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Comparison of Bit Error Rate And Performance Analysis For Multicode CDMA Techniques in Fading and AWGN Channels

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Abstract*— In recent years, wireless communication technology has made great progress. With the rapid growth of video, voice, and data communications, mobile phones have become ubiquitous and so need mobile multimedia communications. To meet the increasing demands of mobile communication services, many solutions have been proposed to reduce the impact of channel effects and increase the speed of data transmission. One of those methods is the use of Multicode Code Division Multiple Access (MTC -CDMA). Two techniques of the MTC-CDMA system have been used, which are multicode system and orthogonal code system. The MTC-CDMA system can support different data rates as needed by next-generation standards. The bit error rate (BER) of the two systems is analyzed in AWGN and Rayleigh fading channels. The multicode system has been simulated with different codes for both code sequence sets and user-specific sequences. These codes are Walsh-Hadamard, orthogonal variable spreading factor (OVSF), Gold, Kasami, and Maximum length sequence (M-sequences) codes. The orthogonal code system is simulated with Walsh-Hadamard spreading code. The results show that the use of Walsh-Hadamard code as user specific sequence and the Gold code as a code sequence gives better BER performance compared with other types of codes for the multicode system. Also, the using of Walsh-Hadamard for sequence sets and PN codes for user specific sequences gives good performance. For the same M-ary, the number of users, and spreading code length, the orthogonal code system can achieve better BER performance than the multicode system, but the maximum number of users that can be accessed is less.

Keywords*— *Wireless Communication, CDMA, Multicode CDMA, Multicode System, Orthogonal Code System.

I. Introduction

Wireless communication is one of the most rapidly growing systems in data and transmission. Every year, the rapidly growing achieves a higher capacity to increase the number of customers accessed. Code Division Multiple Access has emerged as one of the greatest multiple access techniques. All users in CDMA communication systems share the same channel [1][2].

Multicode CDMA is a proposed technique to support multi-rate operation in CDMA networks. It easily integrates rate data streams into a unified architecture with all types of channel modulation under the same carrier, occupying the same bandwidth, and having the same processing gain. There are many techniques for multicode CDMA, such as multicode system and orthogonal code system, etc. Each customer takes a group of M codes named the code sequence set. This system is similar to the M-ary modulation system in that a sequence of codes is used instead of a sequence of bits. The set size of code sequences is based on the requested data rate. In the usual manner, this code set size is 2; that is, there are two code sequences, one symbol representation '0' and the other symbol representation '1'. If a data rate greater than L times the basic data rate is required, the code sequence set will be of size 2^L, and each sequence of L bits will be mapped to one of the code sequences [3][4][5].

A. Multicode System

A multicode system can support variable data rates. The transmitter and receiver block diagrams for the MTC-CDMA system are explained in Fig. 1 and 2 below. Each user has a set of M-code sequences; M can be obtained by dividing the basic data rate by the needed data rate. The M-ary symbol to be sent chooses one of the code sequences of length N, which is then multiplied chip by chip by the user specific sequence U_k. The user-specific sequence is used to identify each user from the others and has a length N that is equal to the length of the code sequence [3][6].

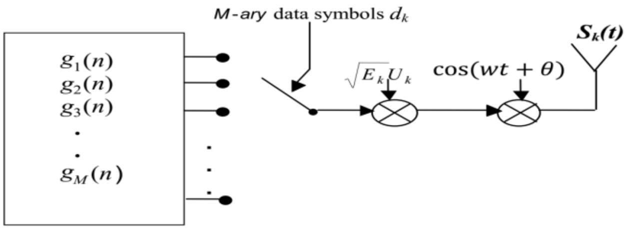

Fig. 1. MTC-CDMA transmitting system [3].

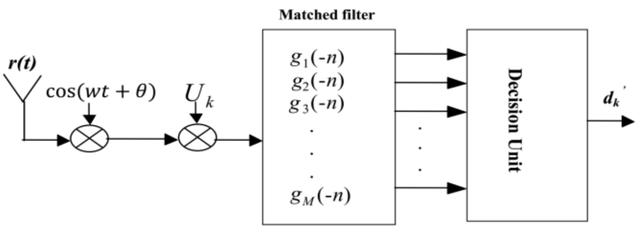

Fig 2. MTC-CDMA receiving system [3].

