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Optimized Cell ID Codes for SSDT Power Control in W-CDMA System

W-CDMA 시스템의 최적의 SSDT 전력 제어용 셀 식별 부호

Young-Joon Song · Bong-Hoe Kim* · Hae Chung

송 영 준 · 김 봉 회* · 정 해

Abstract

The code division multiple access(CDMA) system capacity is limited by the amount of interference of the system. To reduce the unnecessary interference, this paper proposes optimized cell identification codes for site selection diversity transmission(SSDT) power control in wideband code division multiple access system of third generation partnership project(3GPP). The main objective of SSDT power control is to transmit on the downlink from the primary cell, and thus reducing the interference caused by the multiple transmission. In order to select a primary cell, each cell is assigned a temporary identification(ID) and user equipment(UE) periodically informs a primary cell ID to the connecting cells during soft handover. The non-primary cells selected by UE do not transmit the dedicated physical data channel(DPDCH) to reduce the interference.

A major issue with the SSDT technology is the impact of uplink symbol errors on its performance. These errors can corrupt the primary ID code and this may lead to wrong decoding in the base station receivers. The proposed SSDT cell ID codes are designed to minimize the problem and to be easily decoded using simple fast Hadamard transformation(FHT) decoder.

Key words : CDMA, SSDT, Cell ID, Power Control, Interference, FHT

요 약

CDMA(Code Division Multiple Access) 시스템은 간섭량에 의하여 용량이 제한된다. 본 논문은 이러한 간섭량을 줄이기 위하여 3GPP(Third Generation Partnership Project) W-CDMA(Wideband Code Division Multiple Access) 시스템의 SSDT(Site Selection Diversity Transmission) 전력제어에 사용되는 최적의 셀(Cell) 식별 부호를 제안한다. SSDT 전력제어는 소프트 핸드 오버(Soft Handover) 시에 선택된 우선 셀(Primary Cell)에서 신호 전송을 함으로써, 다중 셀에서의 다중 전송으로 인한 간섭 증가를 줄이고자 하는데 목적이 있다. 먼저 각각의 셀은 임시 식별 부호로 구분된다. 그리고 단말기(UE: User Equipment)는 연결된 셀들에 우선 셀 식별 부호를 주기적으로 알려준다. 그러면, 우선 셀로 선택되지 못한 비우선 셀들은 순방향으로 DPDCH(Dedicated Physical Data Channel)의 전송을 중단하여 간섭증가를 줄인다.

이러한 SSDT 기술에서 주된 기술적인 문제점은 단말기가 우선 셀을 선택하기 위하여 역 방향으로 전송하는 우선 셀 식별 부호의 성능이다. 셀 식별 부호에 오류가 발생하여 다른 식별 부호로 잘못 인식되면, 이는 우선 셀을 잘못 선택하는 결과가 된다. 제안된 SSDT 셀 식별 부호는 이러한 문제를 최소화 하고 FHT(Fast Hadamard Transformation) 복호기를 사용하여 간단히 구현할 수 있는 장점을 갖고 있다.

금오공과대학교 전자공학부(Dept. of Electronic Engineering, Kumoh Nat'l Institute of Tech.)

*LG전자 UMTS 시스템 연구소(UMTS System Research Lab., LG Electronics Inc.)

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Ⅰ. Introduction

Site selection diversity transmission (SSDT) is a macro diversity method to be used in soft handover mode activated and deactivated by the network in wideband code division multiple access (W-CDMA) system of 3GPP[1],[2]. The cells from active set of user equipment (UE) are classified into two classes: primary and non-primary cells. When UE is in a soft handover, UE receives signals from several cells. However, the signals from some cells may be poor and then increase interference. In this situation, SSDT allows only primary cells to transmit on the downlink, thus reducing the interference caused by multiple transmissions[1]. Another objective is to achieve fast site selection without network intervention, thus maintaining the advantage of the soft handover[1]. The base station compares its temporary identification (ID) assigned by the network with received ID which a UE sends periodically. A major issue with the SSDT technology is the impact of uplink symbol errors on its performance. These errors can corrupt the primary ID code and this may lead to wrong decoding in the base station receivers. To minimize the problem, we propose optimum SSDT cell ID codes which is currently accepted in 3GPP specification[1],[3]. The proposed SSDT cell ID codes can also be easily decoded using fast Hadamard transformation (FHT) decoder[4].

