| | |
|---|---|
| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **Improvements to the Uplink Channel Sounding Signaling for OFDMA** |
| Date Submitted | **2004-11-04** |
| Source(s) | Frederick W. Vook<br>Xiangyang (Jeff) Zhuang<br>Kevin L. Baum<br>Timothy A. Thomas<br>Philippe Sartori<br><br>Motorola Labs<br>1301 E. Algonquin Road<br>Schaumburg, IL 60196<br><br>Voice: +1-847-576-7939<br>Fred.Vook@motorola.com |
| Re: | IEEE P802.16-REVe/D5-2004 |
| Abstract | Modifications to Uplink Channel Sounding methodology to optionally include DL channel coefficients. |
| Purpose | Adoption of proposed changes into P802.16e |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

# Improvements to the Uplink Channel Sounding Signaling for OFDMA

*Frederick W. Vook, Xiangyang (Jeff) Zhuang, Kevin L. Baum, Timothy A. Thomas, Philippe Sartori*

*Motorola Labs, Schaumburg, IL, USA*

## 1 Introduction

This contribution provides a modification to the Uplink channel sounding methodology in Section 8.4.6.2.7 of IEEE 802.16e to include the optional direct transmission of DL channel coefficients [1][2] in addition to the sounding waveform. The modification extends the UL channel sounding signaling to enable closed-loop transmission in FDD systems and TDD systems in which BS array transceiver calibration is not implemented. The modification consists of an additional bit in the UL_Sounding_Command_IE() for the purpose of indicating whether or not channel coefficients are to be transmitted along with the sounding waveform in the sounding zone. When this functionality for the direct transmission of channel coefficients is used, the sounding waveform specified by the Sounding Command enables the BS to estimate the UL channel, which the BS then uses to estimate the DL channel coefficients being sent by the MSS in the subsequent symbol interval(s). These estimated DL channel coefficients can then be used by the BS to perform closed-loop transmit precoding.

## 2 Specific Text Changes

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

[ In Section 8.4.6.2.7, modify Table 311 as follows: (modifications in RED) ]

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<br>1 = Type B |
| Send Sounding Report Flag | 1 bit | |
| If (Sounding_Type == 0) { | | |
| Include Channel Coefficients | 1 bit | 0 = Do not include coefficients<br>1 = Include channel coefficients<br>(See Section 8.4.6.2.7.3) |
| Num_Sounding_symbols | 3 bits | Total number of sounding symbols being allocated in this Sounding ~~Zone~~ Command, |

| | | |
|---|---|---|
| | | from 1 (“000”) to $2^3$=8 (“111”) |
| Separability Type | 1 bit | 0: occupy all subcarriers in the assigned bands;<br>1: occupy decimated subcarriers |
| if (Separability type==0) { | | (using cyclic shift separability) |
| Max Cyclic Shift Index P | 2 bits | 00: P=4;<br>01: P=8;<br>10: P=16,<br>11: P=32 |
| } 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 randomization | 1 bit | 0= no randomization of decimation offset<br>1= decimation offset pseudo-randomly determined |
| } | | |
| For (i=0;i<Num_Sounding_symbols;i++){ | | |
| Sounding symbol index | 3 bits | Symbol index within the Sounding Zone, from 1 (bits “000”) to $2^3$=8 (bits “111”) |
| Number of CIDs | 4 bits | Number of CIDs sharing this sounding allocation |
| For (j = 0; j<Num. of CIDs; j++) { | | |
| Shorted basic CID | 12 bits | 12 LS bits of the MSS basic CID value |
| Starting Frequency Band | 7 bits | Out of 96 bands at most (FFT size dependent) |
| Number of frequency bands | 7 bits | Contiguous bands used for sounding |
| Power Assignment Method | 2 bits | 0b00 = equal power;<br>0b01 = reserved;<br>0b10 = Interference dependent. Per subcarrier power limit;<br>0b11 = Interference dependent. Total power limit |
| Power boost | 1 bit | 0 = no power boost<br>1= power boost |
| Multi-Antenna Flag | 1 bit | 0=MSS sounds first antenna only<br>1=MSS sounds all antennas |
| if (Separability type==0) { | | |
| 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 { | | |
| Decimation Offset d | 6 bits | Relative starting offset position for the first sounding occupied subcarrier in the sounding |

| | | |
|---|---|---|
| | | allocation |
| } | | |
| Periodicity | 2 bits | 00=single command, not periodic, or terminate periodicity<br>01=repeat sounding once per frame until terminated<br>10= repeat instructions once per 2 frames<br>11= repeat instructions once per 4 frames |
| } | | |
| } | | |
| } else { | | |
| Permutation | 2 bits | 0b00 = PUSC perm.<br>0b01 = FUSC perm.<br>0b10 = Optional FUSC perm.<br>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<br>01=repeat sounding once per frame until terminated<br>10= repeat instructions once per 2 frames<br>11= repeat instructions once per 4 frames |
| Power Assignment Method | 2 bits | 0b00 = equal power;<br>0b01 = reserved;<br>0b10 = Interference dependent. Per subcarrier power limit;<br>0b11 = Interference dependent. Total power limit |
| Power boost | 1 bit | 0 = no power boost<br>1= power boost |
| } | | |

| | | |
|---|---|---|
| } | | |
| } | | |
| Padding | Variable | Pad IE to octet boundary. Bits shall be set to 0 |
| } | | |

[ Add a new section 8.4.6.2.7.3 “Direct transmission of channel coefficients”. Add the following text.]

