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Re:	Ballot #14c
Abstract	
Purpose	Adopt proposed changes to TGe document
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Pilot Allocation in Downlink PUSC

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1 Problem Statement

A fundamental problem exists in the current definition of pilot locations in the downlink-PUSC STC mode [1]. Figure 1 shows the current structure of a cluster pair (i.e. clusters in two consecutive symbols) for the case of 2-antenna STC:

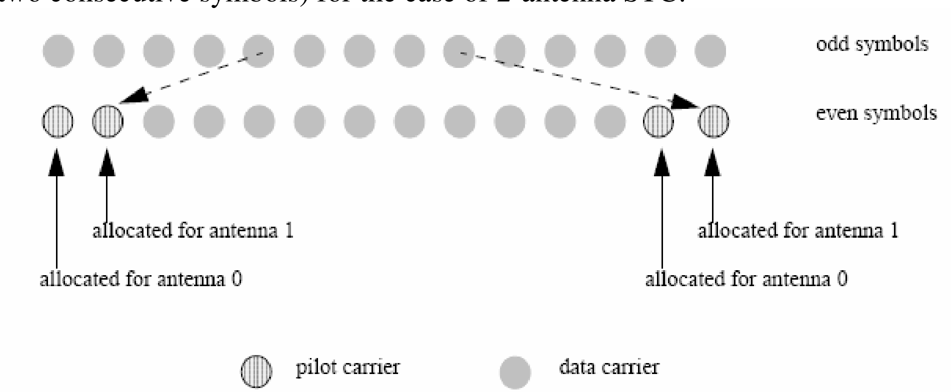

Figure 1 – Current definition of DL PUSC clusters for 2-antenna STC

The pilot spacing of 12 subcarriers leads to very significant channel estimation loss in the presence of channels with relatively high delay spread (delay spread that is however much smaller than the maximum supported cyclic prefix length) when using pilot-aided estimation approaches. Since the goal of STC schemes is to extend the cell range, it is important that they operate well at cell edges, where high delay spread is very likely. Note that in STC mode we can not rely on channel estimation from the DL preamble since the preamble is transmitted by only one antenna.

In effect, estimation loss in highly dispersive channels will severely limit data transfer rate to as low as QPSK modulation using ¼ coding rate, <u>regardless of thermal noise level</u>. A solution to this problem is presented in section 2. A by-product of this solution is the fact that two contiguous symbols, rather than slots, can be STC encoded – this is beneficial in situations where the channel is time-varying.

Section 2 outlines the changes proposed to the structure of clusters in STC mode. Section 3 compares the performance of the proposed solution to that of the current definition. Proposed text changes are described in section 4.

2 Outline of proposed solution

It is proposed to apply the following for FFT-sizes below 2048.

2.1 2-Antenna STC mode:

1. Pilot locations within the cluster shall be defined depending on the symbol index within each quartet of symbols, as follows:

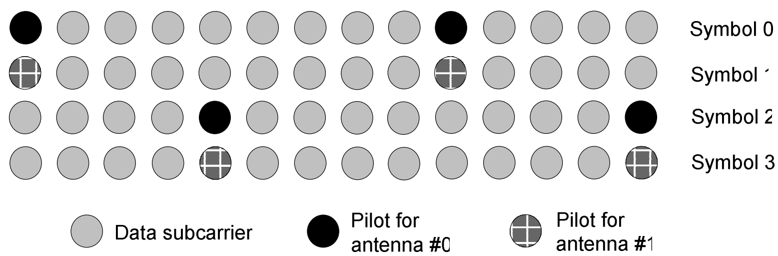

Figure 2 –structure of clusters for DL PUSC in 2-Antenna STC mode

2. STC encoding of subcarriers shall be performed between contiguous symbols rather than between contiguous slots. This is depicted in the following figure:

