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Design of a Novel Multi-Dimensional HCOC Multi-code Spread Spectrum System Using Pre-coding Technique for High Speed Data Transmission of DS-CDMA

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Abstract

Recently, Mc(Multi-code) modulation/demodulation(modem) technique has been explored for high speed data transmission in wireless environment. The conventional Mc modem generates some side effects such as allocating Walsh codes, which motivates to propose a novel Mc modem method with sub-code[1]. Our proposed system should expanded the size of sub-code to provide high-rate data transmission, which also affect adversely to the performance of the system with high PAPR(Peak to Average Power Ratio). Thus, in this paper, we propose a novel pre-coded Multi-Dimensional HCOC(High Capacity Orthogonal Code) Mc modem technique to reduce the high PAPR, which enables the performance improvement. This proposed system can be easily designed by concatenating HCOC Mc modem with the generic Mc modem. The pre-coding technique that is used in this paper is CAC(Constant Amplitude Coding), that helps the system maintain the constant transmission power and reduce the maximum transmission power.

Key words : Multidimensional, HCOC, Multi-Code, Constant Amplitude Coding, DS-CDMA.

Ⅰ. Introduction

Many modem(modulation/demodulation) methods using CDMA(Code Division Multiple Access) techniques have been explored to provide high-rate data transmission. Among them, two techniques called MC CDMA(Multi-Carrier CDMA) and Mc CDMA(Multi-code CDMA), are widely under development. The former uses many orthogonal frequencies to distinguish the parallel converted data symbols and the latter uses many orthogonal codes(OCs) to do the same. Mc modem allocates many orthogonal codes to the parallel sequences to support high-rate data transmission by multiplying the OCs and they help the receiver enable to recover the original data due to their orthogonality. However, if the system allocates many OCs to a single user it may not be possible to support many services to many users because of the limited number of the OCs. In this paper, we base on Mc modem which has less complexity than MC modem and focus on the performance improvement of the generic Mc modem[7]. One of the problems that Mc modem is the limited number of the OCs as many as it can support. We employ Sub-code technique called HCOC(High Capacity Orthogonal Code) as a remedy of this problem[1]. In [1], we can see that the OCs keep their orthogonality and HCOC also keeps its orthogonality as well as the orthogonality between the OCs and Sub-codes. Moreover, it doesn't need to increase hardwares to generate this HCOC because HCOC we can be constructed from the OCs. Employing HCOC can increase the transmission rate but we need to increase more according to users' demands. In this aspect, the article[4] suggested Multi-dimensional systems applying Sub-code to the conventional DS-CDMA(Direct Sequence CDMA). But simply applying Multi- dimensions into the DS-CDMA doesn't seems to be feasible because of high transmission power and increased interferences between symbols, which causes the performance degradation. To mitigate these side effects, we propose a novel Multi-dimensional CAC(Constant Amplitude Coding) HCOC Mc DS-CDMA to provide better stability than the conventional Multi-dimensional systems and to reduce the symbol interferences using CAC.

The rest of this paper is organized as follows. Section 2 discusses the Conventional HCOC Mc-DS CDMA system. The proposed algorithm is explained and discussed the improved performance in session 3. In session 4, we show the result of computer simulation and finally, it ends with conclusion in session 5.

Ⅱ. Conventional HCOC Mc-DS CDMA System

HCOC can resolve the problem of the limited number of OCs in the conventional Mc DS-CDMA systems. In HCOC Mc DS-CDMA, the data symbols can be dis-

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tinguished with HCOC which was done by OCs in the generic Mc systems. Thus we employ $m \times m$ dimensional system using $HCOC_m$.

