Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Corrections for downlink STC in OFDMA PHY
Date Submitted	**2005-01-26**
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	
Release	
Patent Policy and Procedures	

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.

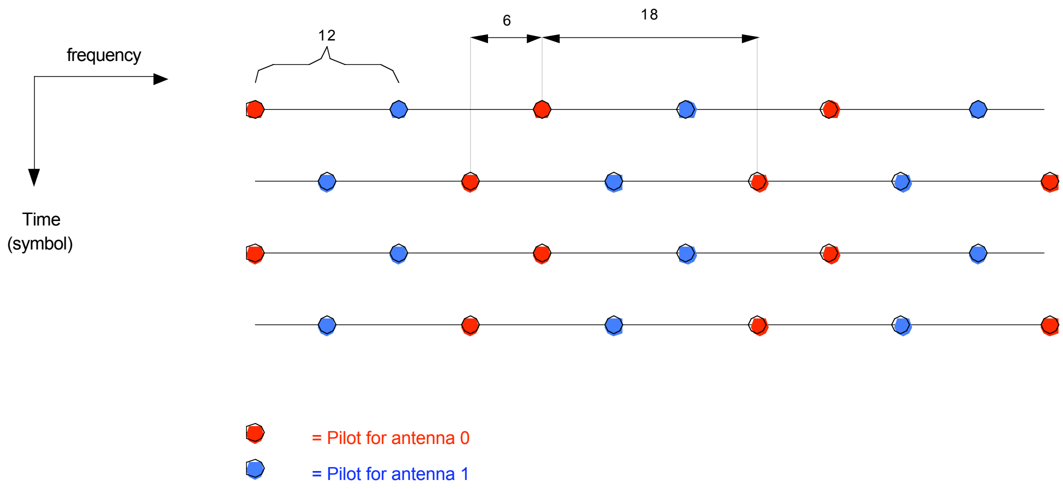
On the other hand, canceling the movement of the pilot will result in regular structure, but will degrade the channel estimation performance (12 tone separation @11Khz carrier spacing = limited to 7us delay spread).

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

The following diagrams show the pilot patterns

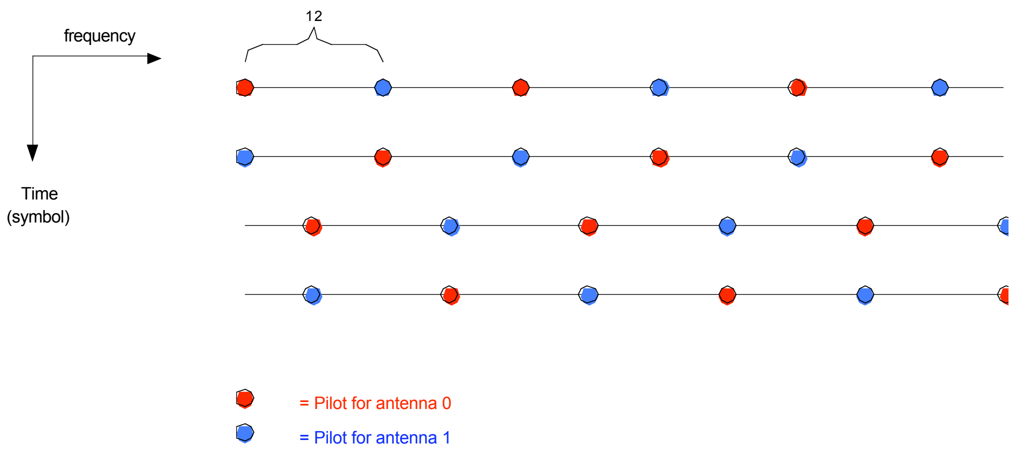
Before the proposed change

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

[Change title of 8.4.8.1.2.1 and add the following text after the title]

8.4.8.1.2.1 STC rate 1 encoding

Two antenna rate 1 scheme is a basic STC scheme, enabled by matrix A as defined in 8.4.8.1.4. Other STC schemes are defined in a matrix notation in 8.4.8.1.4.

[Add the following text after line 49 in p.583]

STC rate 1 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~~ at the same frequency in two ~~different~~ consecutive OFDMA symbols (each OFDMA ~~symbol~~ subcarrier is referred to as a channel use). The STC rate 1 coding is done on all data subcarriers that belong to an STC coded burst 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]**~~

