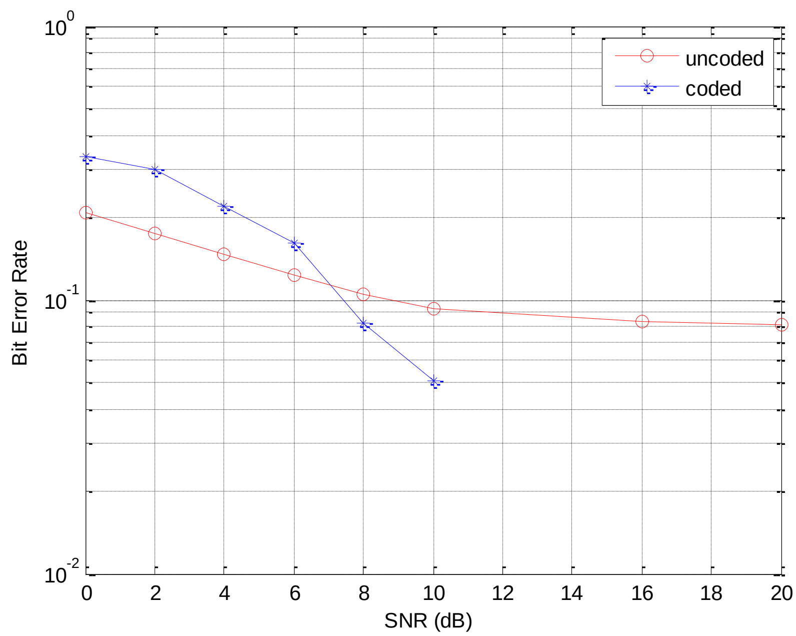

Figure 12. Performance of coded and uncoded DS/CDMA in the multipath channel with a rake receiver.

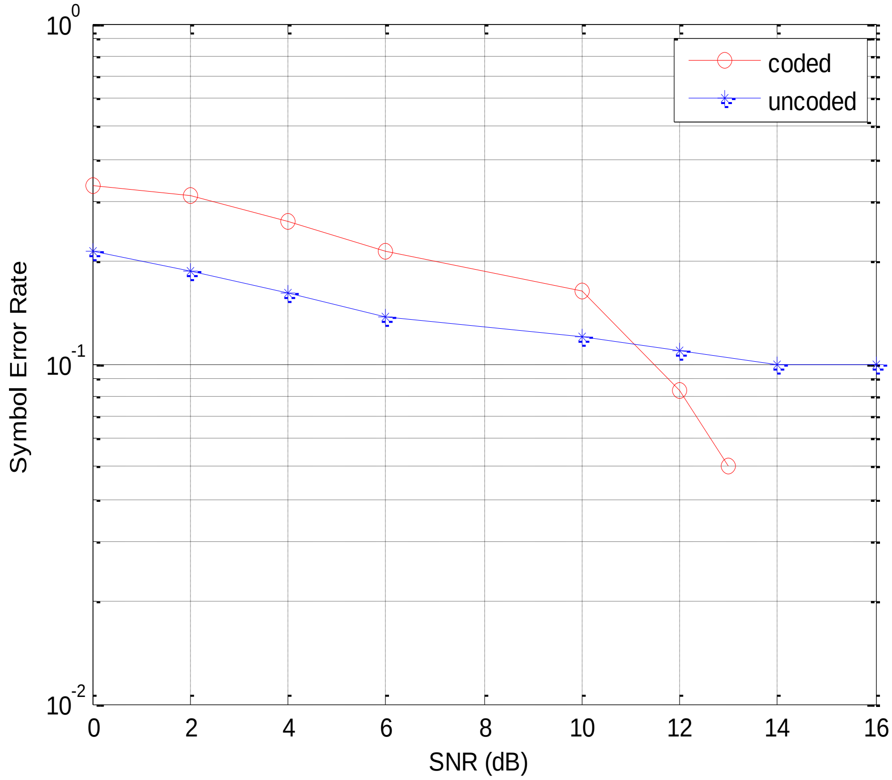

Figure 13. Performance of differential-convolutional concatenated coding CDMA system in a multipath channel.