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Agenda item:	**15**
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Title:	**Further Simulation Results of the Tx Diversity Scheme with Beamforming Feature**
Document for:	**Discussion**

1. Introduction

At the TSG RAN WG1 meeting #15, we proposed a new multiple antennas Tx diversity scheme with a beamforming feature [1]. In last Boston meeting, we demonstrated some initial simulation results of our proposed schemes with two-sub-array antenna configuration [2] and showed that the closed-loop beamforming has many advantages to be applied as Tx diversity scheme with more than two antenna elements. In this contribution, we show some further simulation results in the case applying unequal power allocation for pilot sequences of CPICH [1]. We also discuss about the beam tracking performance against UE mobility and calculate the permissible feedback delay for closed-loop beamforming. Then, we demonstrate that the beamforming weight filtering at Node B is applicable to reduce the feedback information bit error and improve the performance. Finally, we discuss about the method of our proposed scheme in soft handover.

2. CPICH Unequal Power Allocation

If the total CPICH power is constant, say -10dB of total transmission power, increasing the number of antenna elements decreases the channel estimation performance for each transmission antenna. In this case, the channel estimation performance is degraded for the Release'99 UE, since the pilot sequences from only two antenna elements can be utilized. To solve this problem, we proposed to employ unequal power allocation for the pilot sequences of CPICH [1]. In the case of two-sub-array antenna configuration (see Figure 1), the power of pilot sequences P_2 and P_4 can be reduced than that of pilot sequences P_1 and P_3. In the UE, P_2 and P_4 are used for calculation of channel response vector $\underline{h}_2$ and $\underline{h}_4$ respectively. As these parameters are used only for calculation of beamforming weights $\{B_{m,k}\}$, long term averaging of $\{B_{m,k}\}$ can compensate the reduced SIR of $\underline{h}_2$ and $\underline{h}_4$.

Computer simulation is performed to evaluate how much ratio can be applied for unequal power allocation and how much performance improvement can be produced for the Release'99 UE.

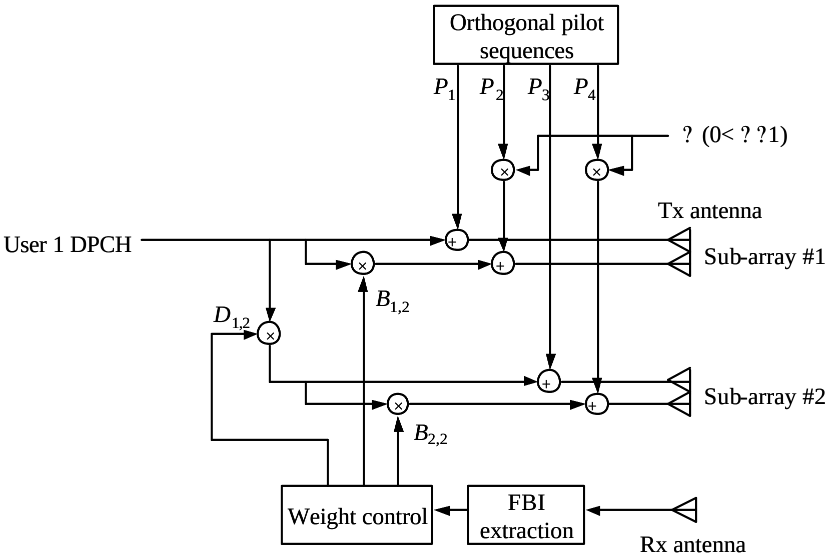

Figure 1. Structure of the combined Tx diversity/beamforming with CPICH unequal power allocation (N=4, M=2).

2.1 Simulation parameters

Simulation parameters were chosen according to [3] and listed in Table 1. Additional simulation parameters were shown in Table 2. The frame format for the feedback information bits are shown in Table 3.

Table 1. Simulation parameters

Bit Rate	12.2 kbps
Chip Rate	3.84 Mcps
Convolutional code rate	1/3
Carrier frequency	2 GHz
Power control rate	1500 Hz
PC error rate	4 %
PC step size	1 dB per antenna
Channel models and UE velocities	ITU Veh. A: 10, 40, 120 km/h
CL feedback bit error rate	4 %
CL feedback delay	1 slot
TTI	20 ms
Downlink DPCH slot format	#11
# of RAKE fingers for ITU channel model	5
Target FER/BlkER	1 %
Geometry (G)	-6, -3 dB
Common pilot	-10 dB total
Performance measure	T_x E_c/I_{or}
CL feedback rate	1500 Hz