According to the M-ary data symbols, d_k is sent at a data rate of $1/T_s$, where T_s is the duration of each symbol. After assigning a code sequence for each symbol, the code sequence set is multiplied chip by chip with $U_k(n)$. The symbol d_k is mapped onto [3][5]:

Where E_k indicates the energy of the symbol of the kth user, $g_{dk}(n)$ indicates the chosen code sequence, f is a rectangular pulse with T_c duration, w is the angular frequency, and θ_k represents a random phase [7].

$$G_m(n) = \{g_m(n), 1 \leq m \leq M\} \quad (1)$$

The sent signal for any user k is explained as

$$s_k(t) = \sqrt{E_k} \sum_{n=0}^{N-1} g_{dk}(n)\, f(t - nT_c)\, U_k(n) \cos(wt + \theta_k) \quad (2)$$

Where E_k indicates the energy of the symbol of the kth user, $g_{dk}(n)$ indicates the chosen code sequence, f is a rectangular pulse with T_c duration, w is the angular frequency, and θ_k represents a random phase [7].

On the receiver side, the received sequence has been multiplied chip by chip with the user specific sequence, and then make a correlation between the result and each of the possible M code sequences. The sequence which gives a larger correlation result is then retrieved into an M-ary symbol [8][9].

B. *Orthogonal code system*

The simple description for an orthogonal code system is explained as follows. Assuming that each user in the system has M different spreading codes. Firstly, every transmitter will divide the incoming data bits into symbols, and each symbol includes m bits where m is equal to $\log_2 M$. The transmitter selects one code from M different codes to represent one symbol of the data. The mapping scheme of the orthogonal code system is explained in TABLE I below. Each symbol selects one of the different spreading codes that are named from g_1 to g_8 [3][6].

TABLE I. TABLE OF MAPPING SCHEME FOR ORTHOGONAL CODE SYSTEM WITH M=8.

Data			Spreading code							
d_0	d_1	d_2	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8
0	0	0	+1	0	0	0	0	0	0	0
0	0	1	0	+1	0	0	0	0	0	0
0	1	0	0	0	+1	0	0	0	0	0
0	1	1	0	0	0	+1	0	0	0	0
1	0	0	0	0	0	0	+1	0	0	0
1	0	1	0	0	0	0	0	+1	0	0
1	1	0	0	0	0	0	0	0	+1	0
1	1	1	0	0	0	0	0	0	0	+1

Fig.s 3 and 4 below are the transmitter and receiver block diagrams for the orthogonal code system, respectively. On the transmitting side, M different spreading codes are allocated for each user, which are named as g_1 to g_8. One code of them must be selected to denote a particular symbol. On the receiving side, the received sequences must be despread by all M spreading codes because the receiver does not know which code which spreading code will receive at a specific time. The outcome from the despreading parts enters a processing unit to choose the sequence that gives maximum output among the M inputs. The code sequence corresponding to this maximum value will be the transmitted code sequence, and then it will be demapped to retrieve the transmitted data bit symbol, as explained in TABLE I [3].

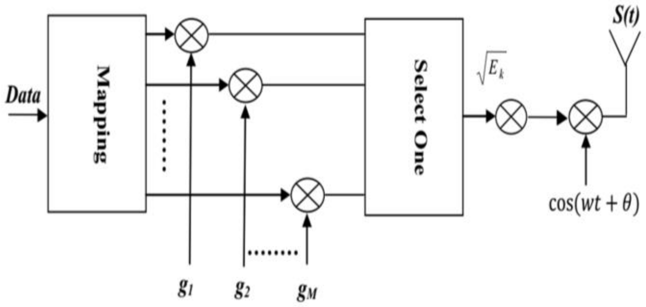

Fig. 3. Orthogonal code system transmitter.

