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Title	Enhancement for 4-antenna soft packet combining scheme using unitary transformation
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Re:	Contribution to the IEEE P802.16e
Abstract	In [1], efficient MIMO soft packet combining schemes based on Alamouti space-time block code (STBC) were proposed for systems with 2 and 4 transmit antennas. In this contribution, we present a soft packet combining scheme which improves upon the performance of the 4-antenna schemes proposed in [1]. The scheme introduces a unitary transformation prior to space-time block coding. The transformation is taken from a finite predetermined set of matrices and changes upon retransmission request. It is demonstrated that with a simple set of unitary matrices, the scheme provides 5dB and 1.7dB gain for matrix option B and C, respectively.
Purpose	Adoption
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Patent Policy and Procedures	

Enhancement for 4-antenna soft packet combining scheme using unitary transformation

Eko Onggosanusi, Anand Dabak, and Muhammad Ikram

1. Introduction

In [1], efficient MIMO soft packet combining schemes based on Alamouti space-time block code (STBC) were proposed for systems with 2 and 4 transmit antennas.

In this contribution, we present a soft packet combining scheme which improves upon the performance of the 4-antenna schemes proposed in [1]. The scheme introduces a unitary transformation prior to space-time block coding. The transformation is taken from a finite predetermined set of matrices and changes upon retransmission request. It is demonstrated that with a simple set of unitary matrices, the scheme provides 5dB and 1.7dB gain for matrix option B and C, respectively.

2. The current STBC-based 4-antenna HARQ scheme

STBC-based MIMO HARQ scheme was proposed by Nortel in [1]. The scheme maximally exploits retransmission diversity gain for systems with 2 transmit antennas. For 4-antenna systems, two STBC blocks are used as described below in Figs. 1 and 2 (for matrix option B and C):