This paper is consisted as follows: dedicated uplink physical channels and compressed mode operation are explained in section Ⅱ, SSDT power control and SSDT ID codes are described in section Ⅲ and Ⅳ, respectively. In section Ⅴ, we show simulation results and finally conclude this paper in section Ⅵ.

Ⅱ. Channel Structure and Compressed Mode

There are two types of DPCH channels. One is dedicated physical data channel (DPDCH) which carries the user data and the other is dedicated physical control channel (DPCCH) which carries the control information. Each DPCH frame is consisted of 15 slots. We can transmit 10 to 960 bits in DPDCH and 10 bits in DPCCH per each slot[5].

SSDT ID codes are transmitted using FBI S-filed of uplink DPCCH. In Fig. 1, uplink DPCCH channel structure and FBI field structure are shown. The length of FBI filed, N_{FBI}, is 0 to 2 bits and the length of FBI S-filed is also 0 to 2 bits. During SSDT operation, in fact, the length of FBI S-field is 1 or 2 bits. Therefore, the sum of the length of FBI S-field in one frame is 15 or 30[1].

In W-CDMA system the compressed mode is needed when making measurements from another frequency without a full dual receiver terminal. The compressed mode means that transmission and reception are halted for a short time, in the order of a few milliseconds, in order to perform measurements on the other frequencies[6],[7]. As illustrated in Fig. 2, the instantaneous transmit power is increased in the compressed frame in order to keep the quality (bit error rate, frame error rate, etc.) unaffected by the reduced processing gain[7]. In compressed mode, maximum 7 slots per frame can be punctured to measure communication systems (e.g. GSM: Global

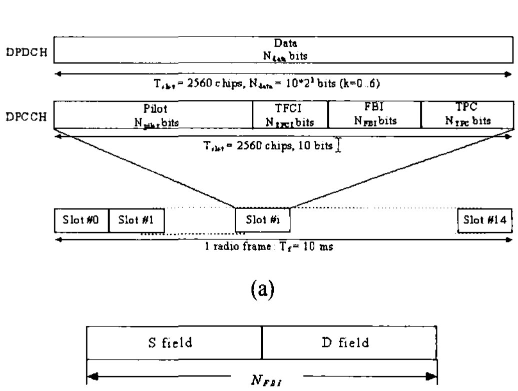

Fig. 1. (a) The structure of the uplink DPCH.
(b) The structure of the FBI field in uplink DPCCH channel.

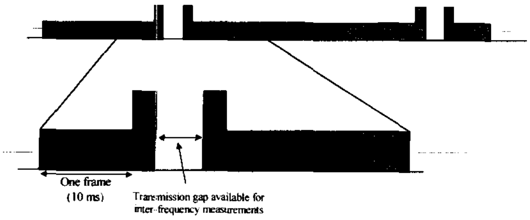

Fig. 2. Compressed mode transmission.

System for Mobile Communications) with different frequency[6]. Since SSDT ID code can be also punctured in compressed mode, we have to design the SSDT ID code to minimize the performance degradation in compressed mode.