Table 2. Additional simulation parameters

Channel estimation	from CPICH with ideal weight verification
CPICH	equal power allocation for each Tx antenna
Correlation between antennas	0: between diversity branches 1: among each sub-array
UE location	preserving 0 degree direction from Node B
Multipath angular spread	0 degree
BF weight step size	45 degree
BF element space	?/2

Table 3. Multiplexing format of feedback information

Slot #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FB bits for D	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0
FB bits for B	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1

2.2 Simulation results

Simulation results are shown in Table 4–7. CPICH power ratio of P_1 to P_2 (P_3 to P_4) was changed and the average Tx Ec/Ior performance were calculated for both the proposed scheme and the Release'99 UE. As the pilot power allocation for P_2 (P_4) decreases, the performance of the proposed scheme is gradually degraded. On the other hand, the performance for the Release'99 UE is improved, since the pilot sequences of only P_1 and P_3 are used for channel estimation. From these results, we can conclude that the CPICH power ratio of 8:2 is appropriate to achieve sufficient performance for both the proposed scheme and the Release'99 UE.

Table 4. Performance with CPICH unequal power allocation (G=-3dB, V=10km/h)

CPICH power ratio	Tx Ec/Ior [dB]	
	2x2 Ant BF	2 Ant CL1 (R99)
5 : 5	-16.8	-14.8
7 : 3	-16.8	-15.0
8 : 2	-16.7	-15.1
9 : 1	-16.2	-15.1
10: 0	☞	-15.1

Table 5. Performance with CPICH unequal power allocation (G=-3dB, V=40km/h)

CPICH power ratio	Tx Ec/Ior [dB]	
	2x2 Ant BF	2 Ant CL1 (R99)
5 : 5	-16.7	-14.7
7 : 3	-16.6	-14.8
8 : 2	-16.4	-15.0
9 : 1	-15.9	-15.0
10: 0	☞	-15.0

Table 6. Performance with CPICH unequal power allocation (G=-3dB, V=120km/h)

CPICH power ratio	Tx Ec/Ior [dB]	
	2x2 Ant BF	2 Ant CL1 (R99)

5 : 5	-15.0	-13.3
7 : 3	-14.8	-13.4
8 : 2	-14.7	-13.4
9 : 1	-14.1	-13.5
10: 0	☞	-13.5

Table 7. Performance with CPICH unequal power allocation (G=-6dB, V=40km/h)

CPICH power ratio	Tx Ec/Ior [dB]	
	2x2 Ant BF	2 Ant CL1 (R99)
5 : 5	-13.2	-11.4
7 : 3	-13.2	-11.5
8 : 2	-13.1	-11.7
9 : 1	-12.4	-11.7
10: 0	☞	-11.9

3. Discussion on UE Mobility

In this section, we first investigate the beam tracking performance of closed-loop beamforming and calculate how much feedback delay is permissible. Then, we demonstrate that the beamforming weight filtering at Node B can be used to reduce the feedback information bit error and enhance the beamforming gain.

3.1 Beam tracking performance

When considering the UE location as shown in Figure 2, the phase difference between two antenna elements is described as

$$? \; ? \; \frac{2?}{?} d \, ?\sin(?) \qquad (1)$$

where d is the inter-element spacing and $?$ is the wavelength. If we assume that the UE moves in the cell keeping a distance r from the Node B with a constant velocity v, the displacement of direction $?$ at a time period $?T$ becomes

$$? ? \; ? \; \frac{v ?? T}{r}. \qquad (2)$$

Hence, the phase displacement of beamforming weight for beam tracking can be written as

$$\begin{aligned} ? ? \; ? \; & \frac{2?}{?} d \, ?\sin(? \; ? \; ? ?) \; ? \; \frac{2?}{?} d \, ?\sin(?) \\ ? \; & \frac{2?}{?} d \, ?\sin(? ?) \; ? \; \frac{2?}{?} d \, ?\sin(v ?? T / r). \end{aligned} \qquad (3)$$

In Table 8, we show some calculation results of equation (3) with v = 120km/h and d = $?$. In general, the inter-element spacing of beamforming array is set between 0.5$?$ and 1.0$?$ to achieve enough antenna correlation. When assuming the distance between UE and Node B of 30 m and $?T$ of 40 ms, the phase displacement becomes 16º, which is less than half of the beamforming weight step size of 45º. Hence, we can say that the feedback delay of 40 ms is fully permissible for the closed-loop beamforming.

