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| Project                      | <b>IEEE 802.16 Broadband Wireless Access Working Group</b> < <a href="http://ieee802.org/16">http://ieee802.org/16</a> >   |  |
| Title                        | <b>Rotated Codebooks for Closed-loop MIMO</b>  |  |
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| Re:                          |  |  |
| Abstract                     |  |  |
| Purpose                      | Adoption of proposed changes into P802.16e<br><br><del>Crossed-out indicates deleted text</del> , <u><a href="#">underlined blue indicates new text change to the Standard</a></u>   |  |
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## Rotated Codebooks for Closed-loop MIMO

### 1. Introduction

Four codebooks tabulated in Section 8.4.5.4.11 in D7 standard contain undesirable beamforming vector  $[1 \ 0 \dots 0]^T$ , where the accepted contribution C80216e-05\_50r7 is not reflected yet. This may cause switch on/off problem and power imbalance at transmitter. This problem can be solved by rotating the whole codebooks by constant angles, where the rotation doesn't change the distance property or PER performance. Since all matrix codebooks except the one for 4x2 3 bit are generated from vector codebooks, the consequent matrix codebooks are equivalently rotated by constant angles. Therefore, the consequent codebooks maintain the original distance property and get rid off the undesirable vector  $[1 \ 0 \dots 0]^T$  as a part of the codeword.

### 2. New Vector Codebooks

Let us assume that BS has 4 Tx antennas and MS has 1 Rx antenna. In addition, the system will use 3 bit quantized beamforming mechanism. In this case, BS and MS shall use the  $V(4,1,3)$  as following

Table 2981— $V(4,1,3)$

| Vector index | 1 | 2                            | 3                            | 4                            | 5                            | 6                           | 7                            | 8                            |
|--------------|---|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|------------------------------|------------------------------|
| v1           | 1 | 0.3780                       | 0.3780                       | 0.3780                       | 0.3780                       | 0.3780                      | 0.3780                       | 0.3780                       |
| v2           | 0 | -0.2698 -<br><i>j</i> 0.5668 | -0.7103 +<br><i>j</i> 0.1326 | 0.2830 -<br><i>j</i> 0.0940  | -0.0841 +<br><i>j</i> 0.6478 | 0.5247 +<br><i>j</i> 0.3532 | 0.2058 -<br><i>j</i> 0.1369  | 0.0618 -<br><i>j</i> 0.3332  |
| v3           | 0 | 0.5957 +<br><i>j</i> 0.1578  | -0.2350 -<br><i>j</i> 0.1467 | 0.0702 -<br><i>j</i> 0.8261  | 0.0184 +<br><i>j</i> 0.0490  | 0.4115 +<br><i>j</i> 0.1825 | -0.5211 +<br><i>j</i> 0.0833 | -0.3456 +<br><i>j</i> 0.5029 |
| v4           | 0 | 0.1587 -<br><i>j</i> 0.2411  | 0.1371 +<br><i>j</i> 0.4893  | -0.2801 +<br><i>j</i> 0.0491 | -0.3272 -<br><i>j</i> 0.5662 | 0.2639 +<br><i>j</i> 0.4299 | 0.6136 -<br><i>j</i> 0.3755  | -0.5704 +<br><i>j</i> 0.2113 |

After multiplying the unitary matrix, the codebook would be rotated while the property of the codebook is same.

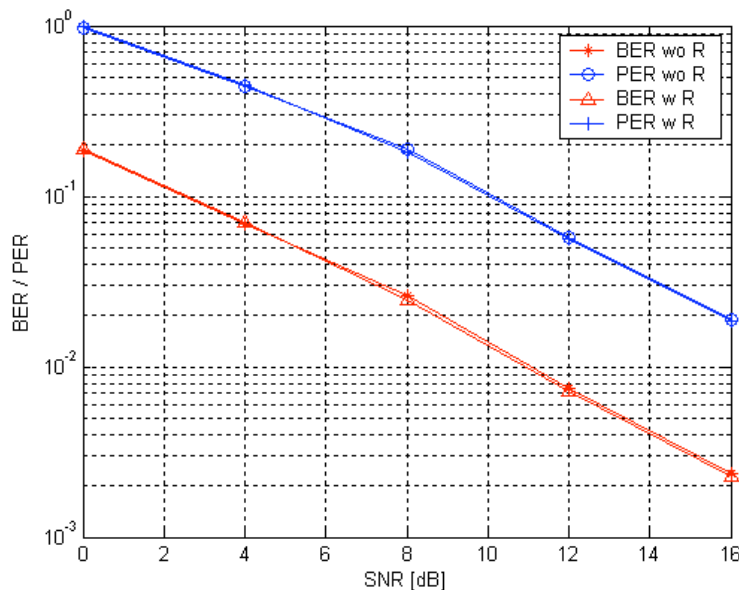


Fig 1. BER/FER Performance for Codebook based CL-MIMO w/o Rotation Matrix R

(Ped A, 3km/h, BandAMC, QPSK, LDPC R=1/2).

