Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Way Forward on Precoding Codebook for SU-MIMO**
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Re:	Call for comments and contributions on Project 802.16m SDD (IEEE C80216m-08_040)
Abstract	Proposal for SU-MIMO codebook properties and evaluation
Purpose	To discuss and adopt the proposal into the IEEE 802.16m SDD (IEEE C80216m-08_003r4)
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Way forward on Precoding Codebook for SU-MIMO codebooks

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Introduction

In prior contributions [1-7], precoding codebooks for SU-MIMO are proposed. It is noted that different proposals have common understanding about some features and required properties of the codebook. However, different codebooks are suggested and evaluated. The evaluation of the proposed codebooks in earlier work has been performed for different scenarios. Due to different performance of the codebooks in different scenarios, some proposals suggest the use of multiple codebooks [1,6]. It is also noted that the new scenario for 8 transmit antenna at the BS is provisioned in 802.16m which does not exist in prior 16 standards. Therefore, the prior codebook such as 802.16e codebook does not handle this case. Also, different codebooks, e.g, DFT codebook or 802.16e codebook show different performance under different correlation scenarios. For example, in [3] it is mentioned that “16e codebooks have been optimized exclusively for uncorrelated scenarios and the performance loss in other scenarios (correlated antennas, dual-polarized antennas) is quite severe.”

In this contribution, we propose a common framework for selection of the precoding codebook. First, we propose to specify the particular scenarios of interest for evaluation of the codebooks. In particular, the antenna configuration, antenna type, space and time correlation and channel model has to be defined. There might be a need to specify several scenarios of interest for a given number of antennas at the BS. The evaluation of all proposed codebook should then be performed for the same set of scenarios before the final decision is made.

Second, we propose a set of properties that are desirable for the codebook. The same properties are considered by different companies earlier, ,e.g., see []. Therefore, it is suggested to agree on the properties of the codebook and then select the codebook.

Once the codebook properties and evaluation scenarios are agreed, the proposed codebooks can be evaluated and selected based on the set criteria.

Codebook Properties

It is suggested that the codebook(s) for 8, 4, and 2 transmit antennas at BS should be designed based on the following properties. The codebook for each antenna configuration, i.e., 8, 4, and 2 is designed separately. The codebook sizes (number of feedback bit per precoder) has to be decided. The codebook for different feedback sizes may be designed separately or the smaller size codebooks could be selected from the larger codebook. Suggested codebook properties for a given codebook size and number of transmit antennas are as follows:

1- **Performance:** It is trivial that the overall throughput performance of a precoding scheme depends on the codebook, and it is the primary measure to select a codebook.

2- **Complexity:** The complexity of precoder selection is a limiting factor for MS due to its limited computational power. It is suggested to reduce the complexity by two means:

   a. The algorithmic complexity may be reduced by imposing appropriate structure to the codebook without sacrificing much of the performance, e.g., using house-holder transformation. Therefore, it is proposed to use a codebook structure which allows for precoder selection with lower computational complexity

   b. The computational complexity can be further reduced, by minimizing the number of multiplication required to select a precoder. It is proposed to use the codebook that can avoid or minimize the number of multiplications for example by using the elements in the form of ±1, ±j, ±1±j, ±2 ±j, … . Please note that multiplication by $\pm 2^{a} \pm 2^{b} j$, for any integer values a and b, can be done only by shifting and summation.

3- **Constant modulus (CM) property:** Due to the limitation of power amplifiers (PA), e.g., one PA per antenna, the codebook should have CM property. Otherwise, the codebook with high PAPR will considerably lose in performance in comparison to the codebook designed with this property.

4- **Nested codebook structure:** It is desirable to have nested codebooks for lower ranks. This allows for simple allocation of MCS if BS requires overriding the requested precoding rank by a MS. The nested structure means that any precoder in the codebook of a lower rank is obtained by eliminating the columns of a precoder in the codebook of higher rank.

5- **Low memory requirement:** it is desirable to avoid unnecessary large memory to store the codebook. Smaller codebook sizes reduce the feedback. Also, the codebooks which can be stored efficiently are more desirable. For example, a nested codebook structure also helps in reducing the memory requirement.

It should also be noted that after the users are selected by BS, the precoders that are going to be used for the transmission have to be reconfirmed by the BS. Such reconfirmation is required in both SU- and MU-MIMO scheme to allow accurate demodulation. For example, in the case that the error in feedback link occurs, the precoder index used by the BS will be different from the one that is fed back by a MS. Also, if a nested codebook structure is used, the BS might do the rank override and send the index of the new precoder to MS.

In conclusion, we have the following text proposal.

References

[1] Introduction of Multiple Codebooks to the 16m System, LGE, IEEE C802.16m-08/862.

[2] Differential codebook for closed loop SU MIMO, Samsung, IEEE C802.16m-08/851r1.

[3] Structure of SU- and MU-MIMO codebooks, Samsung, IEEE C802.16m-08/851r1.

[4] Proposal for a 4-antenna codebook, Nextwave, IEEE C802.16m-08/916.

[5] Differential codebook for closed loop SU and MU MIMO, Samsung, NEC, LGE, Nortel, Nextwave, Intel, Huawei, IEEE C802.16m-08/947r4.

[6] Codebook issues in 802.16m CL-SU-MIMO., LGE, IEEE C802.16m-08/983.

[7] Evaluation of Codebook and Differential Feedback for DL Closed-Loop SU-MIMO, Nortel, IEEE C802.16m-08/1074r1.

[7] Performance Comparison on the Different Codebook for SU/MU MIMO, Intel, C802.16m-08/1183r1.

Proposed Text

Replace the following text from 11.8.2.1.2.1 Precoding technique section of the (IEEE 802.16m 08/003r5), page 83, line 2:

```
------------------------------------ Text Start ----------------------------------------
"For codebook based precoding, the codebook will be a .16e based and/or DFT-based
codebook"
------------------------------------- Text End -----------------------------------------
```

by the following text:

```
------------------------------------ Text Start ----------------------------------------
 "For codebook based precoding, the codebook will be selected with overall best
performance, and with the lowest complexity. The codebook should have constant modulus
property and the nested structure. Constant modulus refers to equal gain transmission from
each antennas and nested structure means that any precoder in the codebook of a lower rank
are obtained by eliminating the columns of a precoder in the codebook of higher rank."
------------------------------------- Text End -----------------------------------------
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Insert a new section 11.8.2.1.4 in page 83 of the (IEEE 802.16m 08/003r5):

```
------------------------------------ Text Start ----------------------------------------
 "11.8.2.1.4 Feedforward for SU-MIMO
 The selected precoders that is used for the transmission will be signalled by BS to MS."
------------------------------------- Text End -----------------------------------------
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Insert a new section 11.8.2.2.4 in page 85 of the (IEEE 802.16m 08/003r5):

```
------------------------------------ Text Start ----------------------------------------
 "11.8.2.2.4 Feedforward for MU-MIMO
 The selected precoders that is used for the transmission to plurality of users will be
signalled by BS to all users in the plurality."
------------------------------------- Text End -----------------------------------------
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