

Agenda Item: 7.10.2
Source: Philips
Title: Suitable size of precoding codebook at eNodeB for MU-MIMO
Document for: Discussion

1. Introduction

In this contribution we address the issue of the size of the codebook for precoding matrices at the eNode B for MU-MIMO operation, when the transmitter has the freedom of constructing a zero-forcing (ZF) precoding matrix out of the PMI (precoding matrix indicator) and CQI (channel quality indicator) fed back by the terminals.

Let $N_q = LM$ be the size of the codebook used for the PMI feedback, in numbers of vectors, where L is the number of unitary matrices in the codebook and M is the maximum number of spatial layers, then the number N_p of possible different ZF precoding matrices equals

$$N_p = \sum_{i=1}^M \binom{N_q}{i}. \quad (1)$$

As an example, if $N_q = 16$, then $N_p = 136$ for $M = 2$, and $N_p = 2516$ for $M = 4$. This shows that the eNode B codebook needs to be large.

In practice, though, the scheduler at the transmitter tries to allocate users which cause minimal interference to one another, and therefore the selected users are likely to be the ones which have reported PMI vectors with small cross-correlation values. In the case where all the selected users have orthogonal PMI's the ZF precoding matrix boils down to a unitary matrix.

As a consequence, one natural way of reducing the size (1) of the codebook at the eNode B, is that of excluding the combinations of reported PMI's with high cross-correlation, which are very unlikely to be selected. Hereafter, we present simulation results showing histograms of the correlation values between couples of PMI vectors reported by the users selected for transmission.

2. Numerical results.

The histograms of the correlation values between pairs of selected users have been obtained by averaging over different SNR's ranging from -5 to 30 dB. The distribution of these values has been drawn for different transmission ranks, from 1 up to M spatial layers, M being the number of transmit antennae. The main simulation parameters are listed in Table I.

The histograms in Fig. 1 and 2 shows that pairs of vectors with high correlation ($\gtrsim 0.7$) are almost never selected in practice.

One way of reducing the number of possible precoders would be by pruning the eNode B codebook in such a way that, in the set of selected users, only pairs of users with reported PMI's having certain correlation values can occur. This operation, however, is not straightforward as we need to list all the possible matrices in the codebook and exclude those with unwanted pairs of vectors.

However, if precoded pilots are provided such a pruning operation would not be required as the eNode B precoding codebook size has no effect on the signalling operation.

Another possibility would be to signal a quantised version of the selected precoding vectors but the performance of such a scheme needs to be verified.

Number of tx antennae	2,4
Number of rx antennae	1,2
Tx antenna spacing	0.5λ
Type of tx precoding	zero-forcing (ZF)
Type of rx beamforming	minimum quantisation error (MQE)
Number of users	20
Terminal speed	3 km/h
Transmission bandwidth	5 MHz
Centre frequency	2 GHz
DFT size	512
Feedback codebook type	DFT
Feedback codebook size	4 bits
Channel model	SCM Urban Micro
Number of paths	10
Subframe time	1 ms
Number of subcarriers per RB	12
Feedback granularity	1 per RB
Delay between feedback and data detection	1.5 ms (3 time slots)
Modulation schemes	QPSK, 16QAM, 64QAM
Turbo coding rates	1/3,1/2,2/3,3/4,4/5
Target FER	10%

TABLE I
LINK-LEVEL SIMULATION PARAMETERS.