Fig. 1 shows the long term BER/FER performance for codebook based closed-loop MIMO system with different vector codebooks mentioned above. As can be seen, there is no performance difference at all. In addition, all transmit antenna will be used for every channel use.

### 3. Specific Text Changes

[Modify the section 8.4.8.3.4.1 as follows]

#### 8.4.5.4.11 MIMO feedback for transmit beamforming

Table 298j— $V(2,1,3)$

| Vector index | 1 | 2                    | 3                   | 4                    | 5                   | 6                   | 7                   | 8                    |
|--------------|---|----------------------|---------------------|----------------------|---------------------|---------------------|---------------------|----------------------|
| v1           | 1 | 0.7940               | 0.7940              | 0.7941               | 0.7941              | 0.3289              | 0.5112              | 0.3289               |
| v2           | 0 | -0.5801 +<br>j0.1818 | 0.0576 +<br>j0.6051 | -0.2978 -<br>j0.5298 | 0.6038 +<br>j0.0689 | 0.6614 +<br>j0.6740 | 0.4754 -<br>j0.7160 | -0.8779 -<br>j0.3481 |

| Vector Index | 1      | 2                   | 3                   | 4                   | 5                   | 6                   | 7                    | 8                    |
|--------------|--------|---------------------|---------------------|---------------------|---------------------|---------------------|----------------------|----------------------|
| v1           | 0.7071 | 0.1805 -<br>j0.1991 | 0.2877 +<br>j0.3313 | 0.6775 -<br>j0.4138 | 0.8290 +<br>j0.3363 | 0.2263 +<br>j0.6677 | 0.9572 -<br>j0.1203  | -0.0323 -<br>j0.6130 |
| v2           | 0.7071 | 0.9424 +<br>j0.1991 | 0.8353 -<br>j0.3313 | 0.4455 +<br>j0.4138 | 0.2941 -<br>j0.3363 | 0.2389 -<br>j0.6677 | -0.2342 +<br>j0.1203 | 0.4975 +<br>j0.6130  |

Table 298k— $V(3,1,3)$

| Vector index | 1 | 2                    | 3                    | 4                    | 5                    | 6                   | 7                   | 8                    |
|--------------|---|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|----------------------|
| v1           | 1 | 0.500                | 0.500                | 0.500                | 0.500                | 0.4954              | 0.500               | 0.500                |
| v2           | 0 | -0.7201 -<br>j0.3126 | -0.0659 +<br>j0.1371 | -0.0063 +<br>j0.6527 | 0.7171 +<br>j0.3202  | 0.4819 -<br>j0.4517 | 0.0686 -<br>j0.1386 | -0.0054 -<br>j0.6540 |
| v3           | 0 | 0.2483 -<br>j0.2684  | -0.6283 -<br>j0.5763 | 0.4621 -<br>j0.3321  | -0.2533 +<br>j0.2626 | 0.2963 -<br>j0.4801 | 0.6200 +<br>j0.5845 | -0.4566 +<br>j0.3374 |

| Vector Index | 1      | 2                    | 3                    | 4                    | 5                    | 6                   | 7                    | 8                    |
|--------------|--------|----------------------|----------------------|----------------------|----------------------|---------------------|----------------------|----------------------|
| v1           | 0.5774 | 0.3509 -<br>j0.2815  | 0.4444 +<br>j0.3855  | -0.3981 +<br>j0.0199 | 0.2240 +<br>j0.2832  | 0.2389 +<br>j0.5213 | 0.1397 -<br>j0.3867  | 0.9754 -<br>j0.0304  |
| v2           | 0.5774 | 0.6687 +<br>j0.5198  | 0.6334 -<br>j0.4512  | 0.7689 -<br>j0.0569  | -0.0844 -<br>j0.5255 | 0.2079 +<br>j0.1413 | -0.0633 +<br>j0.4470 | -0.1892 +<br>j0.0655 |
| v3           | 0.5774 | -0.1535 -<br>j0.2383 | -0.2118 +<br>j0.0657 | 0.4953 +<br>j0.0370  | 0.7264 +<br>j0.2423  | 0.4111 -<br>j0.6625 | 0.7897 -<br>j0.0603  | 0.0799 -<br>j0.0351  |

