3GPP TSG RAN WG 1 ***TSGR1#15 R1-00-1126***
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Agenda Item:

Source: Siemens

Title: Text proposal for RAN WG1 report on Tx diversity solutions for multiple antennas

Document for: Discussion and approval

Summary:

With this paper we contribute a text proposal to the technical report of Tx diversity for multiple antennas. The contents is based on the eigenbeamformer concept as presented at the WG 1 meeting #14.

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Technical Report

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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

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Version x.y.z

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- x the first digit:
  - 1 presented to TSG for information;
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- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[<seq>] <doctype> <#>[([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

[1] 3G TS 25.123: "Example 1, using sequence field".

[2] 3G TR 29.456 (V3.1.0): "Example 2, using fixed text".

[3] Siemens. Advanced closed loop Tx diversity concept (eigenbeamformer). TSG-R WG 1 document, TSGR1#14(00)0853, 4-7th, July, 2000, Oulu, Finland.

[4] Nokia. Recommended simulation parameters for Tx diversity simulations. TSG-R WG1 document, TSGR1#14(00)0867, 4-7th, July, 2000, Oulu, Finland, 5 pp.

[5] Siemens. Channel model for Tx diversity simulations using correlated antennas. TSG-R WG 1 document, TSGR1#15(00)1067, 22-25th, August, 2000, Berlin, Germany.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.
Definition format

<defined term>*: <definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:
Symbol format

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:
Abbreviation format

<ACRONYM> <Explanation>

4 Background and Introduction

5 Descriptions of studied concepts

5.1 Description of the eigenbeamformer concept

The general idea behind the eigenbeamformer concept, which was presented in [3], is a decorrelation of diversity branches to achieve a reduction in dimension for subsequent short-term processing at the UE which provides an increase in diversity and antenna gain/interference suppression. Moreover, the concept allows to add additional antennas (more than 4) without increasing short-term feedback or decreasing the UE velocity threshold, i.e., the concept is generic with respect to the number of antenna elements.

The concept is based on an eigenanalysis of the long-term spatial covariance matrices of the dominant temporal taps. The covariance matrices will be estimated from the CPICH transmitted by UTRAN. The UE determines the eigenvectors with the largest eigenvalues over all temporal taps and feeds them back to UTRAN as weight vector set. The process of calculating the dominant eigenvectors (eigenbeams) takes place at the same time scale as the physical movement of the UE. The required operations at the UE and the required feedback are distributed over a large number of slots. A higher quantization/resolution of the weight vector as in the Release-99 concepts can be used which results in improvement of the antenna gain.

In addition a short-term selection between the eigenbeams is carried out at the UE to account for fast fading at the UE. Feedback to UTRAN is basically done every slot if the vector set consists of two vectors and every second slot if the vector set consists of four vectors. This short-term selection reduces the velocity threshold of the Tx diversity concept.

For higher velocities the UTRAN has the option to apply STTD coding. The coded signal will be mapped on two dominant eigenbeams instead of antenna elements directly.

To summarize the functions of this concept are listed below.

UE long-term functions:

- UE calculates eigenbeam vector set $W=[w_1, w_2, \ldots, w_{Nbeam}]$
    - Channel estimate h_{ni} of n-th tap and i-th antenna will be calculated from CPICH.
    - UE calculates covariance matrix R_n for each tap.
    - UE calculates eigenvectors w_i (i = 1, ..., N_{beam}) for the N_{beam} largest eigenvalues of all the covariance matrices R_n
- UE transmits W to UTRAN.
    - This will be transmitted within a long-term timescale (e.g. 1, 2 or 3 bits per frame).

UE short-term functions:

- UE selects one eigenvector from the set of N_{beam} eigenvectors.
- UE indicates the selected eigenbeam to the UTRAN (short-term feedback).

UTRAN functions:

- The UTRAN transmits to the dedicated UE using the antenna weights based on the selected eigenbeam from the vector set.
- UTRAN transmits CPICH which is extended to the use of four antennas.

6 Performance

6.1 Link level simulation assumptions

6.1.1 Eigenbeamformer concept

Link level simulation assumptions based on the description in [4] were used. They have been extended according to [5] to take into account partial correlated antenna paths.

6.2 Link level simulation results

6.2.1 Eigenbeamformer concept

Simulations using the modified Ped A.channel model with partial correlated antennas have been done. The result is shown in Figure 1. Error-free feedback has been assumed.

The advantages of this Tx diversity concept when the UE is moving at higher velocity is indicated. This is in line with the principle of the eigenbeamformer concept. Further simulations will be provided in future contributions.