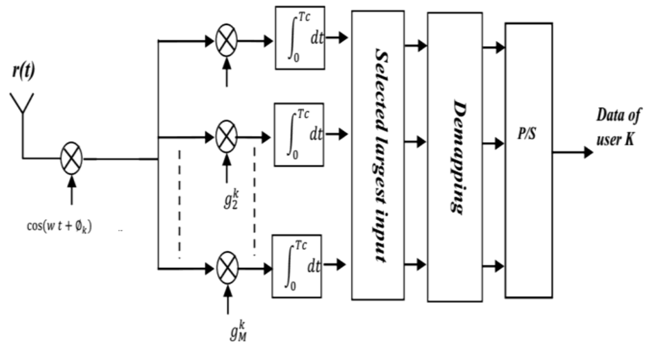

Fig. 4. Orthogonal code system receiver.

II. RELATED WORK

In 2013, M. G. Zia introduced the chaotic sequence's effectivity on the performance of the multicode multicarrier CDMA (MC.MC.CDMA) communication technique. The researcher uses a chaos code for code sequence sets in the part of the multicode system. While a chaos system depends on its initial conditions, then the multicode system is achieved by utilizing a single chaos code generator with different initial conditions for the code sequence group of M-ary modulation, and the MC-CDMA system is achieved by utilizing another chaotic generator with another different initial condition. The simulation outcomes showed that the MC-MC-CDMA system based on the chaotic scheme gives improved performance compared with Walsh codes in the classical MC-MC-CDMA technique [10].

In 2014, T.D.V.A Naidu et al. suggested an MTC-MC-CDMA system for the wireless telecommunication system of the next generation. This system keeps the benefits of MC-CDMA in eliminating the multipath and preventing the interference and gives different and adaptive data rates via the use of a multicode system. The researcher evaluates the performance of multicode CDMA utilizing different code groups in multipath fading channel and in the AWGN channel. Compared with the AWGN channel, the performance of the MTC-CDMA system decreases drastically in multipath fading channel. An MC-MC-CDMA system was proposed that keeps the variable data rate ability of the MTC-CDMA system and its robustness to multi-path fading such as MC- CDMA. The suggested system provides better BER characteristics compared to the main MTC-CDMA scheme [8].

Z. Abdelhak (2016) introduced a new interleaving technique in time and frequency domains depending on MC-MC-CDMA systems, permitting spreading in two dimensions (time and frequency domains). The researcher uses the classical multicode CDMA system for the part of multicode spreading with Walsh-Hadamard code as code sequence sets and PN code as user specific sequence [3].

A. Farzamnia (2018) presents BER performances of Direct Sequence - CDMA, SFH-CDMA, and MultiCarrier-CDMA in slowly varying Rayleigh fading channel as well as Rician fading channel and analyzes the BER performance of all the three wireless communication models for multiple users. From the results obtained, it can be seen that for all the three wireless techniques, the BER performance tends to decrease as the number of users increases which are shown by the decreasing gradient of the graphs. Even so, the BER performance of the MC - CDMA technique is observed to be better compared to the other two wireless techniques[11].

S. Khan et al. (2020) introduce a MultiCode-MultiCarrier-CDMA that is used in the Physical layer of IEEE 802.11ah to satisfy the differing range and throughput demands of a Drones to Drones and to Ground Control Station communication links for Drones swarms. The multicode technique used in this research is like that mentioned in part A of the previous section. In IEEE 802.11ah, MC–MC CDMA was achieved in the AWGN channel. It has been found that changing the modulation order directly changes data rate, with higher modulation orders resulting in poor performance [12].

In our research, to enhance the multicode system performance, the gold code is suggested as a code sequence set to represent the data symbols where the gold code introduces low cross-correlation values than the m-sequence codes. On the other hand, the Walsh-Hadamard code is used for user-specific sequences since it provides orthogonally between the users. Also. the orthogonal code system is used to enhance the BER performance using Walsh-Hadmard codes

III. SYSTEM MODEL

For the multicode system, there are two types of codes have been used, one code is the code sequence set, and the other code is the user specific sequence, the first code has a length of 256 and is used to spread the data symbols, and the second is used to identify each user and has the same of the code sequence length.