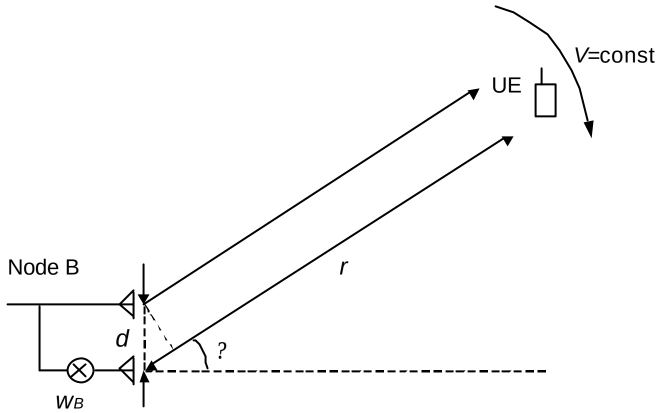

Figure 2. UE location and trajectory

Table 8. Phase displacement of beamforming weight (*v*=120km/h, *d*=*?*)

r [m]	? *T* = 10 [ms]		? *T* = 20 [ms]		? *T* = 30 [ms]		? *T* = 40 [ms]	
	?? [°]	?? [°]	?? [°]	?? [°]	?? [°]	?? [°]	?? [°]	?? [°]
10	1.9	12.0	3.8	24.0	5.7	35.9	7.6	47.9
20	0.95	6.0	1.9	12.0	2.9	18.0	3.8	24.0
30	0.64	4.0	1.3	8.0	1.9	12.0	2.5	16.0
100	0.19	1.2	0.38	2.4	0.57	3.6	0.76	4.8
200	0.10	0.6	0.19	1.2	0.29	1.8	0.38	2.4
300	0.06	0.4	0.13	0.80	0.19	1.20	0.25	1.6
1000	0.02	0.12	0.04	0.24	0.06	0.36	0.08	0.48

3.2 Feedback error reduction by filtering

As shown in Table 3, a single beamformer weight is quantized by 3 bits and transmits in a frame to Node B. If the RF calibration which compensates the phase offset among each sub-array antennas has not been done, the beamforming weight should be calculated for each sub-array separately. Therefore, the feedback delay occurs in proportion to the number of sub-arrays. The feedback delay becomes 20 ms for the two-sub-array antenna configuration.

If the feedback delay of 30 ms is permissible, the feedback error reduction by filtering will be applicable. For example, when the same feedback information bits are detected consecutively, Node B may change the beamforming weight. If the feedback bit error occurs randomly, this filtering method can reduce the feedback error effectively. In Figure 3, we demonstrate the average Tx Ec/Ior performance of our proposed scheme assuming 4% feedback error rate for Tx diversity and 0% feedback error rate for closed-loop beamforming. The simulation results in our previous contribution [2] are plotted in the same figure. Result shows that the extra beamforming gain of about 0.7 dB can be obtained by the feedback weight filtering.

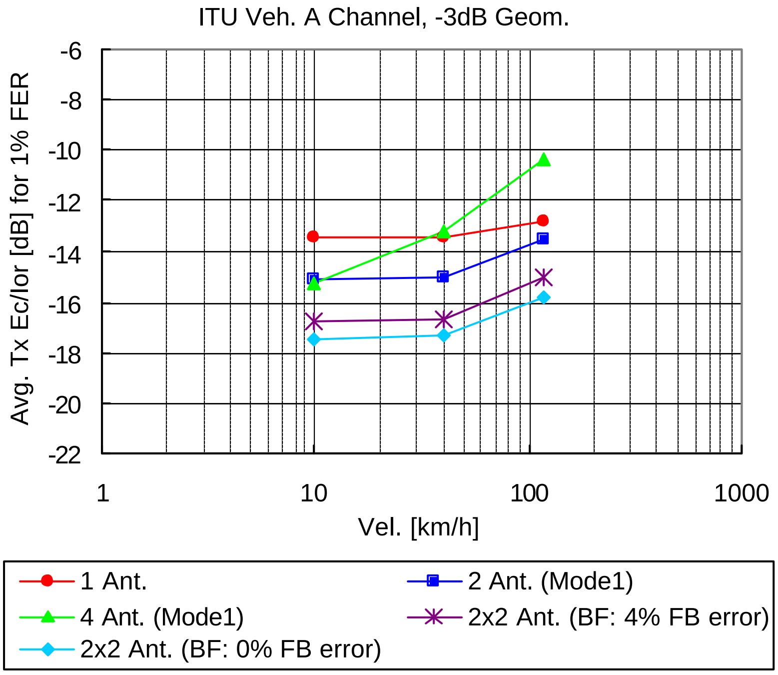

Figure 3. Performance with feedback filtering

4. Closed-Loop Beamforming in Soft Handover

The procedure in soft handover is one of the most important issues to discuss for the feasibility study. Here, we propose two handover methods:

?? The same feedback weights are used to control the beamforming weights of active set of Node B, simultaneously.
?? The individual beamforming weights are calculated and fed back in sequence among active set of Node B.