2-1 High Capacity Orthogonal Code

HCOC can be constructed from Biorthogonal Codes which was used from Hadamard matrix of OCs. HCOC can be defined as eq. (2).

i. Biorthogonal Codes, B_k, can be defined as follows[3]

$$B_k = \begin{bmatrix} H_{k-1} \\ \overline{H_{k-1}} \end{bmatrix} \tag{1}$$

ii. $m \times m$ HCOC can be defined like eq. (2) with the lower part of Biorthogonal Codes of eq. (1)

$$HCOC_m \triangleq \left[\ \overline{H_{k-1}} \ \right] \tag{2}$$

The orthogonality between HCOC matrix and Hadamard matrix(that is, Walsh codes) can be proved as follows. If the row vector of HCOC is given as $\beta_e(e=0, 1, \cdots, m)$, it can be written as[4],[8]

$$H_k\langle\bullet\rangle\beta_e^T \triangleq [\beta_{e,0}H_{(k,m)} | \beta_{e,1}H_{(k,m)} | \cdots | \beta_{e,m}H_{(k,m)}] \tag{3}$$

From eq. (3), we can see that all the scalar products of HCOC and Hadamard Matrix are 0s. Thus, we can see that the orthogonality can be kept between these two codes.

According to [1], the condition to possibly fulfill this constraint is that HCOCs and OCs have the different shapes in the time domain. Thus, HCOC should be adopted from the code groups, called high capacity orthogonal code group as illustrated in Fig. 1. For example, consider a 8×8 WH matrix in Fig. 2.

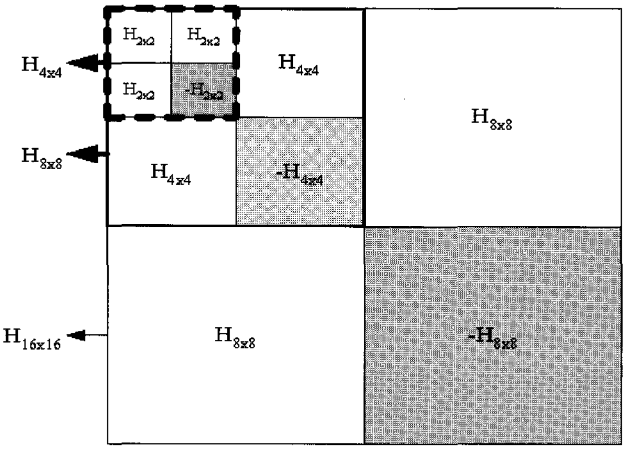


Fig. 1. Construction of WH matrix and HCOCGs(filled areas are the HCOCGs for any WH matrix with size N×N).

$$\begin{array}{cc} \mathrm{OC}(1) \rightarrow & \\ & \\ \mathrm{OC}(3) \rightarrow & \\ & \\ H_{8\times8} = & \\ & \\ & \\ & \end{array} \begin{bmatrix} -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\ -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \end{bmatrix} \begin{array}{l} \\ \\ \rightarrow HCOC_{2\times2} \\ \\ \\ \rightarrow HCOC_{4\times4} \\ \\ \\ \end{array}$$

Fig. 2. Example of WH matrix for OCs and HCOCs.

2-2 HCOC Mc-DS CDMA System

The conventional Mc DS-CDMA uses Walsh modulation to distinguish the each parallel symbol. As the number of Walsh codes that are used for the modulation increases, the number of Walsh codes that will be used for other users or services will decreases. However, employing HCOC technique enables Mc DS-CDMA systems to support same function without sacrificing the number of Walsh codes.

Fig. 3 shows the block diagram of HCOC Mc DS-CDMA with m number of parallel codes and Walsh modulation of T duration. And its transmission signal can be written as eq. (4)[1],[5].

$$s_i(t) = \sum_{e=1}^{m} \sum_{c=1}^{m} \alpha_e \beta_{e,c} \sum_{i=1}^{T_s} \omega(i) p(t - iT_c) \tag{4}$$

Here α_e is the e^{th} symbol of mT_s duration(T_s: symbol duration of the input data), $\omega(i)$ is the one of the OCs with i number of chips, and $p(t)$ is the rectangular pulse with $T_c(T_c)$ is a chip duration.