Firstly the serial data is modulated using BPSK modulation, and then it is mapped into symbols according to the M-ary. After that, each symbol is mapped into a code sequence that is longer than the symbol length. All users used the same code sequences and symbols mapping scheme. The code sequence of each symbol is multiplied chip-by chip with U_k of the particular user.

On the receiving side, the received data is first multiplied by the user specific sequence to fetch the sequence for each user, and then the user sequence enters the matched filter to be correlated with all code sequences, and the output with maximum value has been selected which represent the transmitted code sequence. The code sequence after that was demapped and demodulated to retrieve the original symbol bits. Fig. 5 below shows the block diagram of the multicode system.

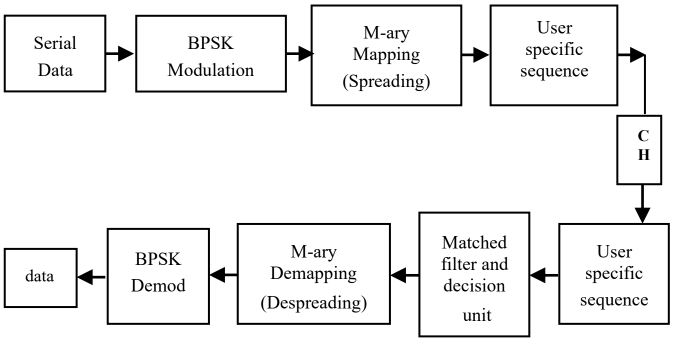

Fig. 5. Block diagram of multicode system

For the orthogonal code system, one type of spreading code has been used, which is the code sequence set used to spread the data symbols. Each user has different code sequences from the other users. The code sequences set for each user depend on the M-ary mapping. For the 4-ary mapping scheme, each user has four different symbols and hence four different spreading codes so that there are only 64 users can access for a code length of 256. While for the multicode system discussed above with the same parameters, there are 256 users that can be accessed.

At first, the serial data is modulated using BPSK modulation and then is mapped into symbols according to the M-ary. After that, each symbol is mapped into a code sequence that is longer than the symbol length. All users utilize different code sequences from each other, and hence there is no need for the presence of user specific sequence. On the receiving side, the received sequence of a particular user is correlated with all the code sequences of that user, and the output with maximum value has been selected, which represents the transmitted code sequence. The code sequence after that was demapped and demodulated to retrieve the original symbol bits. Fig. 6 below shows the block diagram of the orthogonal code system.

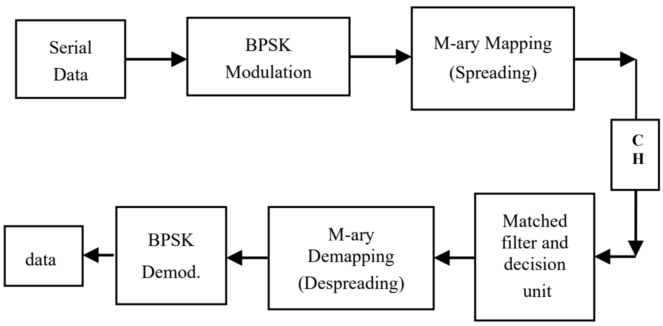

Fig. 6. Block diagram of orthogonal code CDMA system.

IV. RESULTS AND DISCUSSION

The MTC CDMA system has been simulated in AWGN and multipath fading channels. The Walsh-Hadamard code was suggested for user specific sequences to provide orthogonally between the users and hence reduce the interference, and the gold code is suggested as code sequence sets to represent the data symbols where the gold code introduces low cross-correlation values than the m-sequence codes. As a result of the above, It is concluded that the multicode system using Walsh-Hadamard and gold codes for user specific sequences and sequence sets respectively outperforms the system using other codes since it has the best BER performance and hence can support more users for the same BER as shown in Figs 7 and 8 below. They show the performance of the multicode system with different codes for AWGN and multipath Rayleigh fading channel, respectively, where M=16 for symbol mapping and SNR=30dB. Walsh-Hadamard and gold codes have been used as code sequence sets for symbol mapping, and each of them is used with different user specific sequences such as m-sequences, Walsh-Hadamard, Gold, Kasami, and OVSF codes. Also, the using of Walsh-Hadamard for sequence sets and PN codes for user specific sequences gives good performance.

