



Comparison of Coded and Un-coded MC-DS-CDMA System using Linear Block Codes

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Abstract: Recent advances in wireless communication have made use of MC-CDMA (Multi-carrier code division multiple access) in broadband communication to allow high data rates. In this research, the channel coding is being investigated for synchronous MC-CDMA using LBC (linear block codes) by using hamming codes with code rates 0.57 and 0.73 respectively. In the proposed approach the Walsh codes used for spreading users in time domain. In addition, the performance of concatenated error correction codes are analyzed, where BCH hamming code has been used as outer and convolution code has been used as inner code. The OFDM (Orthogonal Frequency Division Multiplexing) has been used to achieve frequency diversity gain and same signal has been sent over different carrier frequencies for testing. The carrier frequencies being adequately separated in frequency domain so they do not interfere with each other and therefore further increased in capacity. In this scheme, the MRC (Maximum Ratio Combiner) for combining the signals coming from different subcarriers were used. In addition, the MRC followed by de-correlating detectors (DD) and results for both receivers were compared and demonstrated with 16 and 32 users.

Keywords: MC-CDMA, LBC, Wireless, Concatenated Codes, Multi user detection

1. INTRODUCTION

In wireless systems the CDMA is a technique to distinguish users in a multiuser environment and OFDM (Orthogonal Frequency Division Multiplexing) is also very famous technique. The idea of multicarrier technique is not new but certain aspects of this system are still uncovered. The concept of Direct Sequence Code Division Multiple Access (DS-SS) and Orthogonal Frequency Division Multiplexing (OFDM) methods are merged and in that users are spread in time domain and separated in frequency domain because of orthogonal frequencies (Chakravarthy, Nunez *et al.* 2005, Hanzo, Keller 2007). Since, these frequencies are sufficiently separated so, in that case the total channel capacity added up and in the result maximum frequency diversity gain along with the spreading gain can be possibly obtained. As the role of spreading codes used in MC-CDMA is subject to its orthogonality and channel hostility is something that limits it, so to combat with such hostile channel conditions may overcome by use of well researched channel coding schemes (Pusane, Smarandache *et al.* 2011, Awasthi, Bhaduria *et al.* 2011, Hanzo, Münster *et al.* 2003). There are a number of channel coding schemes proposed in the literature (Pusane, Smarandache *et al.* 2011, Semenov, Krouk 2011, Yang 2010, Chih-Lin, Gitlin 1995, Awasthi, Bhaduria *et al.* 2011) and which are quite useful in wire and wireless communications. In practical, from many channel-coding schemes the block and convolutional codes are very powerful and widely used in communication systems. In this research, BCH codes

that belong to family of LBC (Linear Block Codes) is used as outer code while convolutional codes is used as inner code. Furthermore, the use of the received signal of all the users as a useful information separates all the user's data that is known as Multi-User Detection (MUD). Two receiver schemes were investigated; one is simple MRC (Maximum Ratio Combiner) and second is DD (De-correlating Detector) and results were compared with different number of users.

This paper is structured into four sections. Methodology and proposed model is explained in section two and simulation results are described in section three. The summary and references presented in section four and five respectively.

2. METHODOLOGY AND PROPOSED MODEL

In this research a multicarrier code division multiple access model is chosen for the investigation of the coded and un-coded performance of different code rates. Matlab 7 has been used as a tool to write the code for the simulation and generating results in graphs. Since channel nonlinearities may affect the orthogonality of spreading codes and how much channel coding pays off in a multiuser environment especially when numbers of users are quite large.

A system with N number of users being communicating over the same channel is suggested in this research. The channel considered here is Rayleigh

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Fading Channel with known Channel State Information (CSI). It is assumed that all these users are simultaneously transmitting the data in a bit synchronized fashion. Each bit of each individual user is being spread using different spreading codes each of length L chips.

2.1 Transmitter

A bit-synchronous MC-CDMA system considered and illustrated in figure 1. Here, K number of data bits each is encoded using a Linear Block Code.

