3GPP TSG RAN WG1 **TSGR1#7(99)c31**
Meeting #7
30th, August-3rd, September, 1999
Hannover, Germany

Agenda item:

Source: Nokia

Title: Further clarifications and text proposal for refined closed loop modes 2 and 3

Document for: Discussion and approval

Summary:

Further clarifications of the refined closed loop modes 2 and 3 are presented in this contribution. In addition, a revised text proposal to TS 25.214 v1.1.2 is included. Although the refined mode 3 was not yet accepted in the WG1 meeting #6 the text proposal covers also it. We propose that the current mode 3 is modified as described in this document.

TABLE OF CONTENTS

1. INTRODUCTION

In the TSG-R WG1 meeting #6 Nokia proposed a slight modification to the closed loop modes 2 and 3 by introducing constellation rotation at UE and filtering at Node B [2]. The modification to the mode 2 was tentatively accepted but the mode 3 remained as it is due to different simulation results by Nokia and Motorola [2, 3]. The text proposal was not yet accepted as based on some offline discussions it seemed to require some clarifications and possible corrections. Moreover, the issue of synchronization of the constellation rotation between UE and active set Node Bs in case of SHO was identified. In this contribution, a new text proposal is made incorporating simple solution to the synchronization problem.

2. CLARIFICATION OF DETAILS OF REFINED CLOSED LOOP MODES 2 AND 3

Table 1 presents a summary of the closed loop modes as proposed in [2]. The refined mode 2 was tentatively accepted in the WG1 meeting #6 but refined mode 3 was not yet accepted.

Table 1. N_{FBI}, N_W, *update rate, feedback bit rate and number of power and phase bits per signaling word for refined feedback modes. Chip rate of 3.84 Mchip/s is assumed.*

Refined FB mode	N_{FBI}	N_W	Update rate	Feedback bit rate	N_{po}	N_{ph}	Constellation rotation
1	1	1	1500 Hz	1500 bps	0	1	N/A
2	1	1	1500 Hz	1500 bps	0	1	π/4
3	2	1	1500 Hz	3000 bps	0	2	π/4

As explained in [2] from UE point of view feedback mode 2 is same as mode 1 except that the signal received from antenna 1 is rotated by $N\frac{p}{4} \bmod p$ so that we get:

$$f_{Tx}[n] = \frac{1}{4}\sum_{i=0}^{3} f_{Rx}[n-i] \qquad (1)$$

where,

$$\begin{aligned} f_{Rx}[0] &\in \{0, p\} \\ f_{Rx}[i] &\in \left\{\{f_{Rx}[i-1]\} + p/4 \bmod 2p\right\} \end{aligned} \qquad (2)$$

The feedback command rate is the same as in mode 1. Mapping between feedback commands and phase difference between transmit antennas for 4 consecutive slots is as shown in the Table 2.

Due to harmonization the number of slots per frame was changed from 16 to 15. As the rotation cycle is of length 4 it does not go even to one frame. In case of non-SHO this is not a problem as we could map the rotations deterministically to superframe structure. However, that creates a problem in SHO case as the superframes of the active set Node Bs may not be synchronized. Even though that problem could be handled by higher layers it is very desirable to solve it at L1.

Table 2. Feedback commands and corresponding phase differences.

Value	ϕ_{Rx}			
	Slot i	Slot i+1	Slot i+2	Slot i+3
0	0	45	90	135
1	180	-135	-90	-45

A simple solution is to reset the rotation cycle at the beginning of the frame so that in slot 0 we always use constellation points 0/180 degrees. Now there is always same deterministic mapping between the rotations and slots in every frame. Therefore, no synchronization problem exists anymore.

When implementing the averaging filter at Node B it should be noted that equation 1 should not be directly used as it leads to phase wrapping problem. Instead, filtering can be done e.g. using complex representation of the constellation points. Moreover, the filter must be implemented so that no "illegal" constellation points are outputted at frame boundaries due to resetting of the rotation cycle. One example solution is to represent the filter as 4 memory elements, each corresponding to one constellation rotation. Now, whenever new command is received, the corresponding memory element of the filter is updated accordingly and average value to be used by the Node B is calculated. This kind of implementation ensures that filter outputs only legal constellation points.