Ⅲ. Design of Dimensional System

It is possible to increase the transmission rate without sacrificing the number of Walsh code using HCOC Mc DS-CDMA system. The bigger size of HCOC we have, the higher transmission rate it can support. However, because HCOC is the subset of Walsh codes, there is a certain limit of its expansion and the highly expanded HCOC can cause some side effect such as performance degradation. Thus we propose to use multiple layers of the single optimized HCOC to support higher trans-

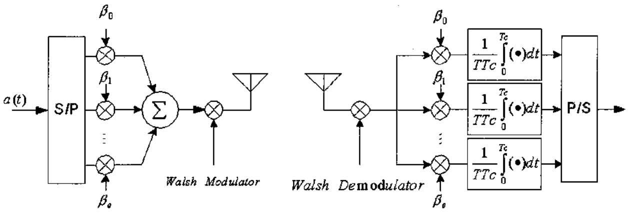


Fig. 3. HCOC Mc-DS CDMA system.

mission rate. Because Mc system and Multi-dimensional system can cause high average power and PAPR(Peak to Average Power Ratio) as the number of parallel branches are increased, therefore we employ CAC technique to reduce them and propose a novel Multi-dimensional CAC HCOC Mc DS-CDMA system.

3-1 HCOC Multidimensional Signaling

The signaling method of Multi-dimensional scheme is to reuse the optimized HCOC. In each dimension we use same HCOC which is optimized and with this we can solve the problem that the size of HCOC can not be exceeded the half of the size of Walsh code.

i. The expansion of HCOC matrix for the multi-dimensional scheme is defined as

$$MD\ HCOC_{m\times D} \triangleq \left[HCOC_m(1) \middle| HCOC_m(2) \middle| \cdots \middle| HCOC_m(G)\right] \quad (D = Gm) \tag{5}$$

In eq. (5), G is given as HCOC reuse factor, m is the rank of HCOC matrix, and D is the maximum number of bits that can be transmitted through the expanded matrix. In multi-dimensional scheme, we use Walsh codes to distinguish replicated HCOC block. If Walsh code is given as ω_G[4],

$$\omega_G \langle\ \cdot\ \rangle MD\ HCOC^T_{m\times D} = 0 \tag{6}$$

Thus it is possible to reuse HCOC. Fig. 4 shows the multi-dimensional scheme using replica of HCOC[7].

In Fig. 4, $a^4_{i,(G)}$ is a set of input data that will be processed with HCOC block. i is the i^{th} input set and (G) is the number of HCOC that is used. If we generalize it, we can have eq. (7).

$$a^m_i = (a_{i,0}, a_{i,1}, \cdots, a_{i,m-1}) \tag{7}$$

Here m is the number of symbols in a set.

3-2 CAC(Constant Amplitude Coding)

CAC is the technique to provide the constant transmission power by reducing the peak power in Mc system[6]. As the number of dimension increases, the peak power of the system also increases. We propose to use CAC to the new multi-dimensional HCOC Mc DS-CDMA system. Eq. (8) shows the input stream that can generate constant amplitude[6].

$$a_{i,0} \oplus a_{i,1} \oplus a_{i,2} \oplus a_{i,3} = 1 \tag{8}$$

To make the pattern of input stream that generates the constant amplitude we use $a_{i,3}$ as pre-coding bit. $a_{i,3}$ can be expressed as eq. (9).

$$a_{i,3} = \overline{a_{i,0} \oplus a_{i,1} \oplus a_{i,2}} \tag{9}$$

Fig. 5 shows CAC method with code rate of 3/4 in eq. (9).

Table 1 shows the signal patterns of HCOC. With this we can find that there are certain patterns of signal that can generate the constant amplitude.

In Table 1, s^4_i is HCOC modulated signal of input a^4_i. s^4_i can be generalized as eq. (10).

$$s^M_j = (s_{i,0}, s_{i,1}, \cdots, s_{i,M-1}) \tag{10}$$

Here M is the number of symbol.

3-3 Multidimensional CAC HCOC Mc-DS CDMA System

In this part, we describe the final system that we propose. To guarantee high-rate data transmission, we need to explore HCOC system and to reduce the side effect of employing HCOC with multi-dimension we apply CAC here.