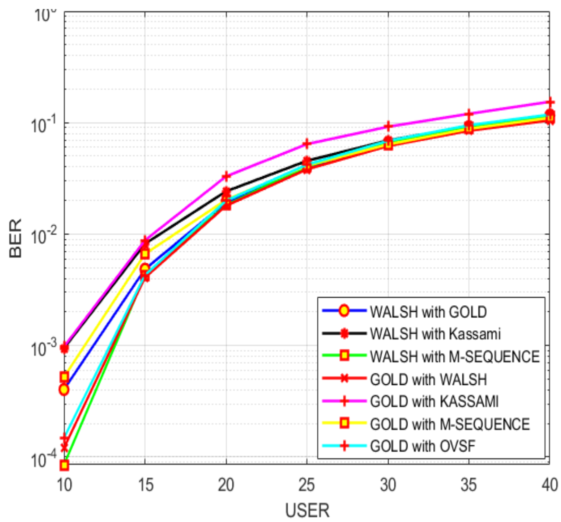

Fig. 7. BER versus number of users for Multicode system with different codes in AWGN. (SNR = 30dB, M = 16)

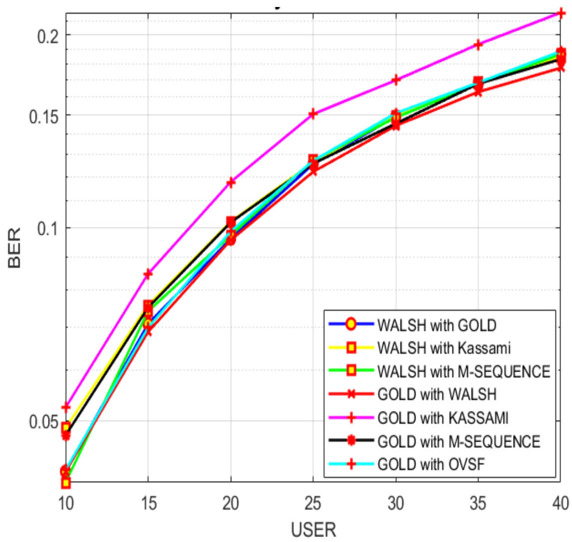

Fig. 8. BER versus number of users for Multicode system with different codes in Rayleigh fading channel. (SNR = 30dB, M = 16)

Since the gold with Walsh-Hadamard codes shows good performance compared with other code sequences for multicode CDMA, then these codes have been utilized for the implementation of the transmitter and the receiver for the multicode CDMA system. Fig. 9 and 10 below show the BER performance of 10 users, a 16-ary multicode system with gold code for code sequence sets, and Walsh-Hadamard, OVSF, Kasami, and M-sequences codes for user specific sequences in both AWGN and multipath Rayleigh fading channels. The results show that the gold with Walsh codes gives the best BER performance.

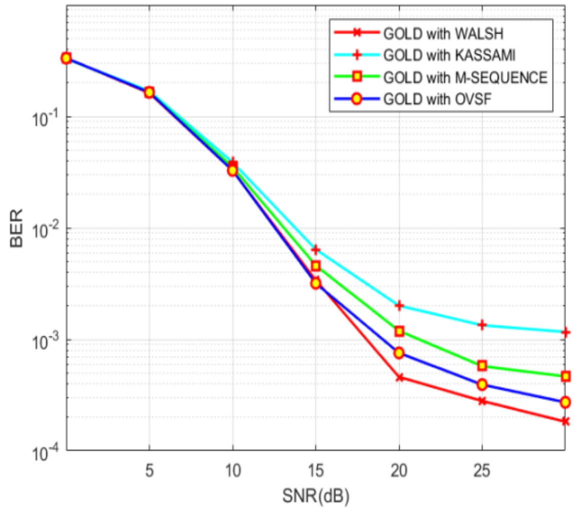

Fig. 9. BER versus SNR for Multicode CDMA system using different codes in AWGN channel (M=16, K=10)