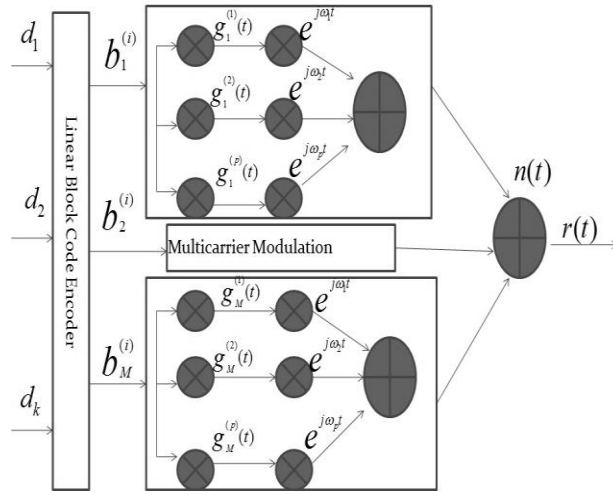


Fig. 1 The transmitter of a MC-CDMA system

After encoding each encoded bit represents a simultaneous user. It is observed in the figure that the encoded bit $b_1^{(i)}$ is spread over subcarrier specific spreading codes. Where there are P parallel subcarriers, each conveying one of the P number of L-chip spreading signature sequences $g_1^{(p)}(t)$, $p = 1, \dots, P$, each of which spans over $(0, T_b)$ interval in time.

$$s_m^p(t) = \sqrt{\frac{2\mathcal{E}_{b,m}}{P}} g_m^{(p)}(t) b_m^{(i)} e^{j\omega_p t} \quad (1)$$

$$s_m(t) = \sum_{p=1}^P s_m^p(t) = \sum_{p=1}^P \sqrt{\frac{2\mathcal{E}_{b,m}}{P}} g_m^{(p)}(t) b_m^{(i)} e^{j\omega_p t} \quad (2)$$

$$s^p(t) = \sum_{m=1}^M s_m^p(t) = \sum_{m=1}^M \sqrt{\frac{2\mathcal{E}_{b,m}}{P}} g_m^{(p)}(t) b_m^{(i)} e^{j\omega_p t} \quad (3)$$

$$s(t) = \sum_{m=1}^M s_m(t) = \sum_{m=1}^M \sum_{p=1}^P \sqrt{\frac{2\mathcal{E}_{b,m}}{P}} g_m^{(p)}(t) b_m^{(i)} e^{j\omega_p t} \quad (4)$$

where $\mathcal{E}_{b,m}$ is the mth user's signal energy per transmitted bit, $b_m^{(i)}$ belongs to $(1,-1)$ the antipodal signaling symbols, where total number of users are $m = 1, \dots, M$ and 'i' denotes the ith transmitted bit of mth user, while the mth user's signature waveform is $g_m^{(p)}$, $p = 1, \dots, P$, $m = 1, \dots, M$; on the pth subcarrier, which again has a length of L chips, and can be written as:

$$g_m^{(p)}(t) = \sum_{n=1}^L g_{m,n}^{(p)}(t) q(t - nT_c) \quad (5)$$

Where T_c is the chip duration, L is the number of chips per bit associated with each subcarrier. We have $T_b/T_c = L$ as the coding gain. The total processing gain in LP, while $q(t)$ is the rectangular chip waveform employed, can be expressed as:

$$q(t) = \begin{cases} 1, & 0 \leq t < T_c \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

It is assumed without the loss of generality, that the signature waveform $g_m^{(p)}(t)$ used for spreading the bits to a total of P subcarriers for all the M users have unit energy, that can be written as:

$$\int_0^{T_b} g_m^{(p)2}(t) dt = 1, \quad m = 1, 2, \dots, M, \quad p = 1, 2, \dots, P \quad (7)$$

2.2 Channel

It is assume that signal of each user $s_m^p(t)$ transmitted on the pth subcarrier is propagated over an independent non-dispersive single-path Rayleigh Fading Channel and where each user face a different amount of fading independent of each other.

2.3 Receiver

The received signal on the path subcarrier can be expressed as:

$$r_p(t) = \sum_{i=-\infty}^{\infty} \sum_{m=1}^M \sqrt{\frac{2\mathcal{E}_{b,m}}{P}} g_m^{(p)}(t - iT_b) \alpha_m^p b_m^{(i)} e^{j(\omega_p t + \theta_m^p)} + \eta(t) \quad (8)$$

Here M is the number of users supported and $\eta(t)$ is the Gaussian noise process with a variance of $N_0/2$. Fig. 2 depicts the receiver end of the proposed scheme. It is important to repeat the same steps but in reverse order to get the things back. Initially, the system needs to demodulate the signal which is carried out by Matched Filtering (MF) of each of the M users and the outputs of the M users' match filters are input to the MRC then feed it to various MUD schemes. The output

of these MUD schemes will be fed to the decoder that will in turn throw out the nearest estimate of the data bits sent at transmitter end.