Ⅲ. SSDT Power Control

SSDT is a macro diversity method to be used in soft handover mode activated and deactivated by the network in W-CDMA[1],[2]. The UE selects one of the cells from its active set to be 'primary', all other cells are classed as 'non primary'. The main objective is to transmit on the downlink from the primary cell, thus reducing the interference caused by multiple transmissions in a soft handover mode[1]. In order to select a primary cell, each cell is assigned a temporary identification (ID) and the UE periodically sends the ID code of the primary cell via portion of the uplink FBI S-field assigned for SSDT use[1],[5]. At the UE, the primary ID code to be sent to the cells is segmented into a number of portions. These portions are distributed in the uplink FBI S-field. During SSDT power control, cells collect the distributed portions of the primary ID code and detect the transmitted ID. The update period of the primary cell depends on the settings of the code length and the number of FBI bits assigned for SSDT use. The primary cell is updated from 1 to 5 times per frame according to the operation modes.

A cell recognizes its state as non-primary if the following conditions are fulfilled simultaneously:

- the received primary ID code does not match with the own ID code;
- the received uplink signal quality satisfies a quality threshold, Q_{th}, a parameter defined by the network;
- when the use of uplink compressed mode does not result in excessive levels of puncturing on the coded ID. The acceptable level of puncturing on the coded ID is less than (int) $N_{ID}/3$ symbols in the coded ID, where N_{ID} is the length of the coded ID.

Otherwise the cell recognizes its state as primary.

The non-primary cells selected by UE switch off the transmission power[1]. However, to maintain the benefit of soft handover, the non-primary cells continue to transmit the DPCCH. SSDT activation, SSDT termination, and ID assignment are all carried out by higher layer signalling [1],[2].

Ⅳ. SSDT ID Codes

There are three types of SSDT ID codes: long, medium, and short SSDT ID codes which are shown in Table 1 and 2. When transmitting each type of SSDT ID codes, we use 1 or 2 bits per slot of FBI S-field in uplink DPCCH channel of Fig. 1. SSDT ID codes of Table 1 and 2 are used for the case of 1 bit and 2 bits per slot of FBI S-field, respectively. For medium SSDT ID code with 1 bit FBI S-field

Table 1. Settings of SSDT ID codes for 1 bit S-field in FBI.

ID label	ID code		
	"long"	"medium"	"short"
A	000000000000000	(0)0000000	00000
B	101010101010101	(0)1010101	01001
C	011001100110011	(0)0110011	11011
D	110011001100110	(0)1100110	10010
E	000111100001111	(0)0001111	00111
F	101101001011010	(0)1011010	01110
G	011110000111100	(0)0111100	11100
H	110100101101001	(0)1101001	10101

Table 2. Settings of ID codes for 2 bits S-field in FBI.

ID label	ID code (Column and Row denote slot position and FBI-bit position.)		
	"long"	"medium"	"short"
A	(0)0000000 (0)0000000	(0)000 (0)000	000 000
B	(0)0000000 (1)1111111	(0)000 (1)111	000 111
C	(0)1010101 (0)1010101	(0)101 (0)101	101 101
D	(0)1010101 (1)0101010	(0)101 (1)010	101 010
E	(0)0110011 (0)0110011	(0)011 (0)011	011 011
F	(0)0110011 (1)1001100	(0)011 (1)100	011 100
G	(0)1100110 (0)1100110	(0)110 (0)110	110 110
H	(0)1100110 (1)0011001	(0)110 (1)001	110 001

of Table 1, the length of SSDT ID code is 7 or 8 bits. Therefore, a medium SSDT ID code with 1 bit FBI S-field is transmitted in such a way that the first 8 bits are transmitted over 8 slots and then the next 7 bits are transmitted over 7 slots since a frame is consists of 15 slots. In the case of 2 btis FBI S-filed of Table 2, 30 bits should be transmitted through S-field during one frame. Thus in the case of medium SSDT ID code of Table 2, 8 bits and 6 bits codes are transmitted 3 times and once per frame, respectively.

Symbol errors can corrupt the primary ID code and this may lead to wrong decoding at the base station receivers. As a result, a wrong cell or even no cell can be assigned as primary cell. In case of compressed mode, the wrong decoding problem may be more serious due to the puncturing of symbols of ID codes[1],[6],[7].

