CHANNEL CODING SCHEMES FOR AN ORTOGHONAL MULTICARRIER DS-CDMA SYSTEM

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A channel coding scheme for an orthogonal multicarrier DS-CDMA system is suggested. The scheme does not reduce the transmission rate of information nor increases the transmitted signal bandwidth of the uncoded multicarrier system. Simulation results for the suggested scheme in a multipath fading channel show considerable coding gain over the uncoded case.

Introduction: Recently, a junction of OFDM (orthogonal frequency division multiplexing) with CDMA (code division multiple access) techniques has been the subject of a lot of research, configuring what is generally named multicarrier CDMA systems [1]. Sourour and Nakagawa [2] suggest an orthogonal multicarrier DS-CDMA system in order to mitigate the multipath effects in a Rayleigh fading channel by using frequency diversity instead of the path diversity achieved with a RAKE receiver. They also demonstrate that the multicarrier system may outperform the single carrier RAKE receiver system. The scheme proposed here combines the uncoded system suggested in [2] with a special form of channel coding procedure, in such a way that the transmission rate of information and the transmitted signal bandwidth of the uncoded system are not changed. The simulation results show that considerable coding gains can be achieved.

System description: The block diagram of the proposed channel coding scheme, at the transmitter side, is shown in Fig. 1. The information bits are serial-to-parallel converted into M streams. If the information bit duration is T_b, at the outputs of the converter the bit duration will be MT_b. Each of the M streams is coded with a code of rate B/C and each coded bit is replicated R times. All the resulting coded bit streams are interleaved and spread by a common pseudo noise (PN) sequence. Each of these bit streams modulates one of the MS orthogonal carriers, where S is the product of the number of outputs of the coder in one of the M streams times the value of R (note that the number of outputs of the coder is not necessary equal to C). The MS modulated carriers are summed to form the transmitted signal. All considerations taken in [2] concerning with the interleaving process, with the type of modulation as well as the frequency spectrum were also taken for the coded system proposed here. It is important to observe that if the code is a repetition code, the system is reduced to the model described in [2].

Fig. 2 shows the block diagram of the receiver for the proposed system. It consists of MS matched filters followed by de-interleavers. Each group of R de-interleaver outputs are then combined (equal gain or maximal ratio combining) to form the soft-decision variables for the corresponding coded bit. If $R = 1$, the de-interleavers outputs feed directly the decoder.

Performance results: To obtain the performance of the coding scheme in a Rayleigh fading channel, the outputs of the de-interleavers were computer generated based on the analytical expressions given in [2]. It was assumed that the channel behaves like a single path fading channel for each carrier. Therefore, the outputs of the de-interleavers can be expressed as the desired coded bit distorted by fading and corrupted by noise and interference from other users. This interference was generated as Gaussian with variances given by the expressions derived in [2]. Due to the fact that the Rayleigh fading amplitudes of the channel model are being generated for the simulations, it is also possible to consider the maximal ratio combining rule for the combiner at the receiver. It was further assumed that the spreading codes are random for all users. In all the simulations, a minimum distance decoding algorithm which uses the Euclidean distance as a distance measure was considered.

Preliminary simulation results for the uncoded system with the equal gain combining rule were obtained and they are described in [3]. All these results are in perfect agreement with the numerical results shown in [2]. Simulation results for the uncoded system with the maximal ratio combining rule are also given in [3]. They show that the use of this rule can improve the performance of the system.

Fig. 3 shows simulation results for the generalised array code (15,5,7), which has the same weight distribution of the BCH (15,5,7) code [4]. The results shown are for $M = 2$, $S = 3$, $R = 1$, number of users $K = 10$ and PN sequence length $N = 34$. The performance of an uncoded system with a single carrier and a conventional RAKE receiver is also shown for reference. The PN sequence length for the single carrier case was adjusted in order to keep the total bandwidth of the transmitted signal equal to the total bandwidth of the multicarrier system.

As can be noticed from Fig. 3, the coded scheme achieves a bit error probability of 10^{-3} for a SNR of about 12 dB, whereas the uncoded system exhibits an error floor for a higher error probability. The SNR is the average received bit energy per noise power spectral density, as defined in [2].

Fig. 4 shows simulation results for the (8,4,4) code, which is a Reed Muller code. The results shown are for $M = 2$, $S = 4(6)$, $R = 2(3)$, number of users $K = 10$ and PN sequence length $N = 18(26)$. All the simulation results shown in Fig. 4 are for the maximal ratio combining rule. In Figures 3 and 4, the performance for the uncoded systems is also shown. It was also assumed in all simulations that the fading variables are uncorrelated. The results shown in Fig. 4 demonstrate that the coded scheme, for the simulated cases, achieves a coding gain of about 5 dB for a bit error probability of 10^{-3}.