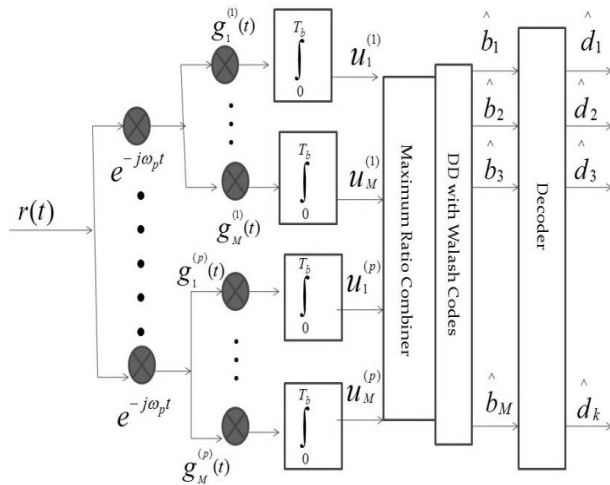


Fig. 2: Schematic of MUD with MC-CDMA receiver:

3. **SIMULATION RESULTS**

The results of all two detectors and both codes that is (7, 4) and (15, 11) Hamming codes are demonstrated in (Fig. 3 to 8).

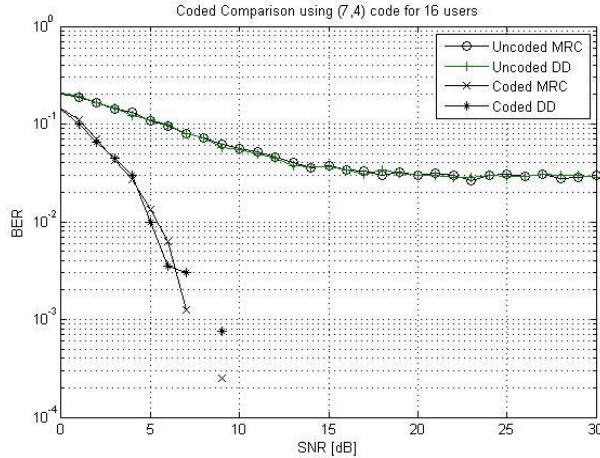


Fig.3: BER performance of coded and uncoded systems for 16 users

Fig. 3 shows the performance of coded system outperforms. Further the use of decorrelating detector makes the performance even better. For example, at 8dB it can be observed that there is approximately an order difference in coded and un-coded system. Though number of users are not much as well as the Walsh codes play their role but coding performance is still significant. So it is apparent from the above figure that coding gain is almost 4dB.

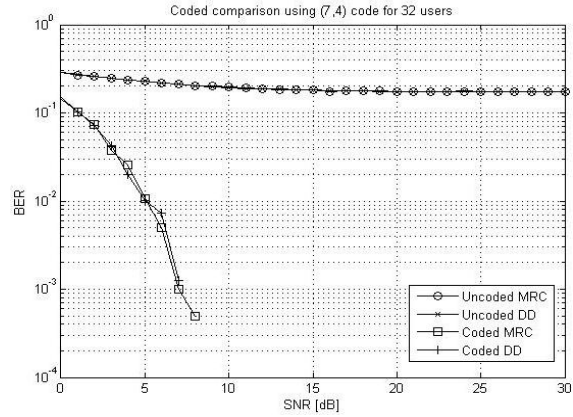


Fig. 4: BER performance of coded and un-coded systems for 32 users

Fig. 4 reveals very interesting results, the results are obtained by using 32 users, that BER is quite high compared to previous case in un-coded environment while coded performance simply outperforms. Though the role of Decorrelating detector is negligible compared to Maximum Ratio Combiner (MRC). As in case of 32 users MAI introduced is quite high but role of error correcting code is elegant. So coded system's performance is not much affected by doubling the number of users while un-coded system is choked.

