TSG-RAN Working Group 1 meeting #14 ***TSGR1#14(00)-0882***
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Agenda item:
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Title: Preliminary version of algorithm and Simulation results for Tx Diversity with more than 2 Tx Antennas
Document for: Discussion

I. Introduction

In TSG RAN WG1 meetings #12 and #13, there have been contributions to closed loop mode Tx diversity with more than 2 Tx antennas [1],[2],[3]. These contributions have shown that the Tx diversity with more than 2 Tx antennas improve performance significantly. In this paper, the algorithm for the contributions [1] is described with simulation results for newly decided simulation environments. The simulation results indicate that there can be significant performance improvement about 3dB at 3km/hr. In addition, the increase of complexity compared to the current 3GPP Mode 2 is shown to be negligible.

II. Tx antenna weights

In closed loop Tx diversity systems, the weights of transmit antennas are determined at a mobile station and fed back to the base station. These weights should result in as high SNR as possible at the mobile. The set of these weights may be viewed as a vector $\underline{w}= [w_1\ w_2\ \ldots w_i \ldots\ w_M]^T$, where w_i is a complex weight associated with the ith Tx antenna. For the maximum SNR at the mobile, the weights should maximize P below:

$$P = \underline{w}^H H^H H \underline{w}, \qquad (1)$$

when $H=[\underline{h}_1\ \underline{h}_2\ \ldots \underline{h}_i \ldots \underline{h}_M]$ and M is the number of Tx antennas. The column vector $\underline{h}_i$ represents an estimated channel impulse response for the ith Tx antenna, and its vector length equals to the number of paths. The weight vector $\underline{w}$ information is periodically fed back to the base station. Note that the amount of feedback information and the implementation complexity increase with the number of Tx antennas. The efficient representation of a weight vector is desired to reduce the amount of feedback data and the implementation complexity. Furthermore, backward compatibility is desirable.

A weight vector with M elements may be represented as a linear sum of basis vectors, which span an M-dimensional space. Examples of basis vectors for 2-, 3-, 4-dimensional spaces are shown in Appendix A. Let's assume for explanation that 4 Tx antennas are used for Tx diversity. The optimal weight vector $\underline{w}_{opt}$ for this system has 4 elements and may be represented as a linear sum of four basis vectors, $\underline{B}_1$, $\underline{B}_2$, $\underline{B}_3$, $\underline{B}_4$, as follows:

$$\underline{w}_{opt} = c_1 \underline{B}_1 + c_2 \underline{B}_2 + c_3 \underline{B}_3 + c_4 \underline{B}_4 \qquad (2)$$

where $c_1,\ldots,c_4$ are complex coefficients associated with corresponding vectors. Assuming that $|c_1|>|c_2|>|c_3|>|c_4|$, we may approximate $\underline{w}_{opt}$ as

$$\underline{w}_{app\_1} \cong c_1 \underline{B}_1, \qquad (3a)$$

$$\underline{w}_{app\_2} \cong c_1 \underline{B}_1 + c_2 \underline{B}_2, \qquad (3b)$$

$$\underline{w}_{app\_3} \cong c_1 \underline{B}_1 + c_2 \underline{B}_2 + c_3 \underline{B}_3, \qquad (3c)$$

These vectors $\underline{w}_{app\_1}$, $\underline{w}_{app\_2}$, $\underline{w}_{app\_3}$, may be viewed as the projections of $\underline{w}_{opt}$ into 1-dim, 2-dim, and 3-dim subspaces. $\underline{w}_{app\_3}$ is more accurate representation of $\underline{w}_{opt}$ than $\underline{w}_{app\_1}$ and $\underline{w}_{app\_2}$.

III. Representation of weight vectors

The conventional representation of the vector $\underline{w}_{opt}$ may require $(M\text{-}1)*N_c$ bits, where N_c bits are required to represent each element of $\underline{w}_{opt}$. This representation indicates that the transmission of $(M\text{-}1)*N_c$ bits at 1500Hz is required to support Tx diversity with M Tx antennas. The reason for $(M\text{-}1)*N_c$ not $M*N_c$ is that one of M Tx antennas may be viewed as reference and the relative weights for other antennas are required. To reduce the required number of bits, we propose to feedback information on the approximated vector, instead of $\underline{w}_{opt}$. The representation of the approximated vector includes the specification of basis vectors and associated coefficients. When there are M Tx antennas and the approximation is made in a S-dimensional subspace, there are ${}_{M}C_{S}$ combinations for selecting S basis vectors among M vectors and the required number of bit to specify the basis vector combination is $\lceil \log_2 ({}_{M}C_{S}) \rceil$.