Table 2981— $V(4,1,3)$ 

| Vector index | 1 | 2                    | 3                    | 4                    | 5                    | 6                   | 7                    | 8                    |
|--------------|---|----------------------|----------------------|----------------------|----------------------|---------------------|----------------------|----------------------|
| v1           | 1 | 0.3780               | 0.3780               | 0.3780               | 0.3780               | 0.3780              | 0.3780               | 0.3780               |
| v2           | 0 | -0.2698 -<br>j0.5668 | -0.7103 +<br>j0.1326 | 0.2830 -<br>j0.0940  | -0.0841 +<br>j0.6478 | 0.5247 +<br>j0.3532 | 0.2058 -<br>j0.1369  | 0.0618 -<br>j0.3332  |
| v3           | 0 | 0.5957 +<br>j0.1578  | -0.2350 -<br>j0.1467 | 0.0702 -<br>j0.8261  | 0.0184 +<br>j0.0490  | 0.4115 +<br>j0.1825 | -0.5211 +<br>j0.0833 | -0.3456 +<br>j0.5029 |
| v4           | 0 | 0.1587 -<br>j0.2411  | 0.1371 +<br>j0.4893  | -0.2801 +<br>j0.0491 | -0.3272 -<br>j0.5662 | 0.2639 +<br>j0.4299 | 0.6136 -<br>j0.3755  | -0.5704 +<br>j0.2113 |

Table 2981  $V(4,1,3)$ 

| Vector index | 1                    | 2                    | 3                    | 4                   | 5                    | 6                   | 7                    | 8                    |
|--------------|----------------------|----------------------|----------------------|---------------------|----------------------|---------------------|----------------------|----------------------|
| $v_1$        | 0.5346               | 0.4603               | 0.5345               | 0.4279              | 0.5387               | 0.5479              | 0.5097               | 0.4230               |
| $v_2$        | 0.4316 +<br>j0.3108  | -0.2440 -<br>j0.4767 | -0.2394 +<br>j0.4778 | 0.0870 +<br>j0.4841 | -0.2739 -<br>j0.3764 | 0.0996 -<br>j0.4084 | 0.0587 +<br>j0.4709  | 0.0841 -<br>j0.5299  |
| $v_3$        | 0.4746 +<br>j0.1022  | 0.3826 +<br>j0.2501  | -0.2335 -<br>j0.4471 | 0.3406 -<br>j0.4375 | -0.4348 -<br>j0.1340 | 0.2573 +<br>j0.4087 | -0.3524 +<br>j0.4280 | -0.4104 -<br>j0.2759 |
| $v_4$        | -0.4406 +<br>j0.0383 | -0.3834 -<br>j0.3814 | -0.3221 -<br>j0.2655 | 0.4693 +<br>j0.2177 | 0.4529 -<br>j0.2845  | 0.2591 +<br>j0.4720 | 0.4397 +<br>j0.1201  | -0.5306 +<br>j0.0851 |

Table 298p—3-bit 4x2 code-book V(4,2,3)

| Matrix index | Column1                     | Column2                     | Matrix index | Column1                     | Column2                     |
|--------------|-----------------------------|-----------------------------|--------------|-----------------------------|-----------------------------|
| 0b000        | 1                           | 0                           | 0b100        | 0.1918 - j0.0472            | -0.3651 - j0.0228           |
|              | 0                           | 1                           |              | -0.3047 + j0.1116           | 0.0237 + j0.7606            |
|              | 0                           | 0                           |              | -0.7347 - j0.2076           | 0.1887 + j0.0124            |
|              | 0                           | 0                           |              | 0.1028 + j0.5121            | -0.3741 + j0.3338           |
| 0b001        | -0.2654 + j0.2992           | -0.5775 - j0.1061           | 0b101        | 0.5901 + j0.1973            | -0.0758 - j0.0492           |
|              | -0.1726 - j0.1816           | -0.4013 - j0.3587           |              | -0.2801 - j0.2880           | 0.3914 + j0.3838            |
|              | -0.3061 - j0.0744           | 0.4080 + j0.4140            |              | 0.1873 - j0.1430            | -0.1034 - j0.7246           |
|              | <del>0.4903 + j0.6616</del> | <del>0.1638 - j0.0302</del> |              | <del>0.1643 - j0.6074</del> | <del>0.2232 - j0.2250</del> |
| 0b010        | 0.0757 - j0.3932            | -0.4334 - j0.3347           | 0b110        | -0.382 + j0.5649            | -0.2255 - j0.0721           |
|              | -0.4725 - j0.3610           | 0.1349 + j0.1587            |              | -0.4605 - j0.2626           | 0.1865 + j0.1422            |
|              | -0.0623 - j0.0840           | -0.0411 - j0.7644           |              | -0.1984 - j0.0946           | -0.8401 + j0.4105           |
|              | 0.4387 + j0.5317            | -0.2402 + j0.1144           |              | -0.159 - j0.4246            | 0.0852 + j0.0860            |
| 0b011        | -0.4279 + j0.1357           | -0.2098 + j0.1569           | 0b111        | 0.6863 + j0.1884            | -0.3818 - j0.1527           |
|              | -0.6872 + j0.0817           | -0.2829 + j0.1676           |              | -0.2705 - j0.2542           | 0.1367 - j0.1581            |
|              | -0.4579 - j0.1706           | 0.4212 + j0.3038            |              | -0.1384 - j0.2577           | 0.4864 - j0.0528            |
|              | 0.2782 + j0.0583            | -0.3991 + j0.6279           |              | 0.1499 + j0.4976            | 0.5162 + j0.5304            |