**Section 8.4.6.2.7.3 Direct transmission of DL channel coefficients**

If the field “Include Channel Coefficients” is set to 1, then the UL Sounding Command IE() enables the MSS to perform the direct transmission of DL channel coefficients to the BS along with the UL sounding waveform. This functionality provides downlink channel state information to the BS in both FDD systems and TDD systems in which BS array transceiver calibration is not implemented. With this functionality enabled, DL channel coefficients are encoded as described below and are transmitted in one or more sounding zone symbols that immediately following each symbol being used to transmit UL sounding waveforms. In this case, the UL sounding waveform is used by the BS to estimate the UL channel so that the DL channel coefficients transmitted by the MSSs can be estimated by the BS. The channel coefficients can then be used to enable closed-loop transmission on the downlink.

There are two cases depending on the value of the separability type field. First, if separability type is 0 (cyclic shift separability in the sounding waveform), then a single additional symbol follows each sounding symbol being allocated with the UL_Sounding_command_IE(). In that additional symbol, an MSS antenna that transmits sounding in the sounding symbol will transmit an encoded channel coefficient waveform that occupies the same sounding bands allocated for the sounding waveform. The encoded waveform for the $u^{th}$ MSS (where $u$ is the cyclic shift index in the UL Sounding Command) is defined for two cases: The first case is for where the MSS has a single transmit antenna, but multiple receive antennas and is told with the sounding command IE to sound all antennas (multi-antenna flag set to 1). In this case, the single transmit antenna transmits the sounding waveform appropriate for the single transmit antenna on the sounding symbol and transmits the following encoded waveform in the next symbol interval:

$$Z_u(k) = \beta_u \sum_{\ell=1}^{M_b} \sum_{m=1}^{M_{m,u}} \hat{H}_{u,m,\ell}(k) s_u(k) \exp\{-j2\pi k(m-1+(\ell-1)M_{m,u})/\alpha_u\}$$

where $\hat{H}_{u,m,\ell}(k)$ is the estimated DL channel coefficient between the $\ell^{th}$ BS transmit antenna and the $m^{th}$ receive antenna of the $u^{th}$ MSS for subcarrier $k$; $\beta_u$ is a scaling to make the average transmit power of the feedback waveform (averaged across all frequency) of $Z_u(k)$ be one; $s_u(k)$ is the sounding sequence of Section 8.4.6.2.7.1; $M_{m,u}$ is the number of receive antennas on the $u^{th}$ MSS, $\alpha_u$ is $M_{m,u}M_b$; and $M_b$ is the number of BS transmit antennas.

The second case for a separability type of 0 is for when the MSS has a number of transmit antennas equal to the number of receive antennas. In this case, the encoded waveform to be transmitted by the MSS antenna assigned to cyclic shift index of $u$ in the UL Sounding Command is

$$Z_u(k) = \beta_u \sum_{\ell=1}^{M_b} \hat{H}_{u,\ell}(k) s_u(k) \exp\{-j2\pi k(\ell-1)/\alpha_u\}$$

where $\hat{H}_{u,\ell}(k)$ is the estimated DL channel coefficient between the $\ell^{\text{th}}$ BS transmit antenna and the MSS antenna assigned to the cyclic shift index of $u$ in the UL Sounding Command for subcarrier $k$; $\beta_u$ is a scaling to make the average transmit power of the feedback waveform (averaged across all frequency) of $Z_u(k)$ be one; $s_u(k)$ is the sounding sequence of Section 8.4.6.2.7.1; $\alpha_u$ is $M_{m,u}M_b$; and $M_b$ is the number of BS transmit antennas.

When separability type is 1 in the UL Sounding Command (decimation separability in the sounding waveform), then every allocated sounding symbol is followed by a number of additional symbols equal to the number of BS antennas. In this case, an MSS antenna that transmits on subcarrier $k$ of the sounding symbol shall transmit the DL channel coefficient for the $i^{\text{th}}$ base antenna to that MSS antenna for the $k^{\text{th}}$ subcarrier on subcarrier $k$ of the $i^{\text{th}}$ additional symbol following the allocated sounding symbol. In equation form, the MSS that transmits a sounding signal on subcarrier $k$ of the sounding symbol shall transmit $\hat{H}_{\ell}(k)$ on the $\ell^{\text{th}}$ symbol following the sounding symbol, where $\hat{H}_{\ell}(k)$ is the DL channel coefficient from the $\ell^{\text{th}}$ BS antenna to that MSS antenna.

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

## References


[1] T. L. Marzetta and B. M. Hochwald, "Fast Transfer of Channel State Information in Wireless Systems," submitted to IEEE Transactions on Communications, June 2004, available at http://mars.bell-labs.com.

[2] T. L. Marzetta and B. M. Hochwald, "Learning the Channel at the Transmitter," *Forty-Second Annual Allerton Conference on Communication, Control, and Computing*, Monticello, IL, September 29-October 1, 2004.