Fig. 6 shows the block diagram of the transmitter that sends u^{th} user's data with Multi-dimensional processing. The *HCOC* and *MD HCOC* is expanded like the number(G) of OCs to the user and without increasing m, we can increase the transmission rate.

Eq. (11) shows the transmission signal. Here, $\{a^{(u)}_{j,e}\}$ (J=1, Q) is the expression of m number of parallel data,

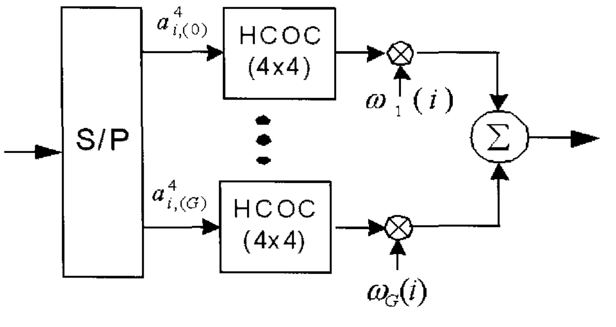


Fig. 4. Multidimensional signaling.

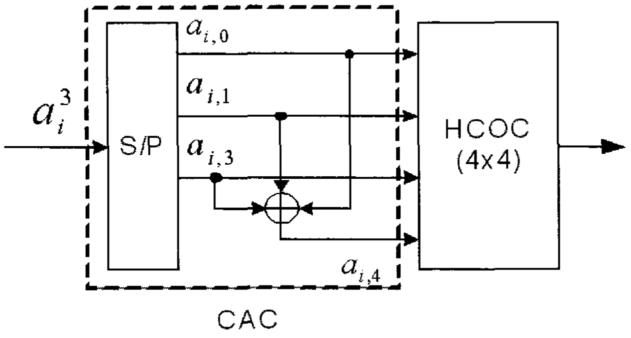


Fig. 5. CAC encoder (code rate: 3/4).

Table 1. Simulation signal patterns of HCOC.

i	a_i^4	s_i^4			
		$s_{i,0}$	$s_{i,1}$	$s_{i,2}$	$s_{i,3}$
0	0000	−4	0	0	0
1	0001	−2	−2	−2	2
2	0010	−2	2	−2	−2
3	0011	0	0	−4	0
4	0100	−2	−2	2	−2
5	0101	0	−4	0	0
6	0110	0	0	0	4
7	0111	2	−2	−2	−2
8	1000	−2	2	2	2
9	1001	0	0	0	4
10	1010	0	4	0	0
11	1011	2	2	−2	2
12	1100	0	0	4	0
13	1101	2	−2	2	2
14	1110	2	2	2	−2
15	1111	4	0	0	0

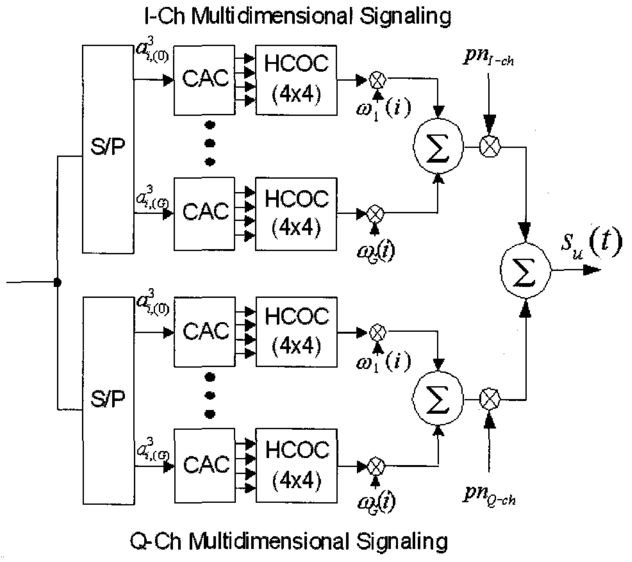


Fig. 6. Multi-dimensional CAC-HCOC Mc-SS system transmission.