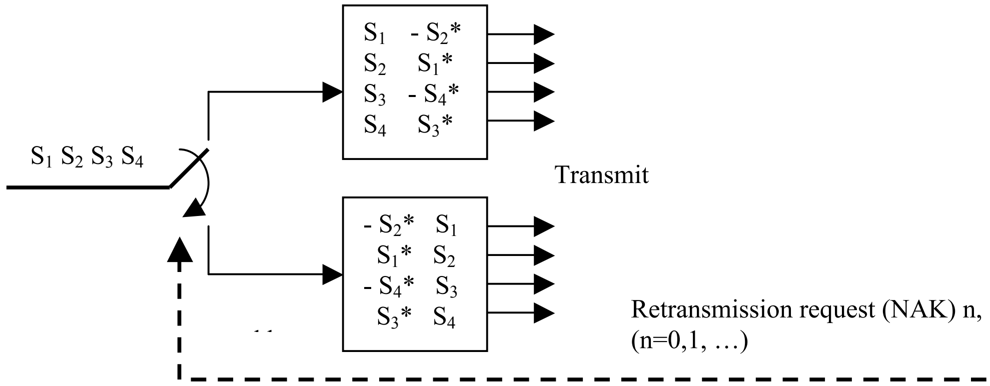

Figure 1: Current 4-antenna HARQ: matrix option B

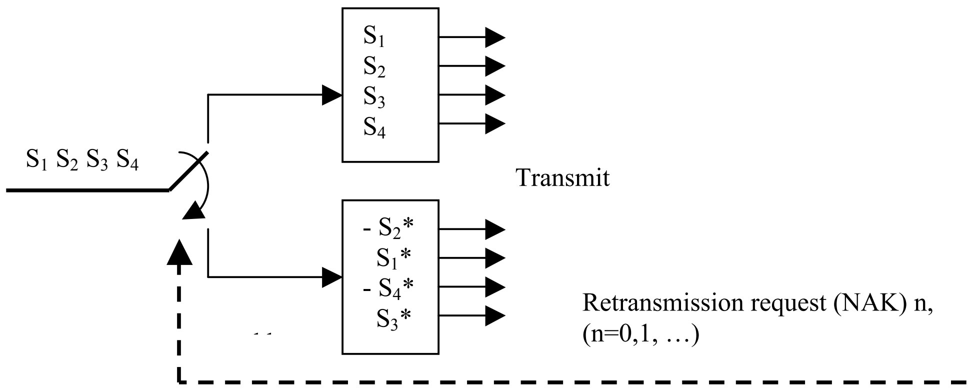

Figure 2: Current 4-antenna HARQ: matrix option C

3. The proposed 4-antenna HARQ scheme

We propose to introduce unitary transformation prior to space-time block coding. The schemes for matrix option B and C are depicted in Figs. 3-4. The 4x4 unitary transformation **V** is taken from a finite predetermined set of matrices $\boldsymbol{S} = \{\mathbf{V}_0, \mathbf{V}_1, \ldots, \mathbf{V}_{N-1}\}$. Upon retransmission request (NAK) n (n=0,1, …), different matrix is chosen from the set S. Given a certain ordering of the set elements, a certain matrix "hopping" pattern (choice of matrix index for the n-th NAK) can be chosen. While the ordering and hopping patterns are arbitrary, we can choose a certain set ordering and a simple hopping pattern. We propose the following simple hopping pattern for option B and C:

$$\begin{aligned}&\text{Option B:}\\&IDX(n) = \mathrm{mod}(n,N), \quad n = 0,1,\ldots\\&\text{Option C:}\\&IDX(n) = \mathrm{mod}\left(\left\lfloor \frac{n}{2} \right\rfloor, N\right), \quad n = 0,1,\ldots\end{aligned} \quad \ldots (1)$$

Notice that the transformation changes upon every NAK for option B. For option C, the transformation is changed every other NAK since it takes 2 transmissions to form a complete STBC codeword.

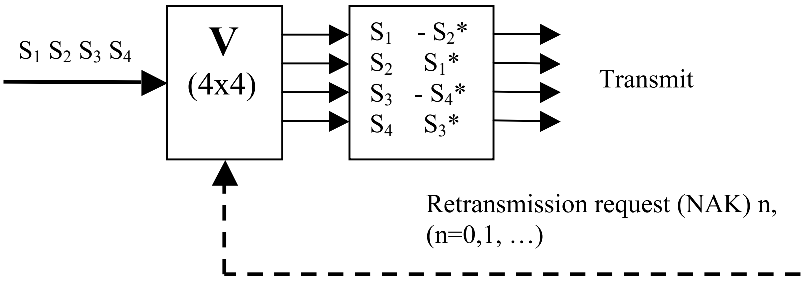

Figure 3: Proposed 4-antenna HARQ: matrix option B

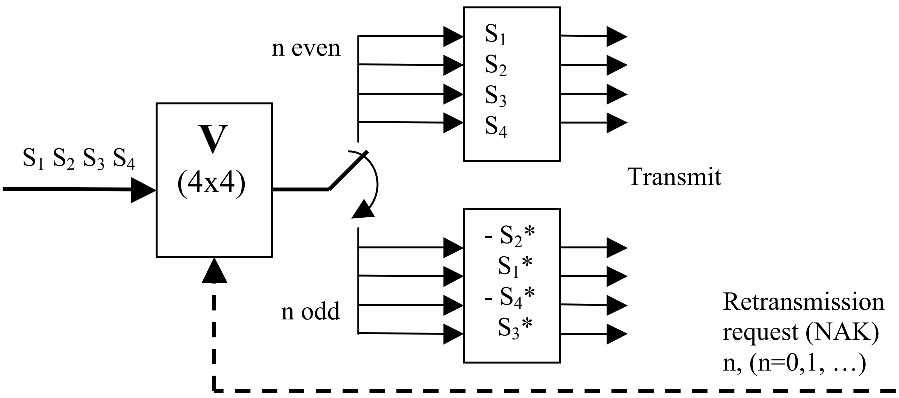

Figure 4: Proposed 4-antenna HARQ: matrix option C

The receiver operation at the n-th soft combining stage can be explained as follows. Let $\mathbf{r}(n)$ denote the Q-dimensional received signal vector associated with the n-th **re**transmission (n=0 indicates the first transmission), where Q is the number of receive antennas. Also, $\mathbf{h}_p(n)$ denotes the channel vector associated with n-th retransmission and p-th transmit antenna. $\mathbf{V}(n)=\mathbf{V}_{IDX(n)}$ is the transformation chosen upon the n-th retransmission. For option C, the composite received signal vector can be written as follows for n=1:

