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Title:	**QO-STFBC / Double-STTD Based H-ARQ for Four Transmit Antennas**
Document for:	**Discussion/decision**

>THIS IS **THE WAY**

Space Time Block Coding Based H-ARQ for Four Transmit Antennas

Nortel

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>THIS IS **NORTEL**

Background and Introduction

> In the MIMO modes transmission, when packet in error, the basic Turbo coding based re-transmission can be employed.

- Such a re-transmission can be based on Chase combing and/or incremental redundancy based coding combing (as per Rel5)

> In general, the H-ARQ exploits the time-diversity with soft packet combing to improve the transmission reliability

> However, in the MIMO mode, we can exploit additional space-time diversity in the packet re-transmission.

- The re-transmitted packet can be design as a space time code words so that the receiver can treat the packet re-transmission as decoding a space time code, therefore, additional gain can be gained.
- Such a re-transmission can be designed as redundancy version in space-time coding domain
    - The simplest version is QO-STBC

> At the Seoul meeting, we presented in R1-051426 the H-ARQ approach for two transmit antennas. To complete the case, we show the orthogonality based retransmission for four transmit antennas.

The Two Basic MIMO Transmission Modes

> STTD
  - Improve the reliability to link performance
  - Independent of MIMO channel matrix illness
  - Does not increase the user bit rate

> Spatial Multiplexing
  - Provides higher user bit rate
  - Sensitive to MIMO channel matrix illness

> The proposed H-ARQ strategy for MIMO transmission
  - Use Spatial multiplexing (respectively Double SFTD) as *first* transmission to gain best bit rate
  - Second transmission built to form double STTD (respectively QO-STFBC) with first transmission
  - The receiver exploits the orthogonal signal design and space diversity gain

H-ARQ Options for MIMO Transmission

> Option-1

- FEC based H-ARQ: rate compatible Turbo codes
- The redundant version is transmitted as different version of code words of Turbo code
- Combined packet decoding at receiver

> Option-2

- Symbol re-transmission: LMS based Chase combining
- Packet re-transmission and soft combined at receiver

> Option-3

- Space time coding based retransmission
- Same Turbo code words same modulation symbol
- Different redundant version in terms of space time code

All the three approaches provide additional energy and time diversity

The Fundamental Limits of FEC Coding Gain*

> FEC coding based incremental redundancy coding exploits coding gain when jointly to combine the code words of Turbo code as a lower code rate

- However, such an additional coding gain is limited, e.g. for RCCC*

m=8	R = 1/4	R = 1/3	R = 1/2
Asymptotic coding gain	4.77 dB	4.77 dB	4.77 dB

> With MIMO case, additional SNR and space diversity gain can be obtained from quasi-orthogonal space time block code (QO-STBC)

***Sue Lin, Error Control Coding: Fundamentals and Applications Prentice Hall, 1983, p. 330**

QO-STBC: an example

	Tx 1	Tx 2	Tx 3	Tx 4
Time 1	$\mathbf{s_1}$	$\mathbf{s_2}$	$\mathbf{s_3}$	$\mathbf{s_4}$
Time 2	$\mathbf{-s^*_2}$	$\mathbf{s^*_1}$	$\mathbf{-s^*_4}$	$\mathbf{s^*_3}$
Time 3	$\mathbf{-s^*_3}$	$\mathbf{-s^*_4}$	$\mathbf{s^*_1}$	$\mathbf{s^*_2}$
Time 4	$\mathbf{s_4}$	$\mathbf{-s_3}$	$\mathbf{-s_2}$	$\mathbf{s_1}$

> Each symbol is transmitted once from each antenna.

> The received signal is quasi-orthogonal.

QO-STFBC based H-ARQ for double-SFTD

	Tx 1	Tx 2	Tx 3	Tx 4
1st trans / f_1	$\mathbf{s_1}$	$\mathbf{s_2}$	$\mathbf{s_3}$	$\mathbf{s_4}$
1st trans / f_2	$\mathbf{-s^*_2}$	$\mathbf{s^*_1}$	$\mathbf{-s^*_4}$	$\mathbf{s^*_3}$
2nd trans / f_1	$\mathbf{-s^*_3}$	$\mathbf{-s^*_4}$	$\mathbf{s^*_1}$	$\mathbf{s^*_2}$
2nd trans / f_2	$\mathbf{s_4}$	$\mathbf{-s_3}$	$\mathbf{-s_2}$	$\mathbf{s_1}$

- First transmission corresponds to double-SFTD
- Second transmission will form together with first transmission a QO-STFBC format
- f_1 and f_2 are two adjacent sub-carriers.

Double-STTD based H-ARQ for SM

	Tx 1	Tx 2	Tx 3	Tx 4
1st trans	$\mathbf{s_1}$	$\mathbf{s_2}$	$\mathbf{s_3}$	$\mathbf{s_4}$
2nd trans	$\mathbf{-s^*_2}$	$\mathbf{s^*_1}$	$\mathbf{-s^*_4}$	$\mathbf{s^*_3}$

- First transmission corresponds to Spatial Multiplexing
- The 2nd retransmission will form a double-STTD with the 1st SM transmission.
- Orthogonality within the constituent codes provides both full order (i.e. 2) spatial diversity and SNR gain.

The benefits of double-STTD/QO-STFBC Based H-ARQ

- The double STTD/QO-STFBC based H-ARQ enables MIMO packet combining to exploit the space diversity gain.
- In addition to the space diversity gain, it is able to significant gains due to
  - the orthogonality within the constituent codes of double-STTD
  - the quasi-orthogonality of STFBC
- The gain is most significant for the slow mobility case.
- The packet combining receiver is simple.
- For the high speed UE case, the gain would be reduced due to loss of orthogonality, but there is no loss compared to the non-STFC based retransmission.

Conclusions

- For spatial multiplexing based systems, the gain from incremental FEC based retransmission is limited.
- For the two transmit antenna case, STTD based H-ARQ is able to introduce additional orthogonality and hence significant SNR gains associated with it (see R1-051426).
- Double-STTD / QO-STFBC based incremental redundancy re-transmission provides significant gain with a simple retransmit and receive structure
- LMS Chase combining should be used to provides good performance for quasi-orthogonal retransmissions
- We recommend RAN1 to consider the adoption of the orthogonality principle for H-ARQ retransmission as illustrated in the two examples given in this contribution (Double-STTD / QO-STFBC)