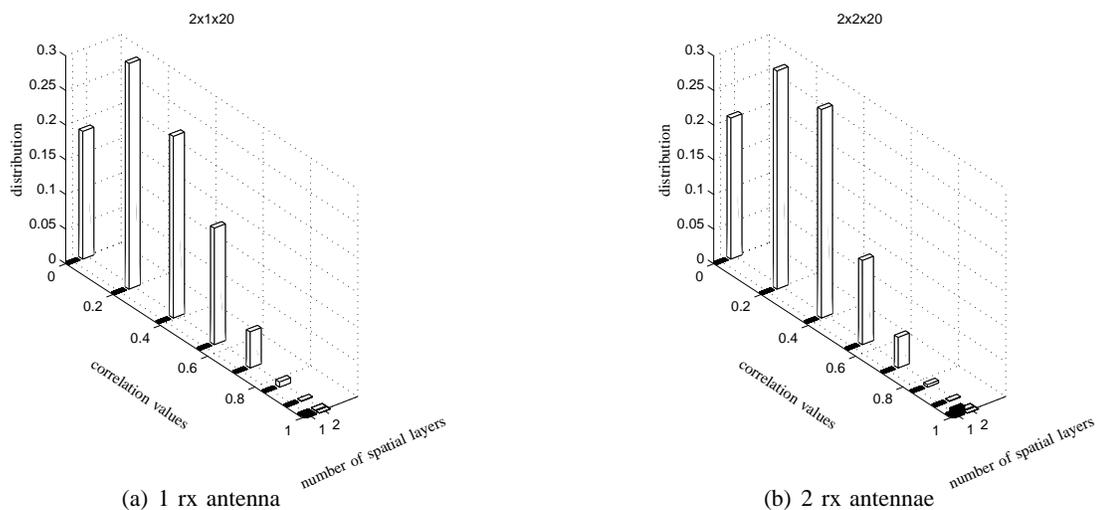


Fig. 1. Histograms of the correlation values between pairs of PMI vectors reported by the users selected for transmission. The values of the bars are normalised such that their sum equals one. 2 tx antennae and different number of rx antennae.

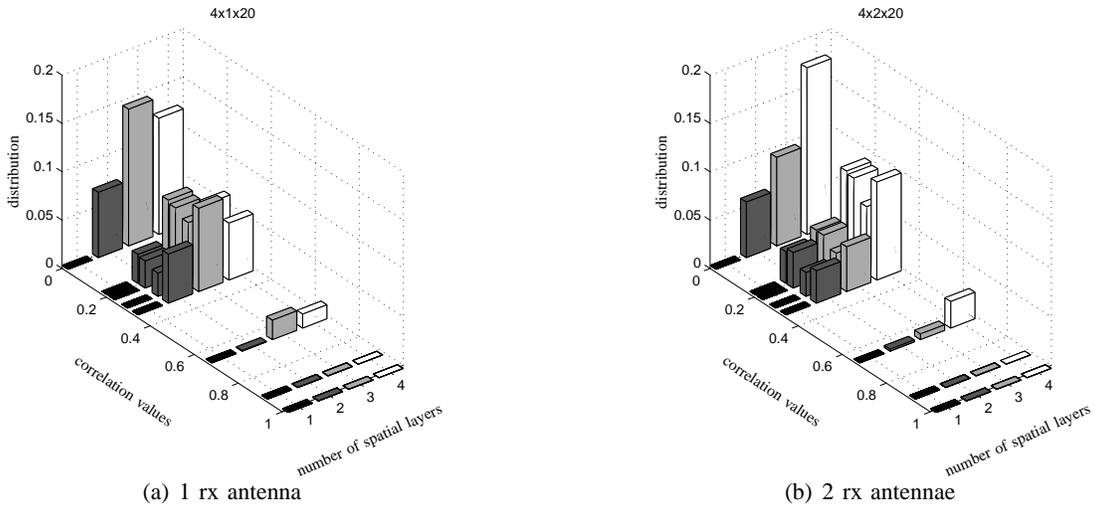


Fig. 2. Histograms of the correlation values between pairs of PMI vectors reported by the users selected for transmission. The values of the bars are normalised such that their sum equals one. 4 tx antennae and different number of rx antennae.

3. Conclusion.

In this contribution we showed that if no pruning is used, the eNode B codebook size potentially needs to be very large.

We presented some simulation results (using ZF precoding at the transmitter) showing the distribution of the correlation values between pairs of PMI vectors reported by users selected for transmission. These results show that pairs with low correlation values are the most likely to be selected. This indication can be used to prune the eNode B codebook in order to reduce the number of possible precoding matrices that need to be signalled to the terminals.

A more desirable solution, however, would be to provide precoded pilots as this method of signalling the precoding weights, among other advantages, is insensitive to the eNode B codebook size.

Another possibility would be to signal a quantised version of the used precoding vectors; the performance of such a scheme would need to be verified.