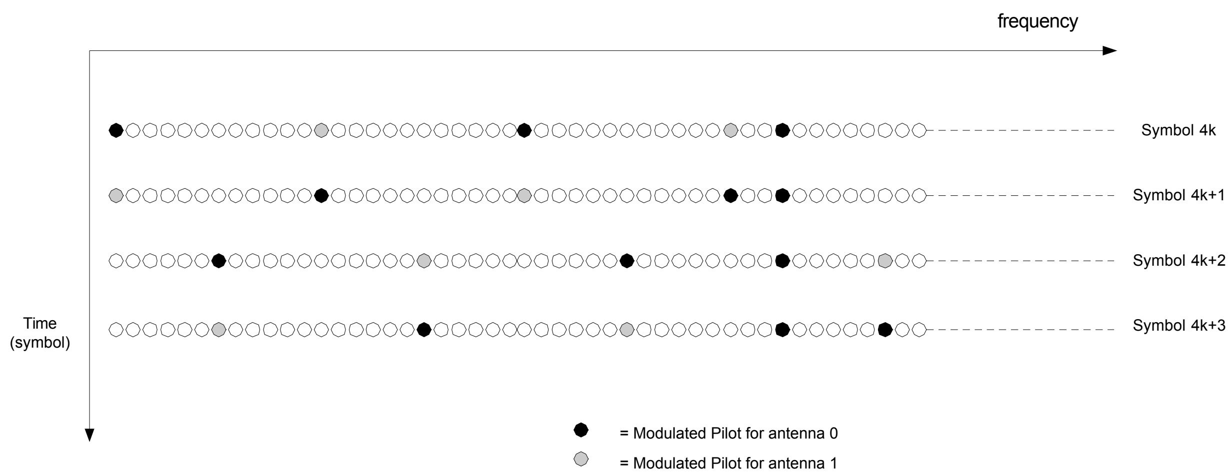
~~The structure shall be modified as depicted in Figure 245 (switching 2 pilot carriers from the odd symbol with 2 data carriers from the even symbols, switching of the data carriers and the pilots carriers shall be performed after constellation mapping and before STC encoding defined in 8.4.8.1.2.1 and subcarrier randomization defined in 8.4.9.4.1.~~

8.4.8.1.2.1.2 STC rate 1 using 2 antennas in FUSC

[~~Add~~ Change the ~~marked~~ text ~~to~~ in the first paragraph as indicated]

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 tras~~n~~mission of the data shall be performed in pairs of symbols as illustrated in Figure 247.

[Replace figure 247 as it is too confusing, with this simpler illustration]



8.4.8.2.2 STC for 4 antennas using FUSC
change the text to:

Even Symbols ~~0~~: antenna 0 uses VariableSet#0 and ConstantSet#0, antenna 1 uses VariableSet#1 and Constant-Set#1, antenna 2 uses indices of (VariableSet#0+1), antenna 3 uses indices of (VariableSet#1+1)
Odd Symbols ~~1~~: antenna 0 uses VariableSet#1 ~~and ConstantSet#0~~, antenna 1 uses VariableSet#0 ~~and Constant-Set#1~~, antenna 2 uses indices of (VariableSet#1+1) and (ConstantSet#0), antenna 3 uses indices of (VariableSet#0+1) and (Constant-Set#1)
~~Symbol 2: antenna 0 uses VariableSet#01 and ConstantSet#0, antenna 1 uses VariableSet#1 and Constant-Set#1, antenna 2 uses indices of (VariableSet#0+1), antenna 3 uses indices of (VariableSet#1+1)~~
~~Symbol 3: antenna 2 uses VariableSet#1 and ConstantSet#0, antenna 3 uses VariableSet#0 and Constant-Set#1~~

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 FUSC permutation is performed on the data subcarriers remaining after allocating the pilots for antennas 0,1 and the Constant pilots. The data subcarriers which overlap with variable pilots allocated to antennas 2,3 are ~~punctured~~replaced with pilots ~~(replaced with the pilot subcarrier)~~.

The data puncturing for CC or the data truncation for CTC shall be performed after STC encoding and before IFFT packet mapping.

[Add figure 251a for illustration]

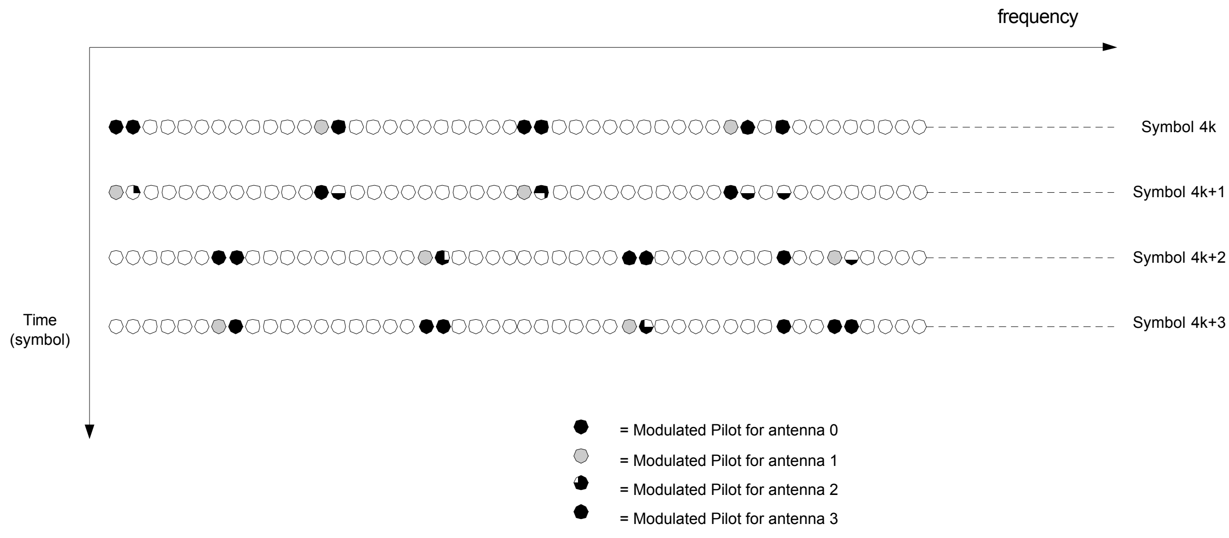


Figure 251a: **STC usage with FUSC for 4 antenna configuration**