$$\mathbf{r} = \begin{bmatrix} \mathbf{r}(0) \\ \mathbf{r}(1)^* \end{bmatrix} = \begin{bmatrix} [\mathbf{h}_1(0) \quad \mathbf{h}_2(0) \quad \mathbf{h}_3(0) \quad \mathbf{h}_4(0)]\mathbf{V}(0) \\ [\mathbf{h}_2(1)^* \quad -\mathbf{h}_1(1)^* \quad \mathbf{h}_4(1)^* \quad -\mathbf{h}_3(1)^*]\mathbf{V}(1) \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} + \mathbf{w} \qquad \ldots (2)$$

And for n=2:

$$\mathbf{r} = \begin{bmatrix} \mathbf{r}(0) \\ \mathbf{r}(1)^* \\ \mathbf{r}(2) \end{bmatrix} = \begin{bmatrix} [\mathbf{h}_1(0) \quad \mathbf{h}_2(0) \quad \mathbf{h}_3(0) \quad \mathbf{h}_4(0)]\mathbf{V}(0) \\ [\mathbf{h}_2(1)^* \quad -\mathbf{h}_1(1)^* \quad \mathbf{h}_4(1)^* \quad -\mathbf{h}_3(1)^*]\mathbf{V}(1) \\ [\mathbf{h}_1(2) \quad \mathbf{h}_2(2) \quad \mathbf{h}_3(2) \quad \mathbf{h}_4(2)]\mathbf{V}(2) \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} + \mathbf{w} \qquad \ldots (3)$$

Extension to arbitrary n is straightforward. From (2-3), different spatial interference resistant MIMO receivers can be used. In this contribution we use linear zero forcing (LZF) receiver as in [1]. For <u>option B</u>, the received signal at the 1st retransmission takes the following form (extension to arbitrary n is straightforward), where i denotes the i-th symbol interval in the STBC codeword:

$$\mathbf{r} = \begin{bmatrix} \mathbf{r}_i(0) \\ \mathbf{r}_{i+1}(0)^* \\ \mathbf{r}_i(1) \\ \mathbf{r}_{i+1}(1)^* \end{bmatrix} = \begin{bmatrix} [\mathbf{h}_1(0) \quad \mathbf{h}_2(0) \quad \mathbf{h}_3(0) \quad \mathbf{h}_4(0)]\mathbf{V}(0) \\ [\mathbf{h}_2(0)^* \quad -\mathbf{h}_1(0)^* \quad \mathbf{h}_4(0)^* \quad -\mathbf{h}_3(0)^*]\mathbf{V}(1) \\ [\mathbf{h}_1(1) \quad \mathbf{h}_2(1) \quad \mathbf{h}_3(1) \quad \mathbf{h}_4(1)]\mathbf{V}(2) \\ [\mathbf{h}_2(1)^* \quad -\mathbf{h}_1(1)^* \quad \mathbf{h}_4(1)^* \quad -\mathbf{h}_3(1)^*]\mathbf{V}(3) \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} + \mathbf{w} \qquad \ldots (4)$$

Again a host of MIMO receivers is available.

For a given set cardinality N, the elements of matrix set $\boldsymbol{S}$ can be chosen to maximize the performance at each soft packet combining stage. While an exhaustive search approach can be done for a given N, we find that the following simple 7-element matrix set provides good performance:

$$\mathbf{V}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_1 = \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \mathbf{V}_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix},$$

$$\mathbf{V}_4 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_5 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \mathbf{V}_6 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix},$$

This set can be extended for larger N. The above set of transformations only involves **shuffling** without any multiplication.

4. Simulation results

To demonstrate the potential gain provided by the proposed shuffling scheme, we simulate the system with minimum number of receive-antennas required for option B and C (2 for option B and 4 for option C). QPSK modulation and linear zero forcing receiver are assumed. Raw bit error rates vs. Eb.N0 are shown in Fig. 5 for option B and 6 for option C. Observe that:

- For option B (4x2), 5dB gain at 1% BER over the scheme in [1] is observed at the 3^{rd} retransmission (4^{th} transmission).

- For option C (4x4), 1.7dB gain at 1% BER over the scheme in [1] is observed at the 7th retransmission (8th transmission).