$$s_u(t) = \left(\sum_{e=1}^{m} a_{1,e}^{(u)} \sum_{c=1}^{m} \beta_{e,c} \sum_{g=1}^{G} \sum_{i=1}^{T} \omega_{1,\langle e\rangle,g}^{(u)} p(t-iT_c) \right) \sum_{n=1}^{N} pn_1^{(u)} p(t-nT_p) + j\left(\sum_{e=1}^{m} a_{Q,e}^{(u)} \sum_{c=1}^{m} \beta_{e,c} \sum_{g=1}^{G} \sum_{i=1}^{T} \omega_{Q,\langle e\rangle,g}^{(u)} p(t-iT_c) \right) \sum_{n=1}^{N} pn_Q^{(u)} p(t-nT_p) \tag{11}$$

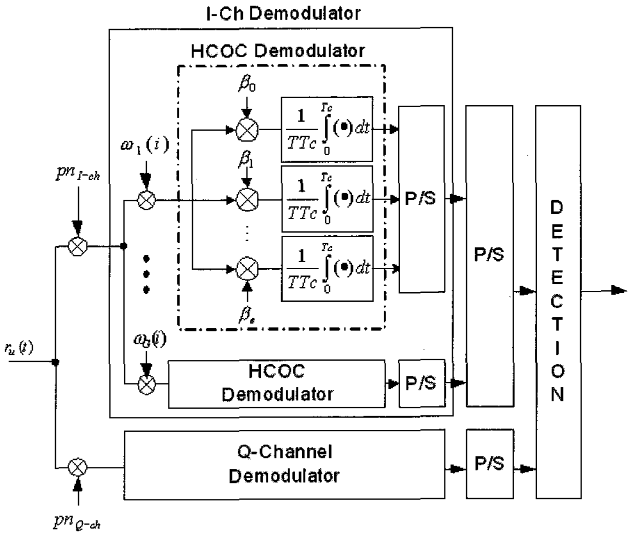


Fig. 7. Multi-dimensional CAC-HCOC Mc-SS system receiver.

Eq. (11) shows the transmission signal. Here, $\{a_{j,e}^{(u)}\}$ (J=1, Q) is the expression of m number of parallel data, $[\omega_{J\langle e\rangle,1}^{(u)}, \cdots, \omega_{J\langle e\rangle,G}^{(u)}]$ is the OC that is used to the u^{th} user, $\{pn_J^{(u)}(t)\}$ is PN(Pseudo Noise) with n number chips, and $p(t)$ is rectangular pulse(T_p is the expression of chip duration). Fig. 7 shows the receiver block diagram of multi-dimensional CAC HCOC Mc DS-CDMA. The received signal can be expressed as eq. (12).

$$r(t) = s_1(t) + \sum_{u=2}^{U} s_u(t-\tau_u)\exp(j\theta_k) + n(t) \tag{12}$$

Here τ_u is the delay of asynchronous channel, θ_u is random signal phase, and $n(t)$ is the channel noise.

Ⅳ. Simulation Result

To analyze the proposed system, we perform computer simulation. We used Walsh code of 64 chips and we use 4 kinds of Walsh modulation. The size of HCOC is given 4 because it is optimized one. And it is performed in frequency selective fading environment. Fig. 8 shows the number of bits that are transmitting in the generic Mc DS-CDMA, HCOC Mc DS-CDMA, Multi-dimensional HCOC Mc DS-CDMA, and proposed Multi-dimensional CAC HCOC Mc DS-CDMA. We can say that in Mc DS-CDMA the number of transmission bits linearly increases with the number of Walsh codes. In HCOC Mc DS-CDMA, we can see that increased size HCOC increases the number of transmitting bits. In multi-dimensional system, as we use HCOC and Walsh together, and we find the increased number of transmitting bits.