In refined feedback mode 3 UE quantizes the phase difference into QPSK constellation. However, no amplitude weighting is used so unlike the current FB mode 3 the refined FB mode 3 is power balanced as all the other FB modes. Constellation is rotated by π/4 yielding:

$$\phi_{Tx}[n] = \frac{1}{2}\sum_{i=0}^{1}\phi_{Rx}[n-i] \qquad (3)$$

where,

$$\begin{aligned} &\phi_{Rx}[0] \in \left\{0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}\right\} \\ &\phi_{Rx}[i] \in \left\{\{\phi_{Rx}[i-1]\} + \pi/4 \text{ mod } 2\pi\right\} \end{aligned} \qquad (4)$$

Table 3. Feedback command and corresponding phase differences.

Value	ϕ_{Rx}	
	Slot i	Slot i+1
00	180	-135
01	-90	-45
10	0	45
11	90	135

Similarly, as in mode 2 the rotation cycle does not go even to the frame structure. Therefore, the cycle is resetted in the beginning of frame. The filtering can be continued as usually at the frame boundaries. Note, though, that averaging can yield a weight vector, w_2 = 0+j0, as same set of constellation points have been used in consequtive slots. In that case one option is to bypass the filter output and use the latest feedback command only.

By adopting the refined FB modes we get the following benefits [2]:

- Reduced number of modes
- Improved performance
- All the modes are power balanced
- Simplified UE operation
- Improved robustness from mode control point of view
    - ★ Less accurate doppler measurement needed as the application range of the modes overlap even more than earlier
- Feedback command rate equals to slot rate ⇒ no slipping of commands over frame boundaries in case of 15 slots per frame

3. TEXT PROPOSAL

The whole chapter 8 of TS 25.214 v1.1.2 is proposed to be replaced with the following:

--Start text proposal--

8 Feedback mode transmit diversity

The general transmitter structure to support Feedback (FB) mode transmit diversity for DPCH transmission is shown in Figure 1. Channel coding, interleaving and spreading are done as in non-diversity mode. The spread complex valued signal is fed to both TX antenna branches, and weighted with antenna specific weight factors w_1 and w_2. The weight factors are complex valued signals (i.e., $w_i = a_i + jb_i$), in general.

The weight factors (actually the corresponding phase adjustments) are determined by the UE, and signaled to the UTRAN access point (=cell transceiver) using the D-bits of the FBI field of uplink DPCCH.

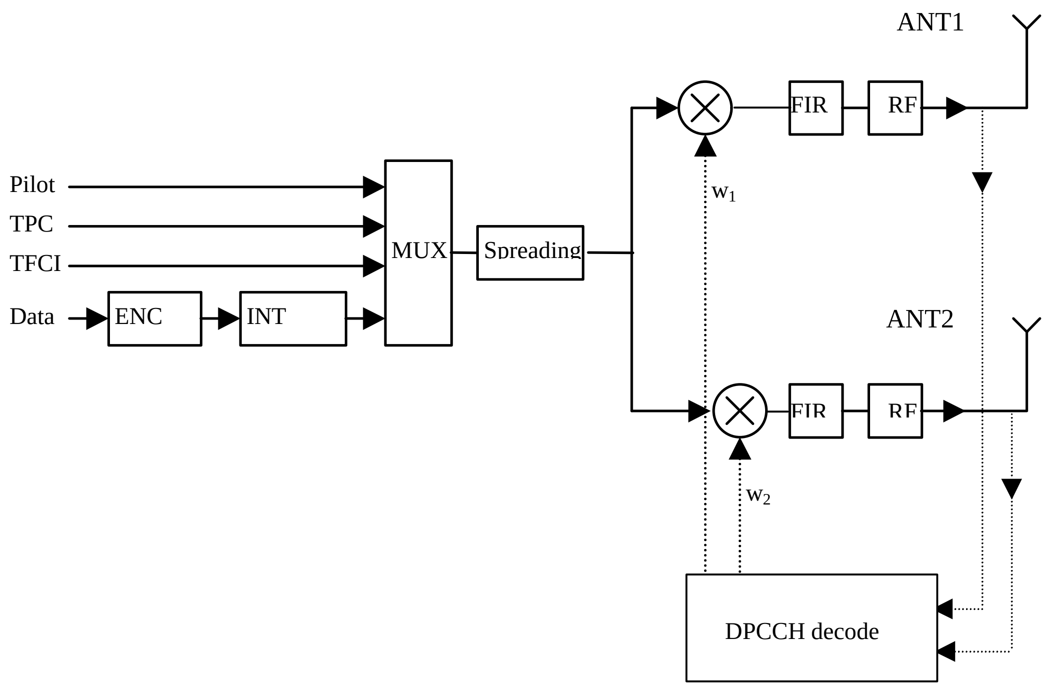

Figure 1. The generic downlink transmitter structure to support FB Mode Transmit Diversity for DPCH transmission (UTRAN Access Point)

There are three feedback modes whose characteristics are summarized in the Table 4. The use of the modes is controlled by the UTRAN access point.