The additional gain comes from increased spatial interference averaging due to matrix hopping.

5. Proposed Text Changes

[Additional material in Section 8.4.8.9 under table 314b.

---------- Start text proposal ----------

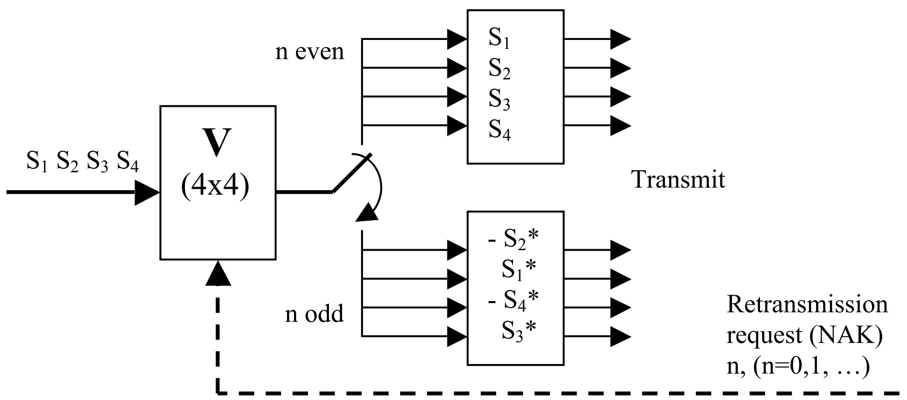

Figure x2: Proposed 4-antenna HARQ: matrix option C

For a given matrix set $\boldsymbol{S} = \{\mathbf{V}_0, \mathbf{V}_1, \ldots, \mathbf{V}_{N-1}\}$, a matrix is chosen from the set upon the n-th retransmission request (NAK). The following selection pattern is used:

:

$$IDX(n) = \mathrm{mod}\left(\left\lfloor \frac{n}{2} \right\rfloor, N\right), \quad n = 0,1,\ldots$$

where the selected matrix is $\mathbf{V}_{IDX(n)}$ and N=7. The following matrix sets are used:

$$\mathbf{V}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_1 = \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \mathbf{V}_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix},$$

$$\mathbf{V}_4 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \mathbf{V}_5 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \mathbf{V}_6 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix},$$

---------- End text proposal ----------

6. References

[1] IEEE C802.16e-04/113r2: Nortel Networks, Soft packet combining for STC retransmission to improve HARQ performance in MIMO mode.