$$\textit{Nmber of bits} = (m-1)\times(\textit{vmber of walsh codes}) \tag{13}$$

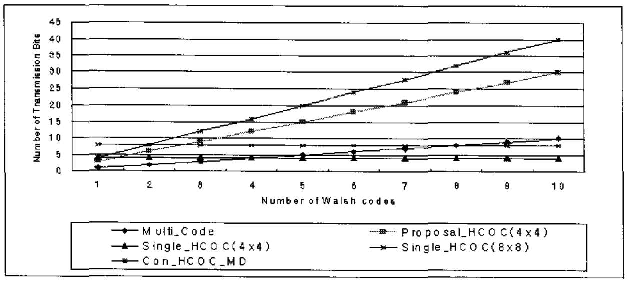


Fig. 8. Number of transmission bits in accordance with allocating OCs in I-channel.

Eq. (13) shows the number bits in I-channel of the proposed system.

Fig. 9 shows the performance curves of the expanded HCOC Mc DS-CDMA system and the proposed Multi-dimensional CAC HCOC Mc DS-CDMA system.

Fig. 10 shows the block diagram of 8×8 HCOC Mc DS-CDMA system with 8 parallel codes and Walsh modulation using 1 Walsh code. The expanded HCOC Mc DS-CDMA system with 8×8 HCOC can transmit 8 bits at a time where as Multi-dimensional CAC HCOC Mc DS-CDMA can support 9 bits as it uses 3 dimensions. Through Fig. 6, we can see that the proposed system can support more bits with better performance.

We compare the BER performance with QAM that transmits similar number of bits. From Fig. 11, we can see that the proposed system with 4 dimensions that transmits 12 bits at a time outperforms to 256 QAM that transmits 8 bits.

Fig. 12 shows the BER comparison of the proposed system and the system without CAC. We can see thatthe performance is improved with CAC. It is considered that CAC helps the system to have more stability and reduce peak power.

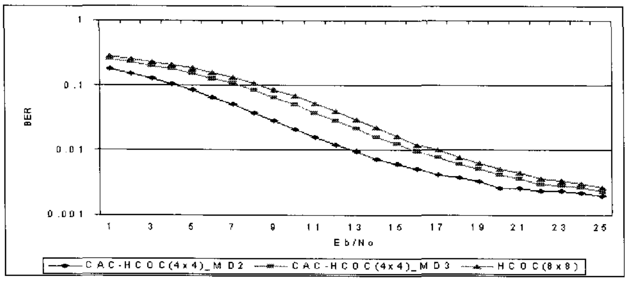


Fig. 9. Expanded HCOC Mc DS-CDMA system and the proposed multi-dimensional CAC HCOC Mc DS-CDMA system.

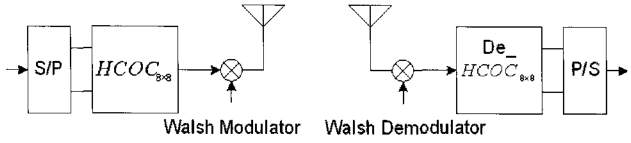


Fig. 10. 8×8 HCOC Mc DS-CDMA system.

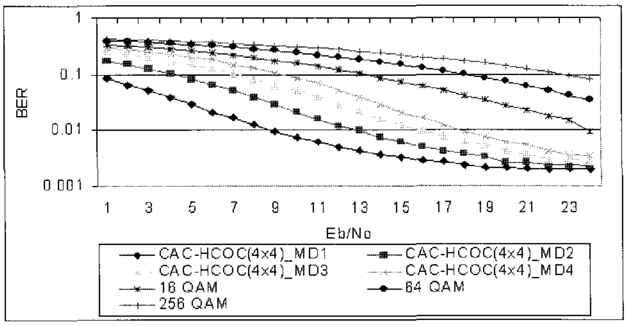


Fig. 11. Proposed system and QAM System.