Table 4. Summary of number of feedback information bits per slot, N_{FBD}, feedback command length in slots, N_W, feedback command rate, feedback bit rate, number of phase bits, N_{ph}, per signaling word and amount of constellation rotation at UE for the three feedback modes.

FB mode	N_{FBD}	N_W	FB command rate	FB bit rate	N_{ph}	Constellation rotation
1	1	1	1500 Hz	1500 bps	1	N/A
2	1	1	1500 Hz	1500 bps	1	$\pi/4$
3	2	1	1500 Hz	3000 bps	2	$\pi/4$

8.1 Determination of feedback information

The UE uses the Common PIlot CHannel (CPICH) to separately estimate the channels seen from each antenna.

Once every slot, the UE computes the phase adjustment, f, that should be applied at the UTRAN access point to maximize the UE received power. In a generic sense for the non-soft handover case, UE solves for weight vector, $\underline{w}$, that maximizes

$$P=\underline{w}^H H^H H \underline{w} \qquad (5)$$

where

$$H=[\underline{h}_1 \;\; \underline{h}_2 \ldots]$$

and where the column vector $\underline{h}_i$ represents the estimated channel impulse response for the i'th transmission antenna, of length equal to the length of the channel impulse response.

During soft handover or SSDT power control, the antenna weight vector, w is determined so as to maximize the criteria function,

$$P=w^H(H_1^H H_1+ H_2^H H_2+\text{xxxx})w$$

where H_i is an estimated channel impulse response for BS#i. In regular SHO, the set of BS#i corresponds to the active set. With SSDT, the set of BS#i corresponds to the primary base station(s).

8.2 Feedback mode 1

In FB mode 1 UE calculates the phase adjustment as described in 8.1 and quantizes it into two values, 0, and π. If value is 0, a command '0' is send to Node B. Correspondingly, if value is π, command '1' is send to Node B.. No constellation rotation is done at UE. Similarly, no filtering of the received weights is performed at the Node B.

Table 5. Feedback commands and corresponding phase difference, f, between the transmit antennas.

FB command	f
0	0
1	180

The weight vector, w, is then calculated as:

$$w=\begin{bmatrix} w_1 \\ w_2 \end{bmatrix}=\begin{bmatrix} 1 \\ \cos f + j\sin f \end{bmatrix} \qquad (6)$$

8.3 Feedback mode 2

In FB mode 2 UE first rotates the CPICH signal received from non-diversity antenna by $N\frac{p}{4} \bmod p$. Next the UE calculates the phase adjustment as described in 8.1 and quantizes it into two values, 0, and π. If value is 0, a command '0' is send to Node B. Correspondingly, if value is π, command '1' is send to Node B.

Due to rotation of the constellation at UE the Node B interprets the received commands according to Table 6 which shows the mapping between phase difference, f,, and received feedback command for each UL slot. Note that no rotation is used (i.e. N=0) when calculating the value of feedback command for first slot of the UL frame.

Table 6. Feedback commands and corresponding phase differences, f, for the slots of the UL radio frame.

FB command	f														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	0	45	90	135	0	45	90	135	0	45	90	135	0	45	90
1	180	-135	-90	-45	180	-135	-90	-45	180	-135	-90	-45	180	-135	-90

The received phases are filtered by averaging over 4 slots. Conceptually, the filter must be implemented as shown in the Figure 2. There are four memory cells, one for each possible FB command. Whenever a new command is received, the value of the corresponding memory cell is updated accordingly. After each update a new average is calculated. Algorithmically, the average is calculated as follows:

$$C = \frac{\sum_{i=0}^{3}\sin(f_i)}{4} + j\frac{\sum_{i=0}^{3}\cos(f_i)}{4} \qquad (7)$$

where,

$$\begin{aligned} f_0 &\in \{0,180\} \\ f_1 &\in \{45,-135\} \\ f_2 &\in \{90,-90\} \\ f_3 &\in \{135,-45\} \end{aligned} \qquad (8)$$

The filtered phase difference between antennas, f_{Tx}, is then calculated from C. The weight vector, *w*, is:

$$w = \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} = \begin{bmatrix} 1 \\ \cos f_{Tx} + j\sin f_{Tx} \end{bmatrix} \qquad (9)$$