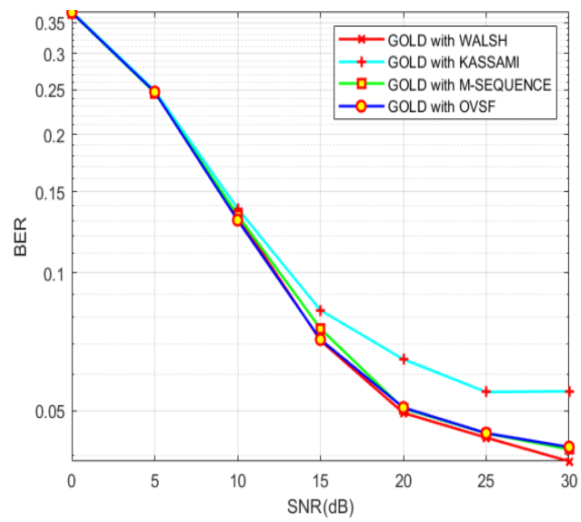

Fig. 10. BER versus SNR for Multicode CDMA system using different codes in Rayleigh fading channel (M=16, K=10).

This 16-ary multicode system gives a high data rate compared with M=2,4 or 8 where four bits per symbol can be transmitted. To enhance the BER of the 16-ary multicode system, a lower degree of M codes is used to represent the data symbols, and hence more users can access at the same BER. In Fig. 11 and 12, different M-ary is compared in both AWGN with SNR of 15dB and multipath Rayleigh fading channels with SNR of 30dB, where the data symbols are spread by M codes, and each symbol has $log_2 M$ bits of data. The performance is better for M=2, where two data symbols are used, which are 0 and 1, and two code sequences are used to spread these symbols. The 16-ary uses more code sequences; therefore, the data rate is increased with the increase of the number of codes and more spectral efficiency increases.

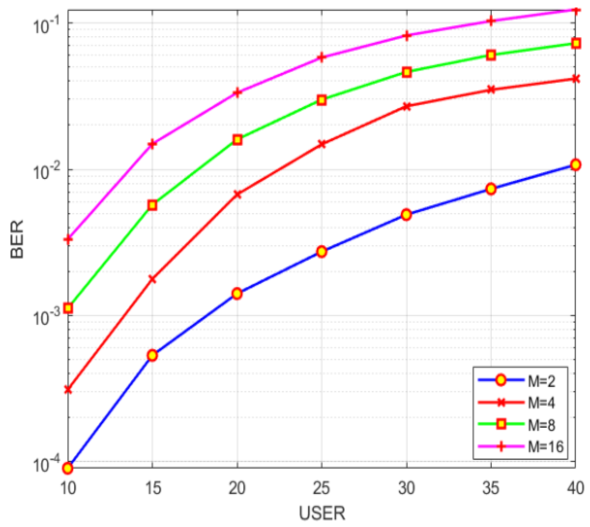

Fig. 11. BER versus SNR for multicode system with various M in AWGN channel (SNR = 15dB).

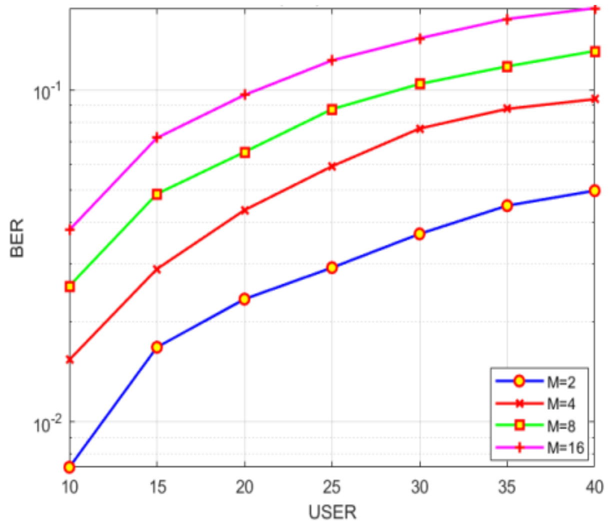

Fig. 12. BER versus SNR for multicode system with various M in Rayleigh fading channel (SNR = 30dB).