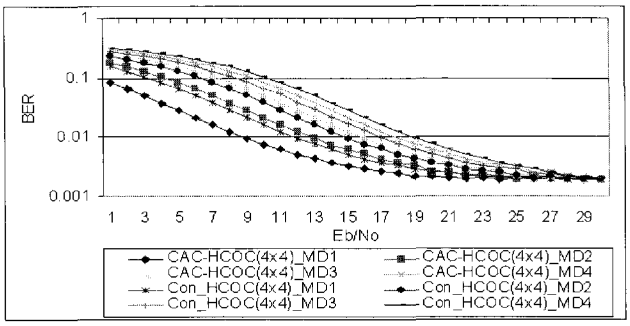
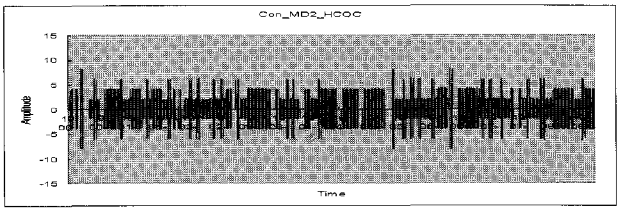


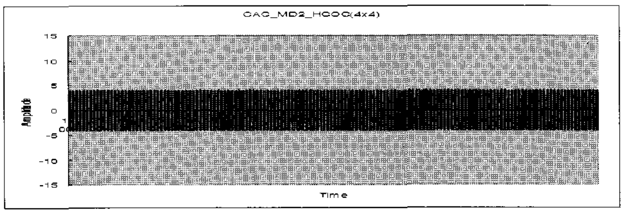
Fig. 12. The proposed system and the system without CAC.

Fig. 13 and Fig. 14 show the analyzed results of the transmission power of the basic multi-dimensional multi-code system and the proposed multi-dimensional multi-code system. In Fig. 13, 2-dimensional multicode system is analyzed. In Fig. 13(a) shows that the transmission power is unstable and (b) shows that the transmission power is higher than the proposed system.

Fig. 14 shows 4-dimensional multicode system. Fig. 14(b) shows slightly higher transmission power than Fig.

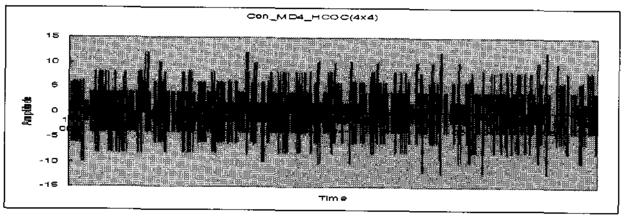


(a) Conventional multidimensional HCOC system

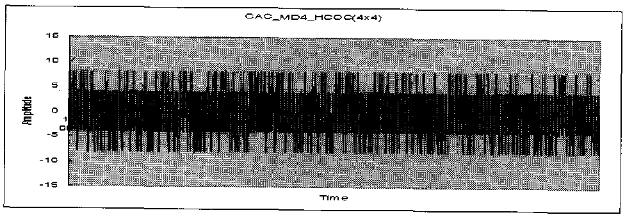


(b) Proposed multidimensional HCOC system

Fig. 13. Transmission power of 2 dimensions.



(a) Conventional multidimensional HCOC system



(b) Proposed multidimensional HCOC system

Fig. 14. Transmission power of 4 dimensions.

13(b). However, Fig. 14(a) has more stable power distribution and lower transmission power compared to Fig. 13(a) which is the basic multi-dimensional system. We can see that as the dimension increases, the proposed system stabilized transmission power, at though the transmission power increases slightly. Fig. 12 shows the performance of the system is improved with lower transmission rate and stabilized transmission power.

Ⅴ. Conclusion

In this paper, we propose multi-dimensional CAC HCOC Mc DS-CDMA system to maximize the transmission rate. Multi-dimensional system enables high-rateproposed system outperforms the conventional ones in data transmission with proper combination of HCOC and Walsh codes. With the result we could see that the aspect of BER performance as well as the number of bits. We remain combination of multi-carrier and the proposed system as a future work to be done.

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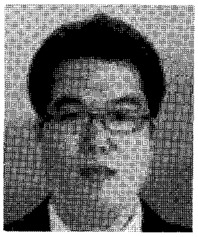

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