To optimize the SSDT performance considering compressed mode, we design the SSDT ID codes so as to minimize the loss of minimum Hamming distance due to puncturing. We also considered the simplicity for decoding of the SSDT ID codes. Therefore, we design the SSDT ID code based on the simplex code[8]. That is, SSDT ID codes are designed by puncturing some bits of Hadamard code. Note that the first bit of Hadamard code is '0'. When puncturing the first bit of Hadamard code, we get no loss in minimum Hamming distance caused by puncturing. The punctured Hadamard code in the first bit position is called simplex code and by using this code we can obtain the benefit in terms of SNR (Signal to Noise Ratio)[8]. The bit in parenthesis of Table 1 and 2 means to be punctured when puncturing is required.

The short SSDT ID codes are designed by puncturing the Hadamard code of length 8. For the short SSDT ID code with 1 bit FBI S-field, 3 bits are punctured, and for the short ID code with 2 bits FBI S-field 2 bits are punctured. When we puncture the original Hadamard code, we design the ID code considering the distance property. For the medium and long SSDT ID code, we design the ID code by puncturing the Hadamard code of length 8 and 16, respectively. The same rule of puncturing is adopted for the medium and long SSDT ID code, too. SSDT ID codes can have code length 5, 8, 7, 15 for 1 bit S-field and 6, 8, 14, and 16 bits for 2 bits S-field as shown in Table 1 and 2. Table 3 shows the minimum Hamming distance of the proposed SSDT ID codes. From[9], we see that the proposed SSDT

Table 3. Minimum Hamming distance of the designed SSDT ID code(d_{min} : minimum Hamming distance).

	1 bit S-field of FBI				2 bits S-field of FBI				
Type	Long	Medium		Short	Long		Medium		Short
Codeword length	15 bits	7 bits	8 bits	5 bits	14 bits	16 bits	8 bits	6 bits	6 bits
d_{min}	8	4	4	2	7	8	4	3	3

ID codes except the ID code of length 14 meet the *maximum possible minimum distance of a binary* linear code. Because of such optimum distance property and simplicity of implementation, the proposed SSDT ID codes are accepted in W-CDMA system of 3GPP specification[1],[3].

Ⅴ. Simulation Results and Discussions

In this section, we show the performance of the designed SSDT ID codes. The performance of the SSDT ID codes of 1 bit FBI S-field and 2 bits FBI S-filed over additive white Gaussain noise (AWGN) channel is shown in Fig. 3 and Fig. 4, respectively. The long ID code shows the best performance due to the best minimum distance property. For 2 bits FBI S-field, the medium and the short ID code show the

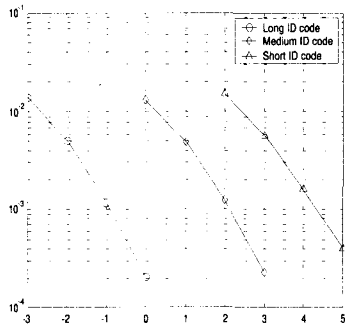

Fig. 3. Performance of SSDT ID code with 1 bit FBI S-field over AWGN.

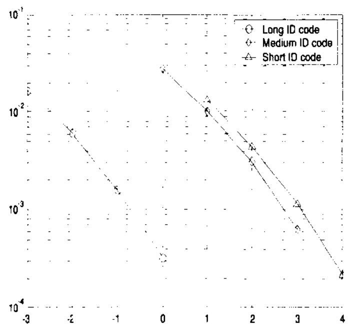

Fig. 4. Performance of SSDT ID code with 2 bits FBI S-field over AWGN.

similar performance. That results from little diffe--rence in the minimum distance.