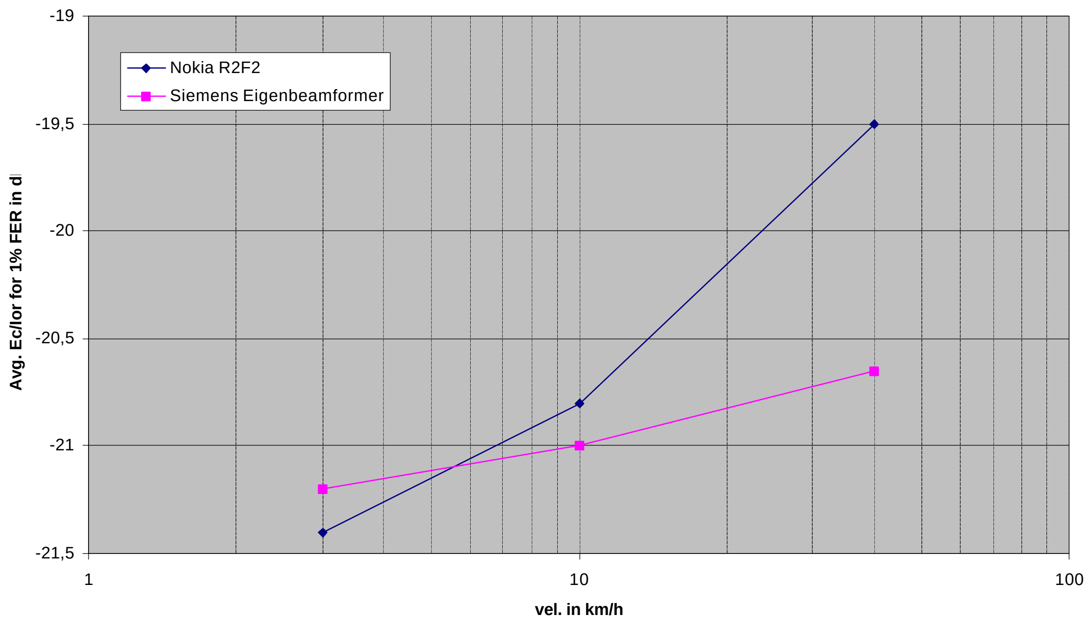

Figure 1: Simulation result for Ped. A channel with partial antenna correlation, geometry 0 dB

7 Impacts to UE and UTRAN implementation

7.1 Impacts to UE implementation

7.1.1 Eigenbeamformer concept

The UE performs a channel estimate over M antennas at N_{tap} dominant temporal taps.

The subsequent UE tasks for the eigenbeamformer are split into long-term (accumulation of covariance matrice and calculation of dominant eigenbeams) and short-term processing.

- Accumulation of long-term spatial covariance matrices (long-term processing)

  It is assumed that the spatial covariance matrix is estimated once per frame and added to the long-term covariance matrix. This is done for all dominant temporal taps. For N_{tap}= 4 and M = 4, we get N_{tap}*M*M = 4*4*4 = 64 complex multiplications, two real multiplications (assuming a forgetting factor), and N_{tap}*M*M = 4*4*4 = 64 complex additions every frame, i.e., 4.3 complex multiplications and 4.3 complex additions per slot.

- Calculation of eigenbeams (long-term processing)

  For the calculation of eigenbeams different techniques can be used. Here, we assume that the complexity approximately equals 4*M*M multiplications (see [3]). Assuming N_{beam} = 4 eigenbeams to be calculated for M = 4 antenna elements yields: N_{beam}*4*M*M = 4*4*4*4 = 256 complex multiplications. If the real and imaginary part of each vector element is quantized with N_{quant} bits, these 4 eigenbeams are described by N_{beam}*M*2*N_{quant} = 4*4*2*4 = 128 bits. If we assume that the (initial) eigenanalysis should not take longer than the retransmission time, this eigenanalysis has to be performed within 128 frames if 1 bit is fed back per frame (long-term). Accordingly, if 3 bits per frame are fed back, it has to be performed within 42 frames. Hence, the average number of complex multiplications per slot is 0.13 or 0.4 respectively. For subsequent updating of the eigenbeams, subspace tracking algorithms can be applied, which significantly reduce the computational effort.

- Eigenbeam selection (short-term processing)

  Assuming that N_{beam} eigenbeams have already been determined by long-term processing, short-term processing is carried out in the following manner: for all N_{beam} eigenbeams the inner product with the spatial channel estimation vector of the corresponding temporal tap is calculated. The eigenbeam is selected which yields the highest inner product (highest SNR). For N_{beam} = 4 and M = 4, we get 16 complex multiplications, 12 complex additions, and 3 comparisons. Hence, required short-term processing power is lower than in Release-99 closed loop Tx diversity mode 2 where (16+8+4+2)/4 = 8 inner products have to be calculated.

In total, we get the following number of complex multiplications per slot for the eigenbeamformer combining short-term and long-term processing/feedback:

4.3 (accumulation of long-term spatial covariance matrices) + 0.13 (0.4) (calculation of eigenbeams) + 16 (eigenbeam selection) = 20.43 (20.7).

This compares quite favourable with Release-99 Tx diversity mode 2 expanded to M = 4 antennas, where 8*M = 32 complex multiplications per slot are required.

7.2 Impacts to UTRAN implementation

7.2.1 Eigenbeamformer concept

Increasing the number of antennas has mainly hardware impacts to the UTRAN implemention. The current assumption is to use 4 antennas at UTRAN. However, the eigenbeamformer concept allows additional antennas to be implemented.

A small memory for storing the current eigenvector set at the UTRAN would be needed.

8 Impacts to physical layer operation

8.1 Eigenbeamformer concept

To calculate the weight vectors at the UE the CPICH needs to be modified. The current modulation scheme of the CPICH could be extended to ensure orthogoality or an additional channelization code could be assigned to the CPICH on antenna 3 and 4.

The procedures for initialization and compressed mode singularities will be defined for the eigenbeamer concept in a straighforward way.

9 Backwards compatibility to Release-99

An appropriate solution for the CPICH on 4 antennas needs to be defined.

9.1 Eigenbeamformer concept

With the eigenbeamformer concept there will be no backward compatibility problem for Release-99.

~~9~~10 Conclusions

History

Document history		
Date	**Version**	**Comment**
	0.0.0	
Editor for 3G TR xx.xxx is:		
Tel. : Fax : Email :		
This document is written in Microsoft Word version.		