Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Corrections for downlink STC in OFDMA PHY
Date Submitted	**2005-01-24**
Source(s)	Yuval Lomnitz Yuval.Lomnitz@intel.com Yigal Eliaspur Yigal.Eliaspur@intel.com Intel. Yigal Leiba yigall@runcom.co.il Yossi Segal yossis@runcom.co.il Runcom Ltd.
Re:	IEEE P802.16REVd/D5-2004
Abstract	Corrections and clarifications of definitions for STC in OFDMA PHY.
Purpose	Adopt changes.
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

Corrections for downlink STC in OFDMA PHY

Yuval Lomnitz, Yigal Eliaspur (Intel)
Yigal Leiba, Yossi Segal (Runcom Ltd.)

1.   Motivation

There are several errors/undefined issues in the definition of downlink STC for two antennas in OFDMA PHY:

1. Pilot locations for FUSC
2. The order of STC and PRBS is undefined

2.   Details

2.1.   Pilot locations for FUSC

Equation (106) in section 8.4.6.1.2.2 (Symbol Structure for FUSC) defines that FUSC variable pilots are shifted by 6 in each odd symbol. However in STC this creates a problem:

1. Shifting the pilots changes the location of data subcarriers, resulting in the fact that the STC doesn't operate on QAM symbols transmitted in the same frequency. This makes STC combining complex and suboptimal.
2. The operation of STC coding is defined as exchanging tones with the same index for two OFDMA symbols. The STC operation is not well defined when data tones change their locations.
3. The movement of the pilots creates an irregular pilot pattern that doesn't improve channel estimation, as depicted below. It seems that the original intention was merely to exchange pilot-sets between the antennas.
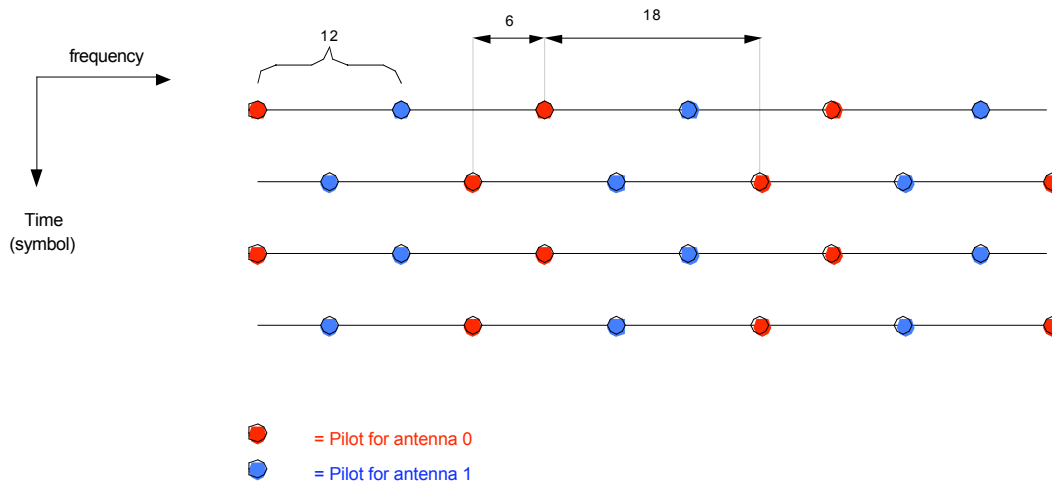
On the other hand, canceling the movement of the pilot will result in regular structure, but will degrade the channel estimation performance (12 tone separation @11Khz carrier spacing = limited to 7us delay spread).

So our proposal is to define that pilot movement is every 2nd symbol.