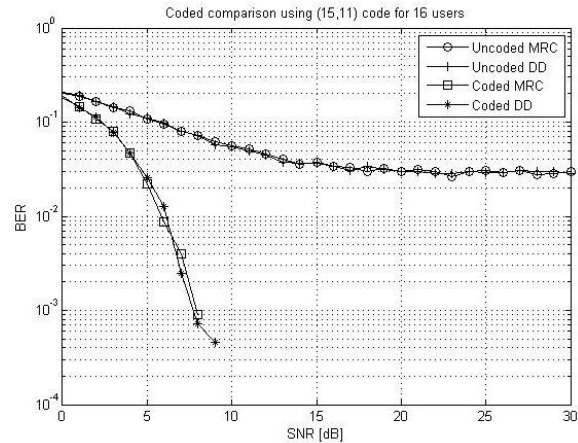


Fig. 5: BER performance of coded and un-coded systems for 16 users using Hamming (15, 11) code

In (Fig. 5) role of (15, 11) Hamming code is investigated for 16 users. This figure reveals almost same kind of facts. A small degradation can be seen compared to (7, 4) Hamming code. Similarly role of Decorrelating detector is better than that of maximum ratio combiner, and as far as coding gain is concerned, the coded system is still an order better than un-coded system. In contrast to Fig. 4 where 10⁻³ BER is achievable at 6dBs; here almost 8dB gives the same results so 2dB gain is achieved in (7,4) versus (15,11) Hamming codes.

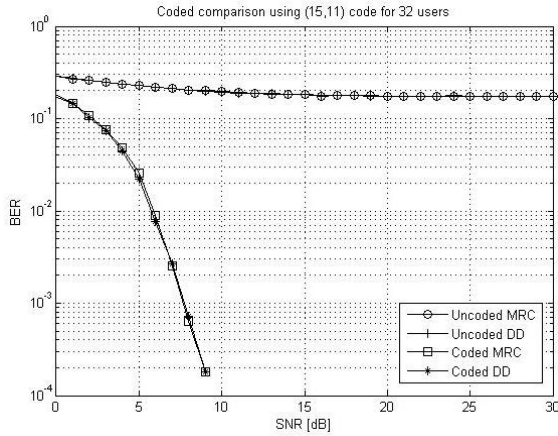


Fig. 6: BER performance of coded and un-coded systems for 32 users using Hamming(15,11) code

In (Fig. 6): number of users supported are 32. In contrast to figure 5 there is a significant difference in performance of both codes that is (7, 4) and (15, 11). For example at signal to noise ratio 6dB , the bit error rate of (7, 4) code is almost 10^{-3} while the same bit error rate in (15, 11) code can be achieved at 7dBs. Moreover, role of decorrelating detector and MRC in coded system is almost similar. In short, the role of coding is almost dominant in all of these figures. So this is number of users that can limit its role but it is still surviving with slight loss of performance in enhanced number of users. And code rate on the other hand is a good figure of merit. Throughout this discussion role of (7, 4) Hamming code is better than (15, 11) Hamming code .

3.1 Performance of Concatenated Codes

In (Fig. 7), sixteen (16) users supported at 10dB BER is 2×10^{-3} . Similarly, in (Fig. 8), , thirty two (32) users are supported and increased till 32. This change users show a slight degradation in performance and at 10dB its approximate BER is 2×10^{-2} .

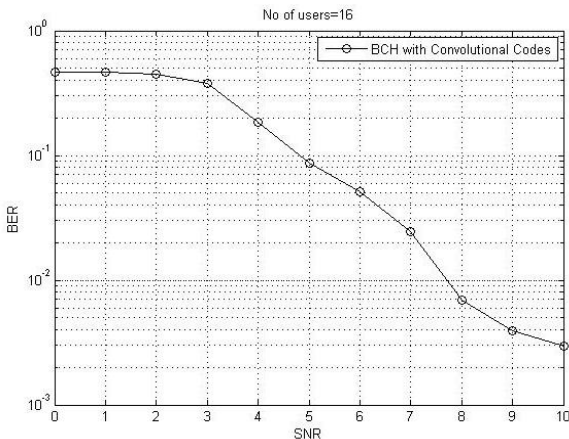


Fig. 7: BER performance of concatenated codes with 16users

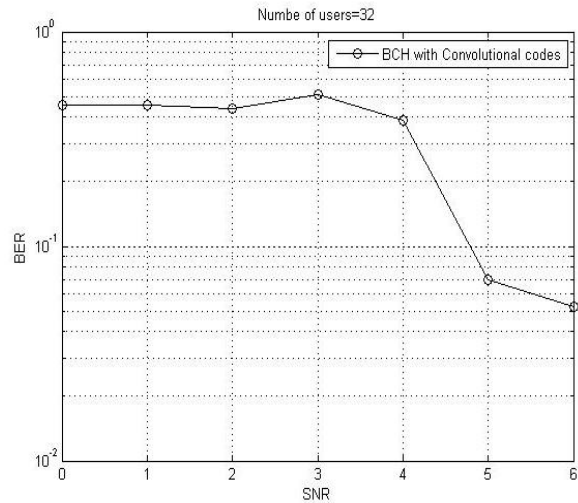


Fig. 8: BER performance of concatenated codes with 32users

3.2 Performance comparison

Following is a comparison given for different number of users versus different coded and un-coded techniques with 8dB signal to noise ratio.

