ON THE SPREADING FACTOR OF MULTICODE MC-CDMA WITH RCPT HYBRID ARQ

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1. Introduction

Multicode MC-CDMA can be used for high data rate transmission under frequency selective fading environments, where multiple data-modulated symbols are code-multiplexed over a number of orthogonal subcarriers using orthogonal spreading sequences defined in the frequency-domain. The same data rate as in OFDM can be achieved by code-multiplexing as many as *SF* data symbols over *SF* subcarriers, where *SF* stands for the spreading factor. It has been found that multicode MC-CDMA using MMSEC provides a superior bit error rate (BER) performance than OFDM for the same data rate and the same bandwidth [1]. With the increase in demand for packet data transmission, hybrid ARQ is essential for error control. When rate compatible punctured turbo (RCPT) coded type II hybrid ARQ (HARQ) is incorporated in a multicode MC-CDMA system, what is the optimum spreading factor? This paper tries to answer this question.

2. Multicode MC-CDMA system with RCPT HARQ

The simplified transmission system model is shown in Fig. 1. The type II RCPT HARQ considered in this paper is obtained by puncturing the parity sequences got after turbo coding with a puncturing period of P=8 [2]. The puncturing matrixes used to obtain the sequences transmitted in subsequent transmissions are as follows (in octal notation):

$$\begin{bmatrix}3&7&7\\0&0&0\\0&0&0\end{bmatrix}\begin{bmatrix}0&0&0\\2&0&0\\0&1&0\end{bmatrix}\begin{bmatrix}0&0&0\\0&0&2\\0&4&0\end{bmatrix}\begin{bmatrix}0&0&0\\0&2&0\\0&0&1\end{bmatrix}\begin{bmatrix}0&0&0\\0&0&4\\1&0&0\end{bmatrix}\begin{bmatrix}0&0&0\\0&1&0\\2&0&0\end{bmatrix}\begin{bmatrix}0&0&0\\1&0&0\\0&0&4\end{bmatrix}\begin{bmatrix}0&0&0\\0&0&1\\0&2&0\end{bmatrix}\begin{bmatrix}0&0&0\\0&4&0\\0&0&2\end{bmatrix}$$

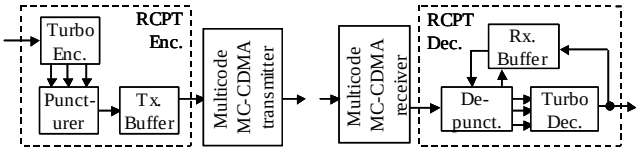

Fig. 1 Simplified transmission model

3. Simulation Results

For the simulation purpose, we consider a rate 1/3 turbo code made from two (13, 15) recursive systematic encoders. The encoded sequences are punctured, interleaved with a square interleaver, and BPSK modulated. The information sequence length, N, is taken to be 1024 bits. To make the data rate of multicode MC-CDMA equal to that of OFDM, we assume that a total of *SF* data symbols are code-multiplexed using Walsh codes. For the simulation purpose, number of sub-carriers N_c is taken to be 256 and hence 256 data symbols are transmitted per MC-CDMA symbol. It is assumed that the propagation channel is a 16-path frequency selective Rayleigh fading channel having a uniform power delay profile with a time delay spacing of 2 FFT samples. The normalized maximum Doppler frequency of each path is f_DT=0.01. The faded multicode MC-CDMA signal is received by M antennas. MMSEC is applied to despread the multicode MC-CDMA signal. It is then demodulated and input to the RCPT decoder. An error free reverse channel and ideal error detection are assumed.

Figure 2 plots the throughput for the type II RCPT coded hybrid ARQ as a function of the average received E_c/N_0 (energy of each coded bit to the noise power spectral density ratio) with *SF* as a parameter for M=1 and 2. It is seen that for lower E_c/N_0 ratio the throughput is independent of *SF*. However, for higher E_c/N_0 the throughput increases with the increase in *SF*. A 20% increase in throughput is seen for E_c/N_0=20dB when M=1. Having $SF=N_c$ gives the best performance at all times. This is because of the largest frequency diversity effect that can be obtained when each symbol is spread over all subcarriers. *SF*=1 is equivalent to the OFDM system. Hence, it can be concluded that the throughput of multicode MC-CDMA is better than that of OFDM.

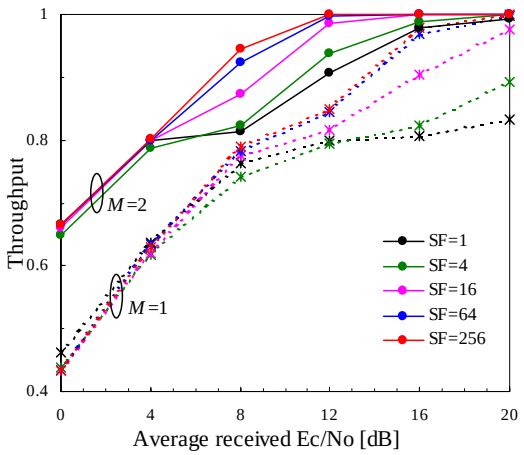

Fig. 2 Throughput performance.

4. Conclusion

It was found that for multicode MC-CDMA with RCPT coded hybrid ARQ the highest throughput can be achieved by using the largest possible spreading factor and is better than that of OFDM.

References

[1] R. Kimura and F. Adachi, Tech. Report of IEICE RCS, March. 2003
[2] D. Garg, R. Kimura, F. Adachi, Tech. Report of IEICE RCS2001-280, March. 2002