Conclusions: We have suggested a channel coding scheme for an orthogonal multicarrier DS-CDMA system, whose parameters can be chosen in such a way that the transmission rate of information is not reduced and the transmitted signal bandwidth is not increased in comparison with the original uncoded system. The proposed scheme offers flexibility concerning the choice of its parameters (code rate B/C, number of bit repetitions R and the values of M and S) in order to achieve a good trade-off among performance, implementation complexity and bandwidth efficiency. It remains an open problem to find optimum design criteria for the proposed coding scheme, aiming to construct the best codes.

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List of Captions:

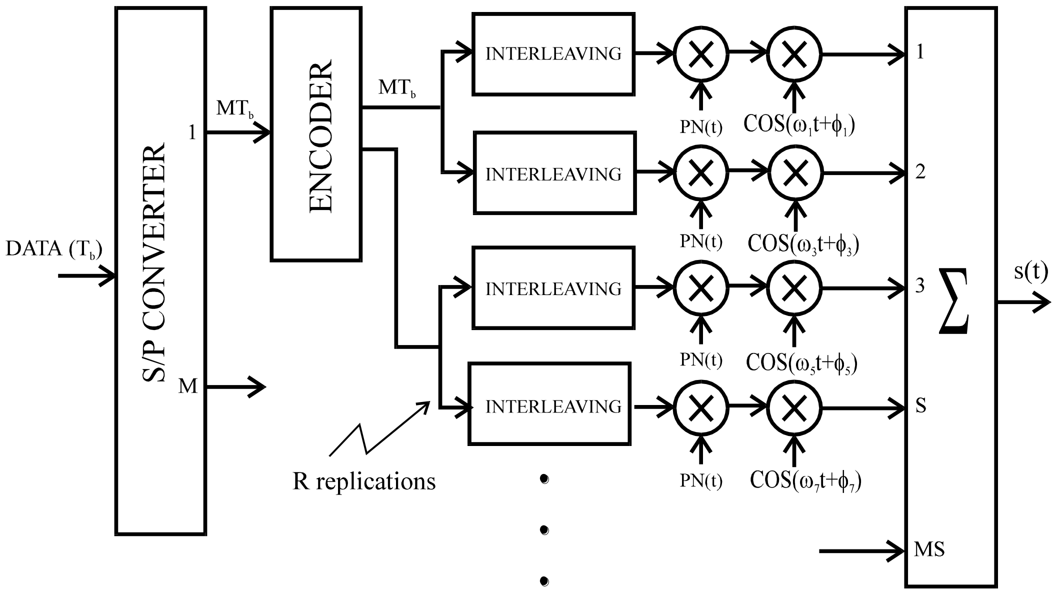

Fig. 1 – Block diagram of the transmitter of the coded Multicarrier DS-CDMA system