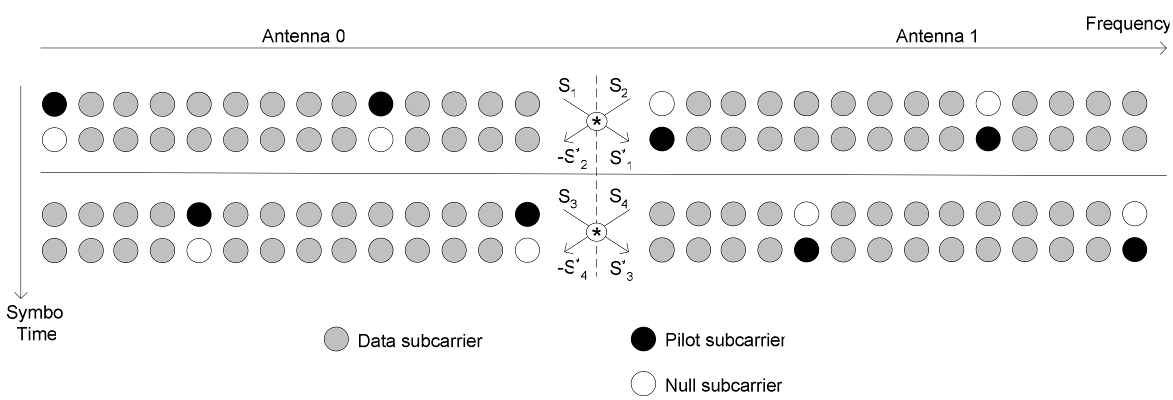

Figure 3 – STC usage with 2-Antennas in DL-PUSC.

2.2 4-Antenna STC mode:

1. In each symbol, 2 data subcarriers per cluster shall be punctured and used as pilots for antennas #2 and #3. Puncturing is done after constellation mapping therefore maintaining

all of the encoding scheme and subchannel allocation scheme. Pilot locations shall be defined as follows:

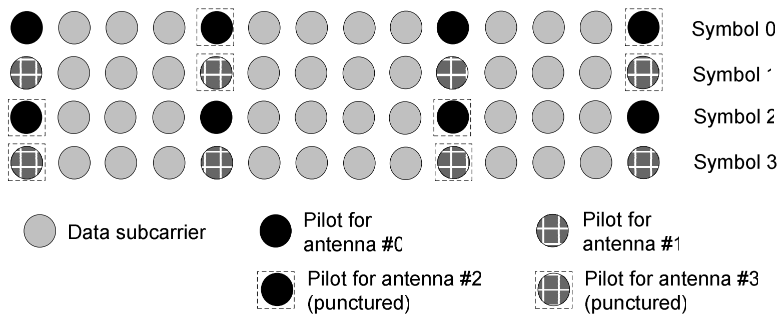

Figure 4 –structure of clusters for DL PUSC in 2-Antenna STC mode

2. STC encoding of subcarriers shall be performed between contiguous symbols rather than between contiguous slots.

3 Channel Estimation Loss

In this section we compare the channel estimation performance of the proposed STC scheme to that of the currently defined scheme. The model and estimator are first briefly described, followed by results showing that the current PUSC STC scheme renders pilot-aided channel estimation useless.

3.1 Model description

Let us consider a channel model with a flat power-delay profile and a flat Doppler spectrum, as depicted in Figure 5.

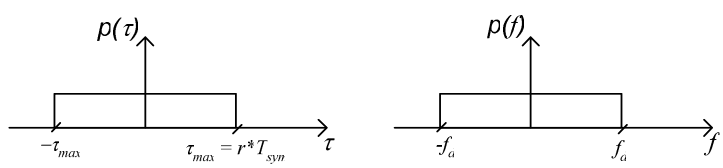

Figure 5 – power-delay and Doppler power profiles

The resulting time-frequency subcarrier correlation function is given by:

$$\rho(\Delta n, \Delta k) = sinc(2 \cdot f_d \cdot (\Delta n \cdot T_{sym})) \cdot sinc(2 \cdot \tau_{\max} \cdot (\Delta k \cdot \Delta f)) \quad (1)$$

where T_{sym} is the OFDM symbol duration and Δf is the subcarrier spacing.

The minimal pilot spacing required according to Nyquist's sampling theorem, <u>*assuming f_d=0*</u>, is

$$\Delta f_{\min} = \frac{1}{2\tau_{\max}} = \frac{1}{2rT_{sym}} = \frac{1}{2r}\Delta f \quad (2)$$

where in the last equality we have neglected the cyclic-prefix for clarity of discussion. Some level of over-sampling is needed in order to further improve estimation S/N.

3.2 Channel Estimator

The channel estimator used is the well-known 2D MMSE estimator [2]. The model is assumed to be exact (i.e. no model mismatch). A block of 4 symbols was used for evaluation (with all possible variations for the location of the first symbol), and the subcarriers for the 3rd symbol were estimated.

3.3 Performance comparison

The figures below compare the channel estimation performance of the current DL PUSC structure definitions vs. the definitions proposed in the previous subsection. Results shown are the combined SNR (thermal noise + channel estimation noise) for Doppler spreads of 0Hz and 250Hz with $\tau_{\max} = 1/16 \cdot T_{sym}$ and $1/32 \cdot T_{sym}$. A subcarrier spacing of 10 KHz is assumed when factoring in the effect of Doppler spread.