IV. Simulation Parameters

Name	Value
Target FER	1%

Comparing output	Required Tx E_b/I_{or}(dB) for satisfying target FER
Chip rate	3.84Mcps
Information bit rate	12.2kbps
Modulation	QPSK
Physical channel rate	30ksps
TTI	20 ms
Coding	1/3 Convolutional coding
Power ratio of traffic and pilot	0dB
Ior/Ioc	0dB
Feedback data rate	1500bps
Number of antennas	3GPP: 2 New Scheme: 4
Required number of bits per feedback signaling message	3GPP Mode 2: 4 bits New scheme: Case 1) 5 bits, Case 2) 6bits
Feedback bit error rate	4%
Power control step	1dB
Power control rate	1500Hz
Power control error	4%
Carrier frequency	2GHz
Bit allocation/slot (data1,TPC,TFCI,data2,pilot)	Slot Format #10 (6, 2, 0, 24, 8)
Speed	3, 10, 40, 120 km/hr
Rake channel estimation (WMSA)	4slot (1,4,4,1)
The number of paths per antenna	1

In the simulation, we consider the two cases for antenna selection: **Case 1)** 2 antenna selection (M=4, S=2), and **Case 2)** 3 antenna selection (M=4, S=3). In both cases, 2bit representation for each element (phase only) is used (N_c = 2). The required number of feedback information per signalling word is: **Case 1)** 5 bits, and **Case 2)** 6bits. The considered frame format of feedback information is:

Case 1)

slot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FBI	S_1	S_2	S_3	P_1	P_2	S_1	S_2	S_3	P_1	P_2	S_1	S_2	S_3	P_1	P_2

S_i: Antenna selection bits

P_i: Phase difference with respect to the coefficient associated with the first basis vector

Case 2)

slot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FBI	S_1	S_2	P_{11}	P_{12}	P_{21}	P_{22}	S_1	S_2	P_{11}	P_{12}	P_{21}	P_{22}	S_1	S_2	P_{11}

S_i: Antenna selection bits

P_{ij}: Phase difference with respect to the coefficient associated with the first basis vector

Note that, in Case 2, the signalling word is not aligned within the frame boundary. We do not consider the frame adjustment in the simulation.

V. Simulation Results

Figure 1 shows how the preliminary version of the algorithm performs in terms of required Tx Ec/Ior for 1% FER at various UE speeds for Case 1 and Case 2. We also plot the performance result of current 3GPP Mode 2 scheme for comparison. The performance gain of the proposed scheme over the current 3GPP Mode scheme is 2.8dB for Case 1 and 3.5dB for Case 2 at 3km/h, respectively.