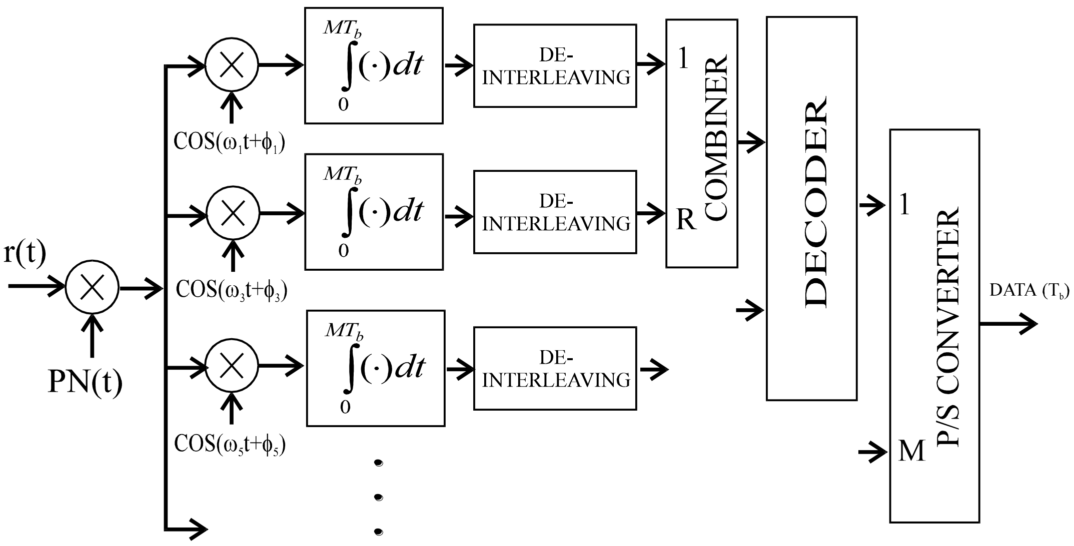

Fig. 2 – Block diagram of the receiver of the coded Multicarrier DS-CDMA system

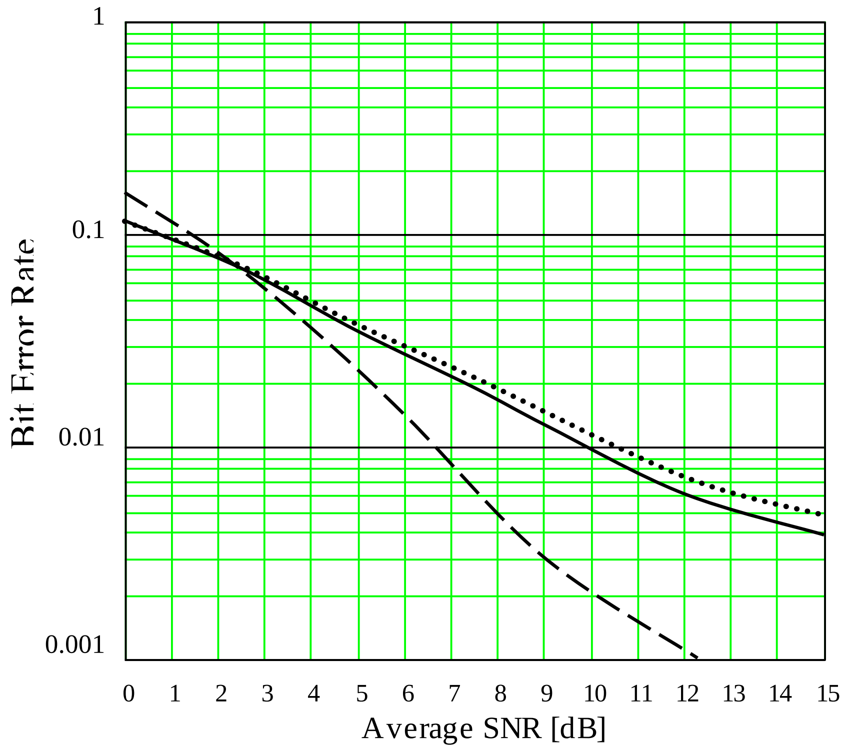

Fig. 3 – Performance of the Multicarrier DS-CDMA system in a multipath Rayleigh fading channel

Uncoded single carrier system ($M = S = 1$) with a RAKE receiver for $K = 10$ ....

Uncoded for $M = 2$, $S = 3$, $K = 10$ and $N = 34$ ———

Coded system with the (15,5,7) code, for $M = 2$, $S = 3$, $R = 1$, $K = 10$ and $N = 34$ — — —

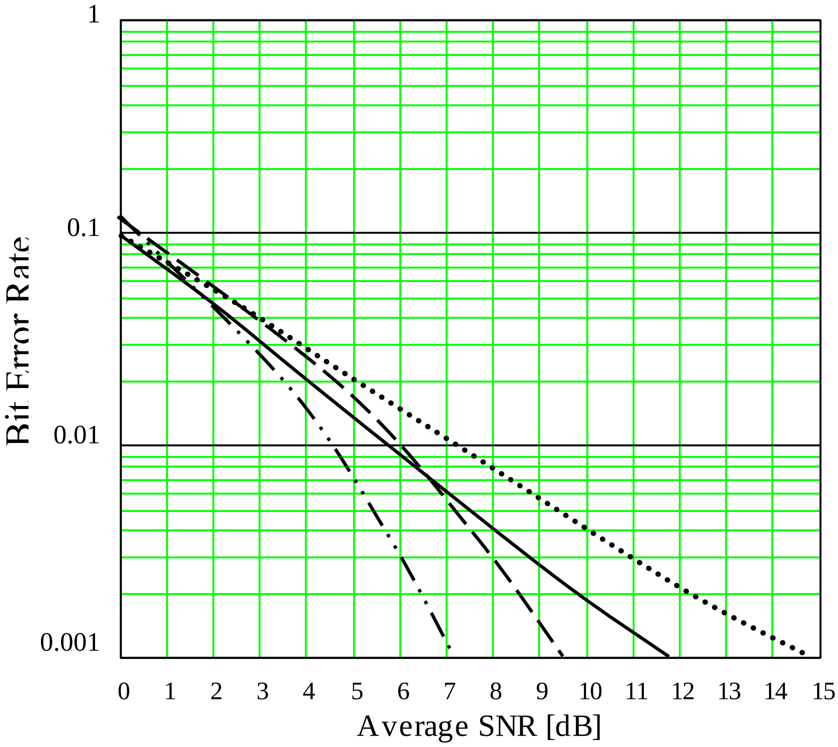

Fig. 4 – Performance of the Multicarrier DS-CDMA system in a multipath Rayleigh fading channel

Uncoded for M = 2, S = 4, K = 10 and N = 18 ········
Uncoded for M = 2, S = 6, K = 10 and N = 26 ———
Coded system with the (8,4,4) code, for M = 2, S = 4, R = 2, K = 10 and N = 18 — — —
Coded system with the (8,4,4) code, for M = 2, S = 6, R = 3, K = 10 and N = 26 — · · —

Fig. 4 – Performance of the Multicarrier DS-CDMA system in a multipath Rayleigh fading channel