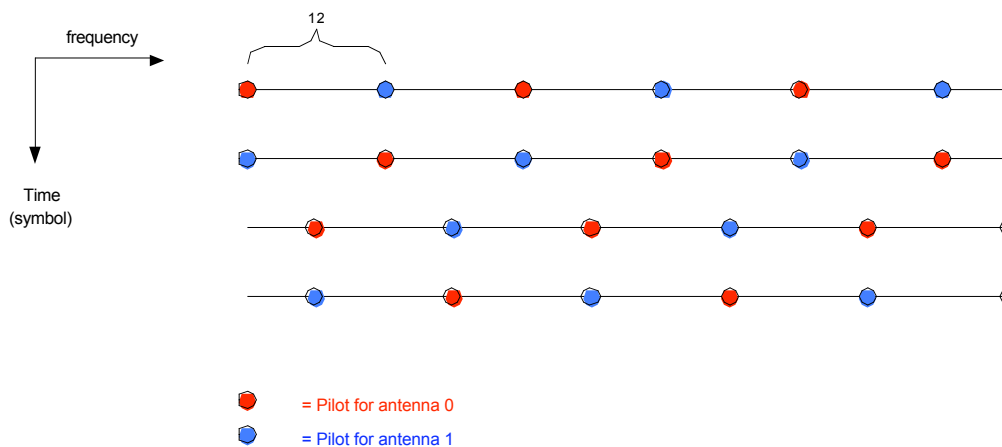The following diagrams show the pilot patterns

Before the proposed change
The maximum pilot spacing over 2 OFDMA symbols is 18 tones (and the minimum is 6 tones)

After the proposed change
The pilot spacing (from one antenna) in two OFDMA symbols is 12 tones.

2.2.   **The order of STC and PRBS is undefined**

It is not defined if STC operates on modulated symbols before or after multiplication by PRBS (defined in 8.4.9.4.1 Permutation definition). Formally, it can be defined either way, however it makes sense to define that STC coding is done before subcarrier randomization (PRBS), because in the reception process, in order to perform STC combining, the channel needs to be estimated, and in order to estimate the channel, the subcarrier randomization (PRBS) has to be removed, at least from the pilots. So the logical order of things in the receiver is: PRBS removal, channel estimation, STC combining. Therefore it makes sense to define that STC coding is done before PRBS.

Note that from BS implementation point of view, if pilots were set aside, it would make sense to place the STC after the PRBS, so that it could be performed after IFFT. This way, IFFT would need to be performed only once per symbol for both antennas (using time inversion to perform complex conjugate

in frequency domain). However, because of pilot sharing and since pilots are PRBS-ed (therefore not repetitive), this is not possible.

Following this definition it should be clarified also that the switching between data subcarriers and pilots (in STC for PUSC) is done **before** STC and **before** subcarrier randomization.

In addition, it is not defined anywhere that STC coding operates on subcarriers with the **same index** (frequency) in different symbols, so it is worth clarifying this.

3. Changes summary

8.4.8.1.2.1 STC encoding
[Add the following text after line 49 in p.583]
STC encoding shall be performed after constellation mapping and before subcarrier randomization defined in 8.4.9.4.1. s_1 and s_2 represent two subcarriers in the same frequency in two different OFDMA symbols (each OFDMA symbol is referred to as a channel use). The STC coding is done on all data subcarriers in the two OFDMA symbols. Pilot subcarriers are not encoded and are transmitted from either antenna 0 or antenna 1. STC encoding is performed on two adjacent OFDMA symbols for FUSC and two OFDMA symbols which are 2 symbols apart for PUSC.

8.4.8.1.2.1.1 STC using 2 antennas in PUSC
[Modify p.583 lines 62-65 as follows]
The structure shall be modified as depicted in Figure 245 (switching 2 pilot carriers from the odd symbol with 2 data carriers from the even symbols, switching of the data carriers and the pilots carriers shall be performed after constellation mapping and before STC encoding defined in 8.4.8.1.2.1 and subcarrier randomization defined in 8.4.9.4.1,

8.4.8.1.2.1.2 STC using using 2 antennas in FUSC
[Add the marked text to the first paragraph]
In FUSC all subchannles shall be used for STC transmission, the pilots within the symbols shall be divided between the antennas, antenna 0 uses VariableSet#0 and ConstantSet#0 for even symbols while antenna 1 uses VariableSet#1 and ConstantSet#1 for even symbols, antenna 0 uses VariableSet#1 and ConstantSet#0 for odd symbols while antenna 1 uses VariableSet#0 and ConstantSet#1 for odd symbols (symbol counting starts at the starting point of the relevant STC zone), defined in 8.4.6.1.2.2. In STC transmission the *FUSC_SymbolNumber* in equation (106) is replaced with floor(*FUSC_SymbolNumber*/2), so that variable pilots shall move every 2nd symbol. The trasnmission of the data shall be performed in pairs of symbols as illustrated in Figure 247.