The performance of the SSDT ID codes over a fading channel is shown in Fig 5 and 6, respectively. The simulation environments are as follows:

- Frequency non-selective fading channel (flat fading channel)
- Carrier frequency: 2 GHz
- Vehicle speed: 30 km/h and 120 km/h
- Jakes' Doppler spectrum
- Perfect channel estimation
- No power control

From the Fig. 5 and Fig. 6, we can see the performance is better when the vehicle speed is high since more time diversity gain can be obtained. We also see that the larger the SSDT ID code gets, the better performance it has because the long ID code has better distance property than those of the medium and the short ID codes. In Fig. 6, the performance of the medium and the short ID code is almost same when the vehicle speed is 30 km/h. The difference in minimum distance between them is zero or one. From this result, we can see that the performance of the SSDT ID code with a slow vehicle speed has little difference although there exists small difference in the minimum distance. On the other hand, a little degradation in the minimum distance property shows relatively large performance

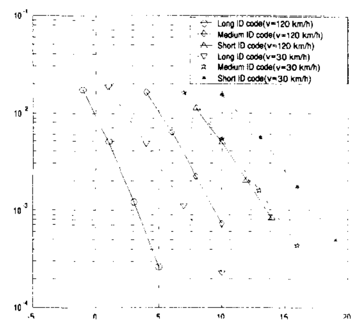

Fig. 5. Performance of SSDT ID code with 1 bit FBI S-field over flat fading channel (v : vehicle speed).

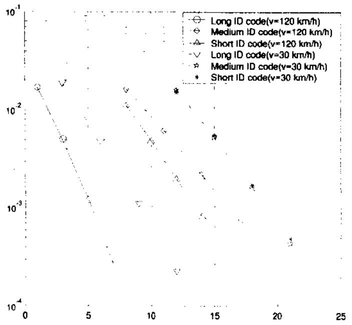

Fig. 6. Performance of SSDT ID code with 2 bits FBI S-field over flat fading channel (v : vehicle speed).

degradation over a fast vehicle speed.

Ⅵ. Conclusions

In this paper, we designed the SSDT cell ID codes, which are adopted in W-CDMA system of 3GPP. We designed the codes by the criterion of minimizing the loss in minimum Hamming distance due to puncturing to consider compressed mode. Furthermore, at the side of base station, the codes can be easily decoded with simple FHT decoder. By using the property of the Hadamard code, we could optimize the SSDT ID code performance in W-CDMA system.

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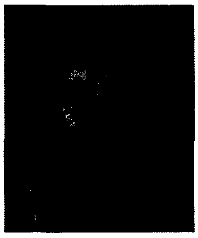
송 영 준

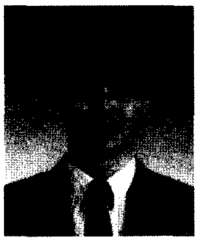
1987년 2월: 한양대학교 전자통신 공학과 (공학사)
1994년 2월: 한양대학교 전자통신 공학과 (공학석사)
1999년 2월: 한양대학교 전자통신 공학과 (공학박사)
1994년 10월~2002년 2월: LG전자 책임연구원
2002년 3월~현재: 금오공과대학교 전자공학부 전임강사
[주 관심분야] 이동통신 시스템, 대역확산통신, 부호이론, 수열 설계

김 봉 회



1992년 2월: 서울대학교 제어계측 공학과 (공학사)
1994년 2월: 서울대학교 제어계측 공학과 (공학석사)
2001년 2월: 한국과학기술원 전자 및 전산학과 (공학박사)
1996년 9월~현재: LG전자 선임연구원
[주 관심분야] 무선이동통신

정 해



1991년: 한국과학기술원 전기 및 전자공학과 (공학석사)
1996년: 한국과학기술원 전기 및 전자공학과 (공학박사)
1996년~1998년: LG정보통신 선임 연구원
1998년~현재: 금오공과대학교 조교수
[주 관심분야] 가입자 액세스망, PON, 트래픽 제어, 통신 프로토콜