Table 1: Performance comparison based on BER

	16 users	32 users
Un-coded MRC	4×10^{-2}	1×10^{-1}
Coded MRC (7,4)	2×10^{-3}	3×10^{-3}
Coded MRC (15,11)	3×10^{-3}	4×10^{-2}
Un-coded DD	3×10^{-2}	1×10^{-1}
Coded DD with (7,4)	1.75×10^{-3}	9×10^{-4}
Coded DD with (15,11)	4×10^{-4}	1×10^{-3}

From the above table it is clear that (7, 4) code performs well compared to (15, 11) and the best performance is achieved by (7,4) with decorrelating detector.

Now the performance of concatenated codes is concluded subsequent slides for different number of user and following conclusions;

- In first (Fig. 7), number of user supported is 16 and at 10dB BER is 2×10^{-3}
- Similarly, in 2nd (Fig. 8), number of users supported is increased till 32 that shows slight degradation in performance and at 10dB its approximate BER is 2×10^{-2}

So it is apparent from the bullets that performance of concatenated codes is significant compared to ordinary Hamming Codes. That is the reason they are suggested for future communication systems.

4.

CONCLUSION

A coded and un-coded MC-CDMA system investigated by using concatenated codes, where BCH Hamming codes were used as outer codes and punctured convolutional codes used as inner code. A rate $\frac{3}{4}$ punctured convolutional code is used in concatenation and three different types of BCH Hamming codes are investigated with different code rates. Communication over Rayleigh Fading channel studied. In a multi-user detection MAI (multiple access interference) was introduced in the literature which makes the detection less efficient and may cause degradation in bit error rate (BER). Therefore, in this model the degradation in BER caused by MAI will be improved by using LBC.

A comparative study is presented by using coded and un-coded system using Walsh codes as spreading codes for 16 and 32 users. In conclusion the proposed coded system is capable of significantly reducing the bit error rate compared to un-coded system especially when the number of users supported is higher than 16. Moreover, Hamming code outperforms than Hamming code in all cases discussed. Secondly, decorrelating detector performs even well compared to the simple maximum ratio combiner (MRC). In practical environment it is accustomed to use coding techniques for better performance.

REFERENCES:

Awasthi, P., S. S. Bhaduria and M. Mishra, (2011) Performance Analysis Of Interleave Division Multiple Access Scheme With Different Coding Techniques. *Advances In Computing, Communication And Control*. Springer, Vol.125, 200-207.

Chakravarthy, V., A. S. Nunez, J. P. Stephens, A. K. Shaw, and M. A. Temple, (2005) Tdcs, Fdm, And MC-CDMA: A Brief Tutorial. *Communications Magazine, IEEE*, 43 (9), S11-S16.

Chih-Lin, I. and R. D. Gitlin, (1995) Multi-Code CDMA Wireless Personal Communications Networks, *Communications, 1995. ICC'95 Seattle, 'Gateway To Globalization', 1995 IEEE International Conference On 1995, IEEE*, 1060-1064. IEEE

Hanzo, L. L. and T. Keller, (2007) *OFDM And MC-CDMA: A Primer*. Wiley-IEEE Press.

Hanzo, L., M. Münster, B. Choi, and T. Keller, (2003) *OFDM and MC-CDMA For Broadband Multi-User Communications, Wlans And Broadcasting*. John Wiley and Sons. UK

Pusane, A. E., R. Smarandache, P. O. Vontobel and D. J. Costello (2011) Deriving Good LDPC Convolutional Codes From LDPC Block Codes. *Information Theory, IEEE Transactions On*, 57 (2), 835-857.

Semenov, S. and E. Krouk, (2011) *Modulation And Coding Techniques In Wireless Communications*. Wiley. USA

Yang, L., (2010) Receiver Multiuser Diversity Aided Multi-Stage Minimum Mean-Square Error Detection For Heavily Loaded DS-CDMA and SDMA Systems. *Communications, IEEE Transactions On*, 58 (12), 3397-3404.