Only the 2-antenna STC case is considered - channel estimation loss with 4-antennas will be identical.

The proposed cluster structure does indeed solve the severe estimation problem for the PUSC STC modes. This is shown in Figure 6 and Figure 7.

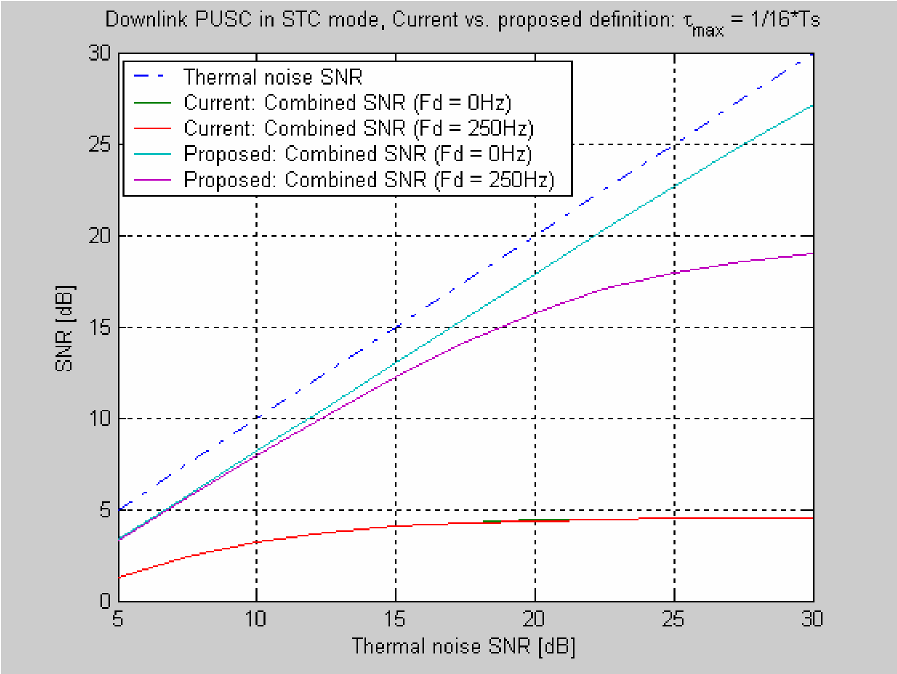

Figure 6 - Comparison between current and proposed DL PUSC structures in STC mode, $\tau_{\max} = 1/16 \cdot T_{sym}$.

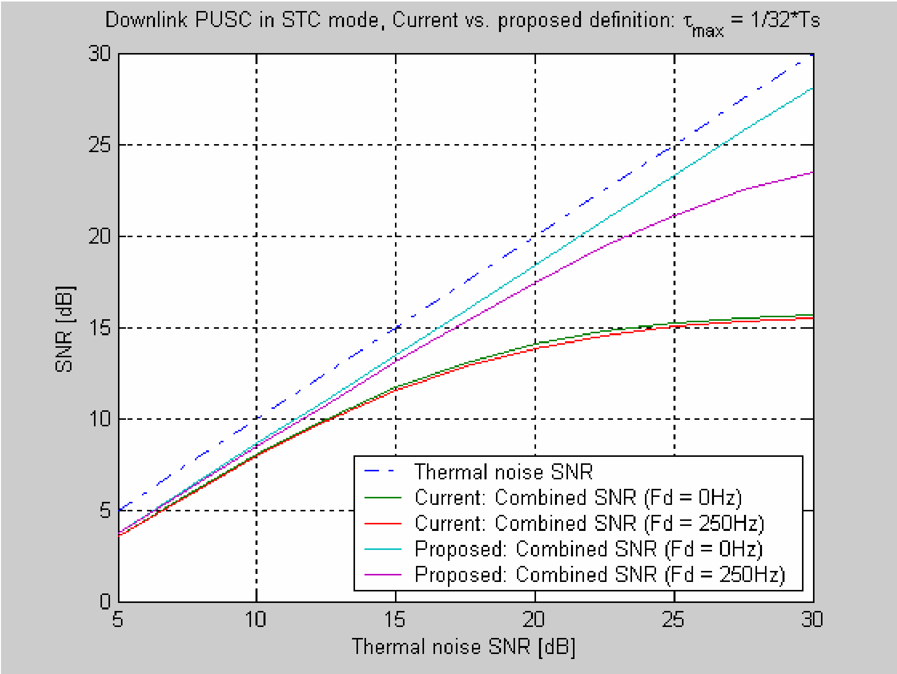

Figure 7 - Comparison between current and proposed DL PUSC structures in STC mode, $\tau_{\max} = \frac{1}{32} \cdot T_{sym}$.