The former is the same method as described in Release'99 specification. In the latter method, the feedback delay occurs in proportion to the number of Node Bs. Since the UE in handover mode generally locates at cell edge, the permissible feedback delay will be much longer than 40 ms. However, this method needs higher layer signalling to assign the order of Node B, whose beamforming weights are transmitted from UE in sequence. On the other hand, the Tx diversity weights, that is vulnerable to feedback delay, are calculated and fed back to Node B in the same manner as described in Release'99 specification.

We should also consider the case in which the Node Bs with different types of Tx diversity mode are mixed in the same active set during soft handover. In this case, only one feedback frame format should be shared to transmit the feedback information bits. For example, when the Node B with 2-sub-array antenna Tx diversity and the Node B with 2-antenna Tx diversity are exist in the same active set, the feedback frame format shown in Table 3 can be used as the common feedback frame format. Table 9 shows the active slots in a frame for each Tx diversity mode. Since only three slots per frame are clipped for the 2-antenna Tx diversity, the performance degradation seems to be negligible. Table 10 is the case where the Node Bs with 2-sub-array, 2-antenna and 4-antenna Tx diversity are mixed in the same active set. Since the 4-antenna Tx diversity should control three different diversity weights, the feedback rate for 2-antenna mode severely decreased. Thus there seems to be the significant performance degradation in a fast fading condition.

Table 9. Active feedback slots for 2-sub-array and 2-antenna Tx diversity.

Slot #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2-sub-array	w_1	w_1	w_1	w_1	w_B	w_1	w_1	w_1	w_1	w_B	w_1	w_1	w_1	w_1	w_B
2-antenna	w_1	w_1	w_1	w_1	–	w_1	w_1	w_1	w_1	–	w_1	w_1	w_1	w_1	–

(w_1: feedback weight for Tx diversity. w_B: feedback weight for beamforming)

Table 10. Active feedback slots for 2-sub-array, 2-antenna and 4-antenna Tx diversity.

Slot #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2-sub-array	w_1	w_1	–	–	w_B	–	–	w_1	w_1	w_B	–	–	–	–	w_B
2-antenna	w_1	w_1	–	–	–	–	–	w_1	w_1	–	–	–	–	–	–
4-antenna	w_1	w_1	w_2	w_2	–	w_3	w_3	w_1	w_1	–	w_2	w_2	w_3	w_3	–

(w_1, w_2, w_3: feedback weight for Tx diversity. w_B: feedback weight for beamforming)

5. Conclusion

We presented further simulation results of our proposed multiple antennas Tx diversity scheme with sub-array antenna configuration. Results showed that the unequal power allocation for the pilot sequences of CPICH is effective to minimize the channel estimation performance degradation for the Release'99 UE. The CPICH power ratio of 8:2 is appropriate to achieve sufficient performance for both the proposed scheme and the Release'99 UE.

However, this technique probably destroys the power balance of each antenna. In [4], Samsung proposed the new CPICH transmission scheme for 4 transmit antenna, which evenly distributes the transmission power to all antennas in order to reduce the PAPR (Peak to Average Power Ratio). We think that Samsung's method is also applicable to our scheme with two-sub-array antenna configuration and effective to solve the problem of inter-element power unbalance.

We also discussed about the beam tracking performance and the permissible feedback delay for closed-loop beamforming. The feedback delay of 40 ms is permissible, unless the UE passes by adjacent of Node B with a speed of more than 120 km/h. The performance of our proposed scheme with the beamforming weight filtering at Node B has been demonstrated. Simulation result showed that the extra beamforming gain of about 0.7 dB was obtained when assuming 0% feedback error rate for closed-loop beamforming compared to the case of 4% feedback error rate.

Finally, we discussed about the procedure of our proposed scheme in soft handover and introduced two methods to control the beamforming weights for active set of Node B. However, further studies are needed to evaluate its feasibility and effectiveness.

References

[1] Fujitsu. Enhance the beamforming feature of the multiple antenna Tx diversity. TSG-R WG1 document, TSGR1#15(00)1065, 22-25, August, 2000, Berlin, Germany.

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[4] Samsung, New CPICH transmission scheme for 4-antenna transmit diversity. TSG-R WG1 document, TSGR1#15(00)1072, 22-25, August, 2000, Berlin, Germany.