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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

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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

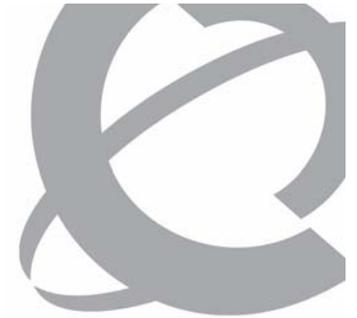
- Improve the reliability to link performance
- Independent of MIMO channel matrix illness
- Does not increase the user bit rate

> 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

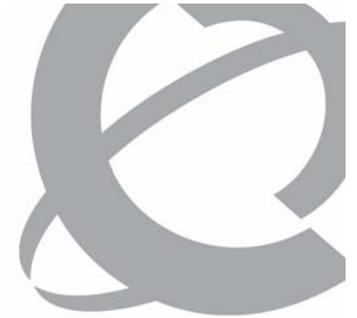
- Symbol re-transmission: LMS based Chase combining
- Packet re-transmission and soft combined at receiver

> 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

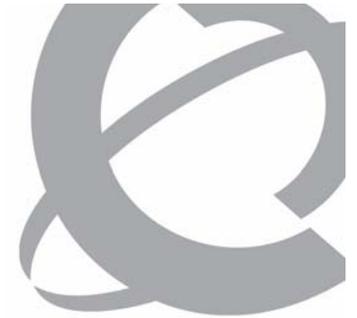
- > Each symbol is transmitted once from each antenna.
- > The received signal is quasi-orthogonal.



QO-STFBC based H-ARQ for double-SFTD

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