Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**GCL Sequences for Uplink Channel Sounding in TDD OFDMA**
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Re:	IEEE P802.16-REVe/D4-2004, ballot #14c
Abstract	This contribution proposes GCL sequences for use by the uplink channel sounding methodology described in Contribution C802.16e-04/263r1: “Uplink Channel Sounding for TDD-OFDMA”.
Purpose	Adoption of proposed changes into P802.16e
Notice	
Release	
Patent Policy and Procedures	

GCL Sequences for Uplink Channel Sounding in TDD OFDMA

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1 Introduction

In the contribution IEEE C802.16e-04/263r1 – "Uplink Channel Sounding for TDD OFDMA" [1], a signaling methodology was defined for enabling the MSS to transmit sounding waveforms on the uplink. This MSS capability is called Channel State Information at the Transmitter (CSIT). The purpose of this signaling methodology was to enable the BS to determine the BS-MSS channel response in a fast and efficient manner in mobile TDD OFDMA systems. The BS can then perform closed-loop transmit processing, which can significantly increase system performance (as discussed in [1][3]).

The Contribution C802.16e-04/263r1 [1] defined the structure and signaling messages used by the TDD-OFDMA UL sounding strategy, but did not define the actual sequence that should be used. The purpose of this contribution is to propose Generalized Chirp-Like (GCL) sequences [2] for use as the sounding sequences in the Uplink Channel Sounding strategy proposed in [1] for TDD-OFDMA.

2 Summary of Solution and Justification

References [2][3][4] provide some background material on GCL sequences and discuss many of their advantages over pseudo-random binary sequences. The main benefit of using GCL sequences in the UL channel sounding methodology is that the GCL sequences have significantly lower Peak-to-Average Power Ratio (PAPR) than pseudo-random binary sequences. For situations of relevance to the OFDMA PHY, the PAPR for GCL sequences tends to be anywhere between 4 and 7 dB lower than the PAPR for pseudonoise (PN) binary sequences. For realistic power amplifiers on the MSS, this lower PAPR means the UL transmit power can be boosted between 4 and 7dB more than when PN sequences are used. As a result, GCL sequences have a significant performance benefit over PN sequences especially in low SNR situations.

This contribution proposes additions to the proposed text in Contribution C802.16e-04/263r1 to enable the use of GCL sequences in the TDD-OFDMA sounding strategy. Text is added to show how to determine the specific GCL sequence to be used. Two methods are proposed for determining the specific GCL sequence to be used: one for when cell planning can be used and one for when cell planning is not or cannot be used. Text is then added to show how to calculate the values of the chosen GCL sequence.

3 Specific Text Changes

---------------------- Beginning of Text Changes -------------------------------------

[In the specific text changes of Contribution C802.16e/263r1, make the following modifications to the UL_Sounding_Command_IE(): add two rows to the table so that the table appears as follows (Additions to this table are in blue text): Note that this table has been modified to reflect the modifications made in harmonized Contribution 263r1]

Table ??: UL_Sounding_Command_IE()

Syntax	Size	Notes
UL_Sounding_Command_IE(){		
Extended UIUC	4 bits	0x09
Length	4 bits	Variable
Sounding_Type	1 bit	0 – Type A 1 – Type B
If (Sounding_Type == 0) {		
Multi-CID mode	1 bit	
If Multi-CID mode==1, {		
N_CID	4 bits	Number of CIDs sharing this sounding allocation
For (i=0;i<N_CID;i++) {		
Shortend basic **CID**	12 bits	12 LS bits of the MSS basic CID value
}		
}		
Num_Sounding_symbols	3 bits	Number of sounding symbols being allocated, from 1 (“000”) to 2^3=8 (“111”)
for (i=0;i<Num_Sounding_symbols;i++){		
If Multi-CID mode==0, {		
Shortend basic CID	12 bits	12 LS bits of the MSS basic CID value
}		
Sounding symbol index	3 bits	Symbol index within the Sounding Zone, from 1 (bits “000”) to 2^3=8 (bits “111”)
Starting Frequency Band	7	Out of 96 bands at most (FFT size dependent)
Number of frequency bands	7	Contiguous bands used for sounding
Separability Type	1 bit	0: occupy all subcarriers in the assigned bands; 1: occupy decimated subcarriers
if (Separability type==0) {		(using cyclic shift separability)
Max Cyclic Shift Index P	2 bits	“00”: P=4; “01”: P=8; “10”: P=16, “11”: P=32
Cyclic time shift index m	5 bits	Cyclically shifts the time domain symbol by multiples (from 0 to P –1) of N/P where