Table 298p V(4,2,3)

| Matrix index | Column 1          | Column 2          | Matrix index | Column 1          | Column 2          |
|--------------|-------------------|-------------------|--------------|-------------------|-------------------|
| 0b000        | -0.2708 + j0.8679 | -0.0944 + j0.0112 | 0b100        | 0.0751 - j0.1422  | 0.1846 - j0.4631  |
|              | -0.0600 - j0.1530 | 0.2193 - j0.3085  |              | 0.0938 - j0.4576  | 0.1671 + j0.4407  |
|              | -0.0516 - j0.2875 | 0.1492 + j0.5635  |              | -0.3732 - j0.7764 | -0.1388 + j0.0367 |
|              | 0.1353 + j0.2069  | 0.7124 + j0.0194  |              | 0.0469 + j0.1080  | 0.1857 + j0.6886  |
| 0b001        | -0.0073 - j0.5940 | 0.1045 - j0.3673  | 0b101        | -0.3026 + j0.7382 | 0.1155 + j0.0479  |
|              | -0.1109 - j0.1173 | -0.4875 + j0.5234 |              | 0.0382 - j0.0432  | 0.9120 - j0.1901  |
|              | 0.3992 - j0.6292  | 0.0392 + j0.1304  |              | 0.1598 + j0.0426  | -0.2180 + j0.2586 |

|       |                      |                      |       |  |                      |                      |
|-------|----------------------|----------------------|-------|--|----------------------|----------------------|
|       | 0.1580 +<br>j0.2021  | -0.2646 -<br>j0.5040 |       |  | -0.5367 -<br>j0.2115 | 0.0423 - j0.0150     |
| 0b010 | 0.2297 +<br>j0.0535  | 0.6464 -<br>j0.2850  | 0b110 |  | -0.2263 -<br>j0.3800 | 0.0557 - j0.4473     |
|       | -0.1360 +<br>j0.1466 | 0.6718 +<br>j0.0154  |       |  | -0.0183 -<br>j0.1668 | -0.3082 -<br>j0.6856 |
|       | -0.3051 -<br>j0.6848 | 0.1863 -<br>j0.0591  |       |  | 0.3656 -<br>j0.0189  | -0.4433 +<br>j0.0438 |
|       | 0.0929 -<br>j0.5777  | 0.0853 +<br>j0.0616  |       |  | -0.7961 -<br>j0.0918 | 0.1289 +<br>j0.1294  |
| 0b011 | 0.0564 -<br>j0.5185  | -0.0774 -<br>j0.3896 | 0b111 |  | -0.3209 +<br>j0.4112 | 0.0016 - j0.2893     |
|       | 0.1022 -<br>j0.1047  | -0.3252 +<br>j0.6537 |       |  | 0.0833 -<br>j0.1153  | 0.1442 +<br>j0.5480  |
|       | -0.3537 -<br>j0.4371 | 0.1804 -<br>j0.3426  |       |  | 0.0177 -<br>j0.8201  | -0.1520 -<br>j0.0435 |
|       | -0.6013 -<br>j0.1697 | 0.2059 +<br>j0.3420  |       |  | 0.1439 -<br>j0.1184  | 0.4718 - j0.5896     |

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*End text proposal*

### References:

[1] IEEE P802.16-REVd/D7-2004 Draft IEEE Standards for local and metropolitan area networks part 16: Air interface for fixed broadband wireless access systems