For the orthogonal code system, several M different spreading codes have been allocated for each user so that the interference where illuminated because each symbol of each user has different orthogonal spreading codes from the other symbols. The custom codes will be equally divided between the users according to the M-ary mapping schemes, and each symbol includes $m=\log_2 M$ bits

The Walsh-Hadamard code has been used for the orthogonal code system with a code length of 256 to spread the symbols. Fig. 13 below illustrates the BER performance of the orthogonal code system compared with the multicode system. The orthogonal code system has been simulated with a different number of users, and from the results, it's clear that the BER is almost constant for a different number of users.

For the 4-ary and code length of 256 Orthogonal code system, the maximum number of users is 64, which is equal to the spreading code length divided by M. on the other hand, and for the same parameters, the maximum number of users that can be accessed for the multicode system is 256 users.

The orthogonal code system maintains orthogonally between users because each different symbol of each user has been spread with different orthogonal code. As a result of the above, the orthogonal code system with a maximum number of users (64 users) and 4-ary gives better BER performance than the multicode system with ten users with 2, 4-ary mapping schemes.

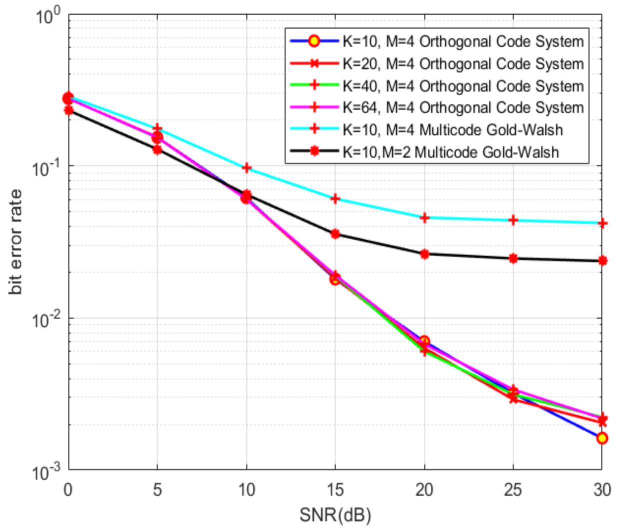

Fig. 13. Simulation results for BER versus SNR for orthogonal code system and multicode system Rayleigh fading channel.

V. CONCLUSION AND FUTURE WORKS

Multicode CDMA is a proposed technique to support multi-rate operation in CDMA communications. Two techniques of Multicode CDMA have been designed and simulated, which are multicode system and orthogonal code system. For the multicode technique, the maximum number of users that can be used is equal to the spreading code length. The results show that the use of the Walsh-Hadamard code as user specific sequence and the Gold code as a code sequence gives better BER performance compared with other types of codes. Also, the using of Walsh-Hadamard and PN codes for sequence sets and user specific sequences respectively gives good performance. For the orthogonal code system, the number of users that can be used equals the spreading code length dividing by the number of M codes allocated for each user to represent the different data symbols. For the same M-ary, the number of users, and spreading code length, the orthogonal code system can achieve better BER performance than the multicode system, but the maximum number of users that can be accessed is less. For 4-ary and code length of 256, the maximum number of users that can be accessed is 256 for the multicode system, while for the orthogonal code system, the maximum number of users is 64.

Our future researches are to design and implement the M-ary BPSK multicode technique and implement an optimization method to choose the best codes to enhance the BER performance. The other future research is to implement the optimized M-ary BPSK technique with the MC-MC-CDMA system.

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