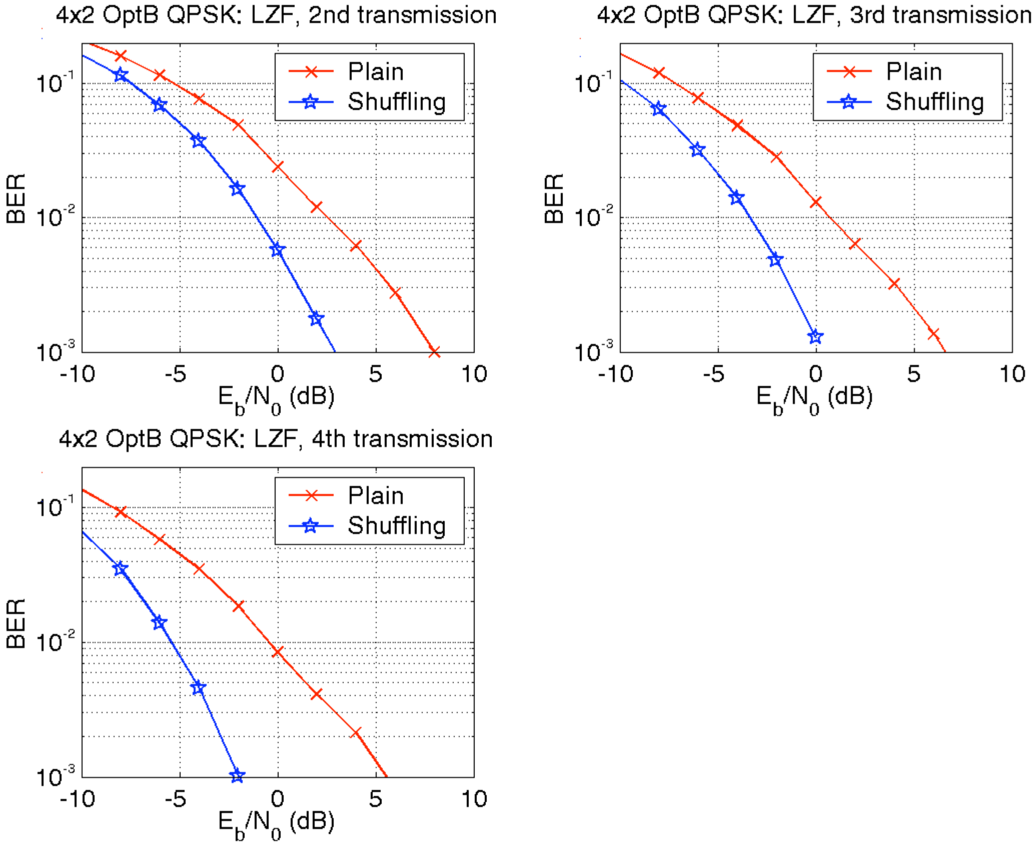

Figure 5: Enhancement of matrix option B: 4 transmit and 2 receive antennas

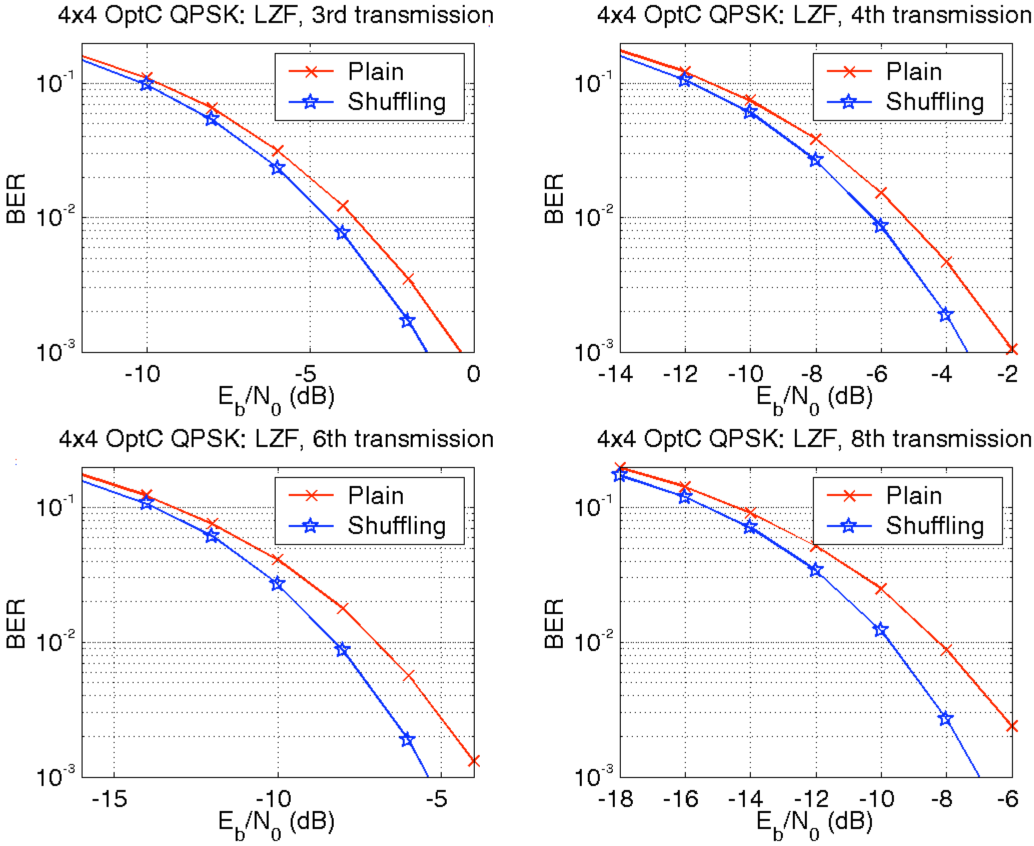

Figure 6: Enhancement of matrix option C: 4 transmit and 4 receive antennas.