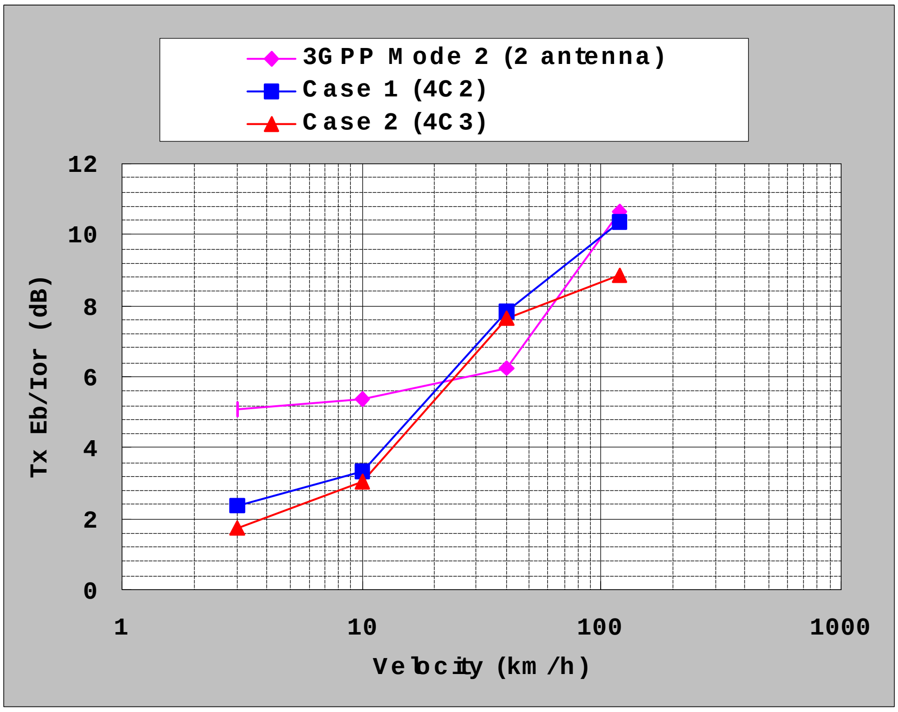

Figure 1. Required Tx Eb/Ior@1% FER of Case 1 ($_4C_2$) and Case 2 ($_4C_3$)

VI. Complexity Issue

In order to obtain feedback weight in UE, it is necessary to perform the matrix operation in Eq. (1). In general, it is known that the searching is one of the efficient methods to calculate the weight for antennas. If the number of antenna is limited by selection, then the complexity of calculation could be reduced.

In detail, the number of multiplication of Eq. (1) is proportional to M^2+M if the weight for each antenna is transmitted, where M denotes the number of antenna. It is worth noting that the (M^2+M) is for only one weight vector. Thus the resultant number of multiplication is proportional to (size of weight vector set)* (M^2+M). Note that the size of weight vector set is L^M, where $L=2^{Nc}$ is the possible number of weight vector per antenna.

If the weight for the reference antenna is set to one, then the number of multiplication is proportional to (size of weight vector set)*(M(M-1)+M-1), where the size of weight vector is L^{M-1}.

If the number of transmit antenna is reduced to S, then the number of multiplication reduces to (size of weight vector set)*(S(S-1)+S-1). In this case, the size of weight vector set reduces to $_MC_S$*L^{S-1} due to the reduced number of antenna.

For example, in case of M=4, S=2, N_c=2, the number of multiplication of the proposed scheme is proportional to 6*4*3=72 while that of the full representation with reference antenna is 4^3*(12+3)=64*15=960. Note that in case of M=2, N_c=4 (3GPP Mode 2), the number of multiplication is 16*3=48.

VII. Conclusion

In this contribution, efficient schemes to approximate and represent weight vectors for Tx diversity systems are presented. The use of these schemes for 4 transmit antenna systems are found to improve performance about 3dB, compare to 2 transmit antenna systems specified in 3GPP Release 99, when the UE moves at 3km/hr. In addition, the increase of the required number of calculation is negligible compared to the current 3GPP Mode 2 scheme. In the future, we will submit multipath simulation results based on the common simulation parameters.

References

[1] R1-00-0506, “Proposal for the use of closed loop Tx diversity with more than 2 Tx antennas,” TSG-RAN WG1#12, Seoul, Korea, April 2000

[2] R1-00-0683, “Further simulation results of Tx diversity for more than 2 antennas,” TSG-RAN WG1#13, Tokyo, Japan, May 2000

[3] R1-00-0712, “An extension of closed loop Tx diversity mode 1 for multiple Tx antennas,” TSG-RAN WG1#13, Tokyo, Japan, May 2000

Appendix A

$$\begin{array}{c} \\ \underline{B}_1 \\ \underline{B}_2 \end{array} \begin{bmatrix} \text{Ant1} & \text{Ant2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{bmatrix}$$

(a) 2 Tx antennas

$$\begin{array}{c} \\ \underline{B}_1 \\ \underline{B}_2 \\ \underline{B}_3 \end{array} \begin{bmatrix} \text{Ant1} & \text{Ant2} & \text{Ant3} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{\sqrt{2}} \end{bmatrix}$$

(b) 3 Tx antennas

$$\begin{array}{c} \\ \underline{B}_1 \\ \underline{B}_2 \\ \underline{B}_3 \\ \underline{B}_4 \end{array} \begin{bmatrix} \text{Ant1} & \text{Ant2} & \text{Ant3} & \text{Ant4} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \frac{1}{2} & -\frac{1}{2} & \frac{1}{2} & -\frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \\ \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

(c) 4 Tx antennas