		N=FFT size, and P=Max Cyclic Shift Index
}		
Else {		(using decimation separability)
Decimation Value D	3 bits	Sound every D^{th} subcarrier within the sounding allocation. Decimation value D is 2 to the power of (2 plus this value), hence 4,8,… up to maximum of 64.
Decimation Offset d	6 bits	Relative starting offset position for the first sounding occupied subcarrier in the sounding allocation
Decimation offset randomization	1 bit	0= no randomization of decimation offset 1= decimation offset pseudo-randomly determined
}		
Sequence Index Selection Method	1 bit	1= pseudo-randomly select the Sequence Index and the next field does not exist 0 =select the Sequence Index according to the next field
If (Sequence Index Selection Method=1) {		
Sequence Index q	2 bits	Sequence index within the 4-member group assigned to the BS based on its cellID.
}		
Multi-antenna sounding mode	1 bit	0=sound first MSS antenna only. 1=sound all MSS antennas.
Periodicity	2 bits	00=single command, not periodic, or terminate periodicity 01=repeat sounding once per frame until terminated 10= repeat instructions once per 2 frames 11= repeat instructions once per 4 frames
}		
}		
Else {		
Permutation	2 bits	0b00 = PUSC perm. 0b01 = FUSC perm. 0b10 = Optional FUSC perm. 0b11 = Adjacent subcarrier perm.
Idcell	6 bits	
Num_Sounding_symbols	3 bits	
for (i=0;i<Num_Sounding_symbols;i++){		
Number of CIDs	7 bits	
For (j=0; j<Number of CIDs; j++) {		
Shortend basic CID	12 bits	12 LS bits of the MSS basic CID value

Subchannel offset	7 bits	The lowest index subchannel used for carrying the burst, starting from subchannel 0
Number of subchannels	3 bits	The number subchannels with subsequent indexes, used to carry the burst.
Periodicity	2 bits	00=single command, not periodic, or terminate periodicity 01=repeat sounding once per frame until terminated 10= repeat instructions once per 2 frames 11= repeat instructions once per 4 frames
}		
}		
}		
Padding	Variable	Pad IE to octet boundary. Bits shall be set to 0
}		

[At the end of the EDITOR'S NOTE in the proposed text changes of Contribution C802.16e/263r1, insert the following text:]

After receiving the contents of the UL_Sounding_Command_IE(), the SS will calculate the signal values that are to be used on the subcarriers that it will occupy in the Sounding Band as follows:

$$s_u(k) = \exp\left\{-j2\pi u \frac{k(k+1)}{2N_G}\right\}, \quad k = 0 \cdots L_S - 1$$

where L_s is the number of subcarriers that are occupied in the assigned sounding band(s), k increments in order across those occupied subcarriers, N_G is the smallest prime number that is larger than L_s. The length L_s of the sequence is calculated as follows: If separability type is 0, then L_s is equal to the number of assigned sounding frequency bands multiplied by 18. Otherwise, if separability type is 1, then L_s is the number of sounding frequency bands multiplied by 18 and then divided by the decimation value D. The value of u in the above equation is calculated depending on the value of the "Sequence Index Selection Method" as follows.

If the Sequence Index Selection Method is 0, then a sequence reuse strategy is used among multiple adjacent cells and sectors, which is appropriate for situations where cell planning can be used. In this strategy, the value of u is calculated from the assigned 2-bit sounding sequence index q of the sounding instructions and the CellID of the BS as follows:

v1=1 + decimal value of lowest 3 bits of the UL_IDcell

v2=1 + decimal value of the sequence index q of the sounding instructions

u=((v1)(v2)-1)mod(N_G-1)+1

This strategy acts to assign four distinct GCL sequences to each sector/cell when the UL_IDcell values are chosen so that nearby cells / sectors have unique values for the lowest 3 bits of their UL-IDcell. This insures that MSSs in adjacent cells will not sound with the same GCL sequence, which will insure that reliable channel estimation can be performed at the BS when multiple MSSs sound on the same sounding resources.

If the Sequence Index Selection Method is 1, then the value of u is pseudo-randomly generated based on the UL_IDcell and the frame number. As a result, the chosen GCL sequence pseudo-randomly changes from frame to frame and from cell-to-cell, which helps mitigate intercell and/or intracell interference in situations where cell planning is not or cannot be used. In this case, the value of u is pseudo-randomly calculated to be 1 plus the decimal equivalent of the first ceil($\log_2$(Ls)) (where L_s is calculated below and the ceil function returns the next highest integer) output bits of the PRBS generator of Figure 243 of Section 8.4.7.3 after the PRBS is first initialized with the seed: b0…b15 = f0,f1,…,f7,s0,s1,…,s6, where s6:s0 = the 7 LSBs of the UL_IDcell, and f7:f0 = the 8 LSBs of the Frame Number in which the UL_Sounding_Command_IE() is transmitted.

-------------------------- End of Text Changes --

References

[1] F. W. Vook, X. Zhuang, K. L. Baum, T. A. Thomas, M. C. Cudak, "Uplink Channel Sounding for TDD-OFDMA," IEEE C802.16e-04/263r1 (08/29/04).

[2] B.M. Popovic, "Generalized Chirp-Like Polyphase Sequences with Optimal Correlation Properties," *IEEE Transactions on Information Theory*, vol. 38, pp. 1406-1409, July 1992

[3] F. W. Vook, X. Zhuang, K. L. Baum, T. A. Thomas, M. C. Cudak, "Signaling Methodologies to Support Closed-Loop Transmit Processing in TDD-OFDMA," IEEE C802.16e-04/103r2 (07/07/2004)

[4] X. Zhuang, K. L. Baum, M. C. Cudak, F. W. Vook, V. Nangia, "Preamble Designs for OFDMA PHY Layer, FFT sizes of 1024, 512, and 128," IEEE C802.16e-04/241 (07/12/2004)