4 Proposed Text Changes

4.1 STC-related changes

Section 8.4.8.1.2.1.1:

[Add figure 245a and accompanying caption on page 584 following figure 245]

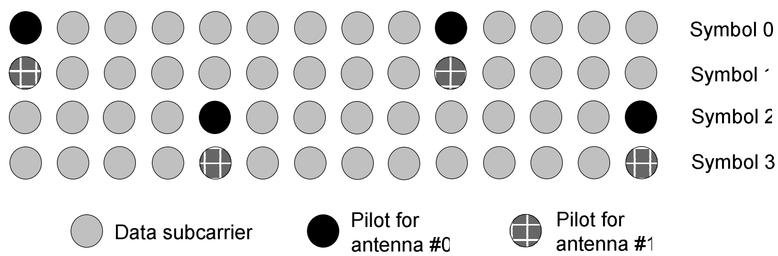

Figure 245a – structure of PUSC clusters in 2-antenna STC mode for FFT sizes below 2048

[Replace caption of figure 245 on page 584]

Figure 245 – structure of PUSC clusters in 2-antenna STC mode for FFT-2048

[Apply the following changes to the text from line 56 on page 583 up to line 5 of page 584 from BEGIN to END:]

BEGIN

In PUSC the data allocation to cluster is changed ~~(Figure 245)~~ to accommodate two antennas transmission~~ with the same estimation capabilities,~~;each cluster shall be transmitted ~~twice from each antenna~~ from both antennas.

The clusters composing the subchannels used by the STC mode shall be allocated and subcarriers numbered as defined in 8.4.6.2 with pilots in each consecutive pair / quartet of PUSC symbols allocated as depicted in figure 245 for FFT-2048 / figure 245a for FFT sizes below 2048. ~~The cluster structure of the subchannels allocated for STC is slightly modified to fit the STC requirments. 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, therefore maintaining all the encoding scheme and the subchannel allocation scheme).~~ For FFT-2048, switching 2 pilot carriers from the odd symbol with 2 data carriers from the even symbols is performed (switching of the data carriers and the pilots carriers shall be performed after constellation mapping, therefore maintaining all the encoding scheme and the subchannel allocation scheme). In this scheme, transmission on regular subchannels and STC subchannels is possible and is determined by the MAC layer (the allocation is performed by allocating major groups of subchannels for regular or STC transmission). ~~The trasnmission~~ STC encoding of the data shall be performed ~~in pairs of symbols~~ as illustrated in Figure 246 for FFT-2048 and in Figure 246a for FFT sizes below 2048. The number of OFDMA symbols in a PUSC STC-encoded allocation shall be a multiple of four.

END

[Add figure 246a on page 584 following figure 246:]

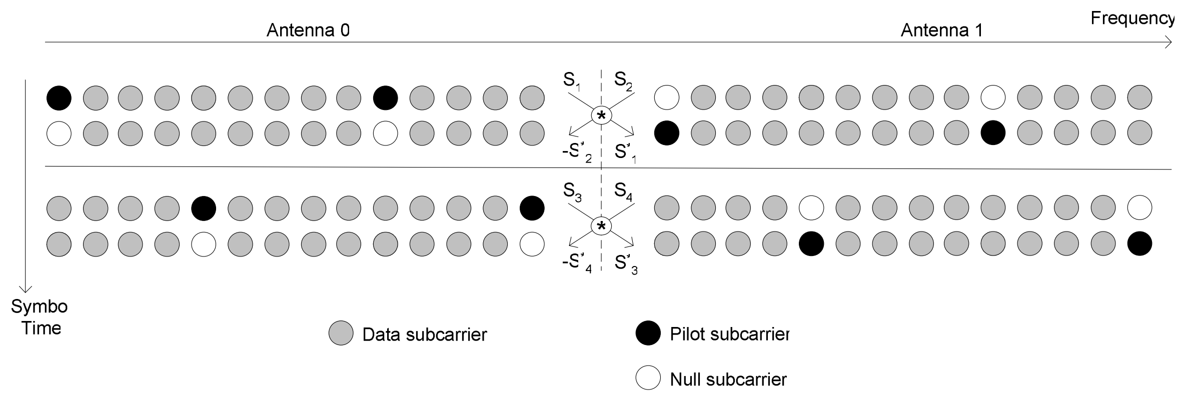

Figure 246a – STC usage with PUSC for FFT sizes below 2048

[Replace caption of figure 246 on page 584]