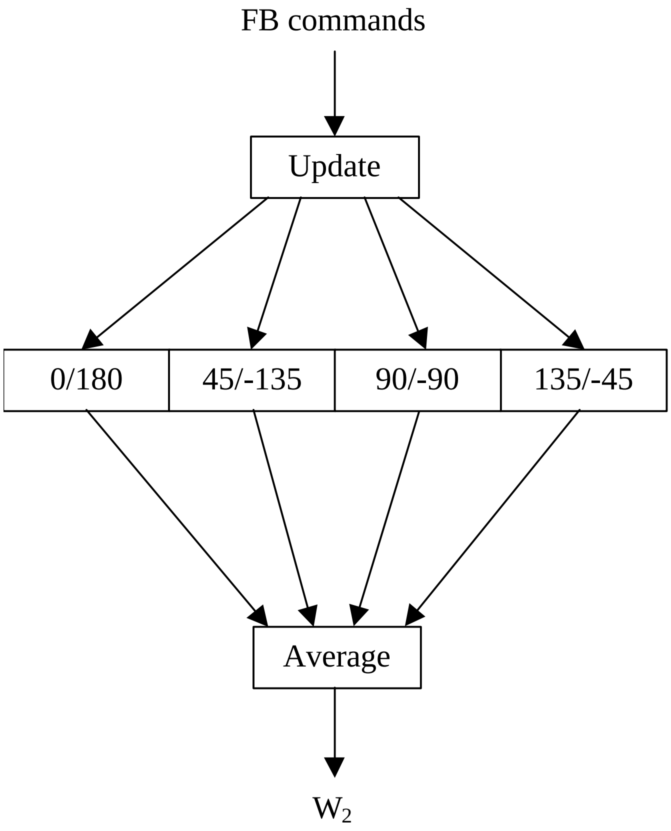

Figure 2. Conceptual description of the Node B filter for FB mode 2.

8.4 Feedback mode 3

In FB mode 3 UE first rotates the CPICH signal received from non-diversity antenna by $N\frac{p}{4} \bmod \frac{p}{2}$. Next the UE calculates the phase adjustment as described in 8.1 and quantizes it into QPSK constellation $(0, \frac{p}{2}, -\frac{p}{2}, \pi)$ The corresponding UL feedback commands are 00, 10, 01, 11, respectively.

Due to rotation of the constellation at UE the Node B interprets the received commands according to Table 7 which shows the mapping between phase difference, f,, and received feedback command for each UL slot. Note that no rotation is used (i.e. N=0) when calculating the value of feedback command for first slot of the UL frame.

Table 7. Feedback commands and corresponding phase differences, f, for the slots of the UL radio frame.

FB command	f														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
11	180	-135	180	-135	180	-135	180	-135	180	-135	180	-135	180	-135	180
01	-90	-45	-90	-45	-90	-45	-90	-45	-90	-45	-90	-45	-90	-45	-90
00	0	45	0	45	0	45	0	45	0	45	0	45	0	45	0
10	90	135	90	135	90	135	90	135	90	135	90	135	90	135	90

Received phase differences are filtered by a moving average filter over 2 slots. Algorithmically, we first average over two received phases as follows:

$$C = \frac{\sum_{i=k}^{k+1} \sin(f_i)}{2} + j\frac{\sum_{i=k}^{k+1} \cos(f_i)}{2} \qquad (10)$$

The filtered phase difference between antennas, f_{Tx}, is then calculated from C. The weight vector, *w*, is:

$$w = \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} = \begin{bmatrix} 1 \\ \cos f_{Tx} + j\sin f_{Tx} \end{bmatrix} \qquad (11)$$

At frame borders, where the same set of phases is used in the last slot of a previous frame and in the first slot of the next frame, the equation (10) may yield *C*=0+j0. In that case f_{Tx} is set to last received phase (i.e. no averaging is done) and *w* is calculated normally using equation (11).

---End text proposal--

4. CONCLUSIONS

A revised text proposal and a clarification of the tentative approved refined closed loop mode 2 has been made. Although the refined mode 3 was not yet accepted in the WG1 meeting #6 the text proposal covers also it. We propose that the current mode 3 is modified as described in this document.

REFERENCES

[1] Ad Hoc #6. Ad Hoc #6 report to RAN WG1 meeting #6. TSG-R WG1 document, TSGR1#5(99)790, 13-16th, July, 1999, Espoo, Finland, 5 pp.

[2] Nokia. Proposal to simplify the Tx diversity closed loop modes. TSG-R WG1 document, TSGR1#6(99)945, 13-16th, July, 1999, Espoo, Finland, 18 pp.

[3] Motorola. Simulation results: refined Tx AA mode vs. current Tx AA modes. TSG-R WG1 document, TSGR1#6(99)980, 13-16th, July, 1999, Espoo, Finland, 13 pp.