Figure 246 – STC usage with PUSC for FFT-2048

Section 8.4.8.2.1:

[Apply the following changes to the text on lines 39-44 of page 588 from BEGIN to END:]

BEGIN

~~Tor~~ For this configuration the basic cluster structure is changed ~~as indicated in Figure 251~~ to ~~accumudate~~ accommodate the transmission from 4 antennas ~~(pilots for antennas 2/3 override data subcarriers in the even symbols, switching and erasing of the data subcarriers shall be performed after constellation mapping, therefore maintaining all the encoding scheme and the subchannel allocation scheme)~~, as indicated for FFT-2048 in Figure 251 and for FFT sizes below 2048 in Figure 251a. For FFT-2048, pilots and data subcarriers are switched as in the 2-antenna STC mode, and pilots for antennas 2/3 override data subcarriers in the odd symbols. For FFT sizes below 2048, pilots for antennas 2/3 override data subcarriers as depicted in figure 251a. Switching and erasing of data subcarriers shall be performed after constellation mapping, therefore maintaining all the encoding scheme and the subchannel allocation scheme as in the 2-antenna STC mode).

END

[Add figure 251a on page 589 following figure 251:]

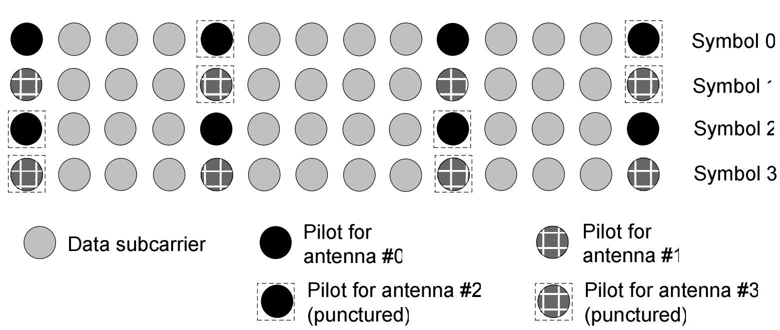

Figure 251a – structure of clusters in the 4-antenna STC mode for FFT sizes below 2048

[Replace caption of figure 251 on page 589]

Figure 251 – structure of clusters in the 4-antenna STC mode for FFT-2048

4.2 Changes to non-STC PUSC definition

Section 8.4.6.1.2.1:

In light of the change to pilot allocation in STC mode (figures 245a and 251a), it is desirable (from implementation point of view) to make a slight modification to the pilot locations so that the same subcarrier permutation generator can be applied during both STC and non-STC subchannel allocation procedures. This can be achieved if in both STC and non-STC modes, the pilots are located either at locations 1 & 10 or at locations 5 & 14. The proposed change does not affect channel estimation performance.

[Add figure 234a on page 567 following figure 234:]

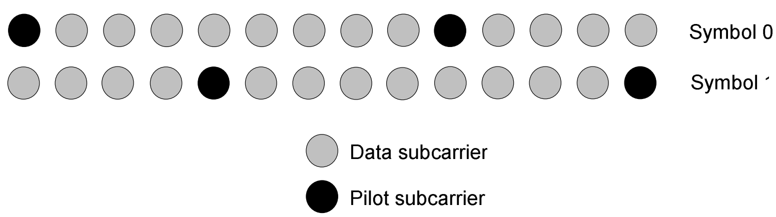

Figure 234a – structure of PUSC clusters for FFT sizes below 2048

[Replace caption of figure 234 on page 567]

Figure 234 – structure of PUSC clusters for FFT-2048

[Apply the following changes to the text on line 1 of page 567 from BEGIN to END:]

BEGIN
Figure 234 depicts the cluster structure for FFT-2048, and figure 234a depicts the cluster structure for FFT sizes below 2048:
END

5 References

[1] IEEE P802.16REVd-D5.

[2] P. Hoeher, S. Kaiser, and P. Robertson. “Two-Dimensional Pilot-Symbol-Aided Channel Estimation by Wiener Filtering”. Proc. IEEE ICASSP '97, Munich, Germany, pp. 1845-1848, Apr. 1997.