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# Modified closed loop modes for WCDMA

Texas Instruments, August 24th 1999

## 1.0 Introduction

Closed loop antenna diversity for WCDMA currently consists of 3 modes which are shown in the following table [1]

| FB mode | $N_{FBI}$ | $N_W$ | Update rate | Feedback bit rate | $N_{po}$ | $N_{ph}$ | Constellation rotation | Applicable Doppler, f (Hz.) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1500 Hz | 1500 bps | 0 | 1 | N/A | ~ 60 < f |
| 2 | 1 | 1 | 1500 Hz | 1500 bps | 0 | 1 | π/4 | ~ 10 < f < 60 |
| 3 | 2 | 1 | 1500 Hz | 3000 bps | 1 | 3 | N/A | ~ f < 10 |

*Table 1: Modes 1, 2 of the 3 closed loop modes currently defined in the WCDMA standard and the approximate Doppler velocity for the different modes is shown.*

The mode 1 currently consists of a 1 bit command per slot corresponding to a 0 or a 180 phase rotation of the antenna weights for the DPCH at the base station. A set of orthogonal pilot patterns is transmitted on the DPCH, for the verification at the mobile of the phase used by the base station, and to improve the channel estimates from the CPICH. The current mode 2 is similar to mode 1 from the UE point of view, except the signal received from antenna 1 is rotated at the mobile by $N\frac{p}{4} \bmod 2p$ . The weights transmitted by the mobile are filtered at the base station. It is possible to do antenna beam former verification for the current mode 2, even though it is currently not introduced in the standard. As can be seen from table (1) the current closed loop modes require two switches, one approximately at 10 Hz (to and from modes 2, 3) and the second one at approximately 60 Hz (to and from modes 1, 2).

*In this submission we propose a small modification to the current closed loop modes 1, 2 by combining them into a single closed loop mode. The combined closed loop mode is very similar to the current mode 2 except that the signal received from antenna 1 is rotated at the mobile by $N\frac{p}{2} \bmod 2p$ . Thus we propose to have only two-closed loop modes as shown pictorially in figure (1) and in table (2) below*:

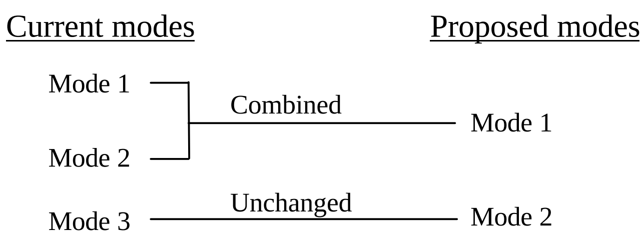


*Figure 1: The combining of the current modes 1, 2 and the new proposed mode is shown. The current mode 3 is unchanged.*

| Proposed FB mode | $N_{FBI}$ | $N_W$ | Update rate | Feedback bit rate | $N_{po}$ | $N_{ph}$ | Constellation rotation | Applicable Doppler, f (Hz.) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1500 Hz | 1500 bps | 0 | 1 | π/2 | ~ 10 < f |
| 2 | 2 | 1 | 1500 Hz | 3000 bps | 1 | 3 | N/A | ~ f < 10 |

*Table 2: Modes 1 and 2 of the proposed closed loop modes and the applicable Doppler velocity is shown.*

The advantages of this proposed mode are as follows:

(1) Only one mode switching is required for closed loop modes (from the proposed mode to and from the current mode 3), since the proposed mode can be employed both in place of the current modes 1, 2.

(2) Beam former verification (BV) for the proposed mode has the same complexity as the BV for the current mode 1.

(3) Simulations results show that the performance of the proposed mode with BV is always better than or equal to the best of the performance of the current mode 1 (with BV) and current mode 2 (with and without BV). *Thus, the proposed closed loop mode gives improved performance over both the current modes 1, 2.*

***Hence we propose that the current closed loop modes 1,2 be merged into a single mode. The current mode 3 is unchanged.***

**2.0 The proposed mode**

As mentioned above, the proposed mode is the same as the current mode 2 except that the signal received from antenna 1 is rotated by $N\frac{p}{2}\bmod 2p$ so that we get:

$$e^{jf_{Tx}[n]} = \frac{1}{\sqrt{2}}\sum_{j=0}^{1} e^{jf_{Rx}[n-j]} \qquad (1)$$

where,

$$f_{Rx}[0] \in \{0, p\}$$
$$f_{Rx}[n] \in \left\{\{f_{Rx}[n-1]\} + p/2 \bmod 2p\right\} \qquad (2)$$

The feedback commands and the corresponding phase differences are give in table (3)

| Feedback command value | Slot n = 2i | Slot n = 2i + 1 |
|---|---|---|
| 0 | 0 | $p/2$ |
| 1 | $p$ | $-p/2$ |

*Table 3: The feedback commands and the corresponding phase differences for the proposed mode.*

**2.1 Beam former verification (BV) for the proposed mode**

A straightforward beam former verification (BV) for the proposed mode similar to the current mode 1 would involve a 4-hypothesis test which would be slightly more complex (2 extra multiplies per beam former verification) than the BV for current mode 1. However, a simplified BV for the proposed mode with about the same performance as the 4-hypothesis test and requiring only a 2-hypothesis test per slot is possible.

### 2.1.1 Simplified Beam former verification (SBV) for proposed mode

To understand the SBV for the proposed mode, refer back to equation (1) for the proposed mode and define a function $f(.)$ as;

$$f[n] = \frac{p\left(1-\sqrt{2}\left(\mathrm{Re}\left\{e^{jf_{Tx}[n]}\right\}\right)\right)}{2}; \qquad \text{for n even} \qquad (3)$$

$$f[n] = \frac{p}{2}\sqrt{2}\left(\mathrm{Im}\left\{e^{jf_{Tx}[n]}\right\}\right); \qquad \text{for n odd} \qquad (4)$$

we can now see that

$$e^{jf_{Tx}[n]} = \frac{1}{\sqrt{2}}\left(e^{jf[n]} + e^{jf[n+1]}\right) \qquad (5)$$

Equations (3), (4) and (5) can now be used to construct the SBV for the proposed mode. A block diagram of the SBV for the proposed mode is given in the following figure (2).

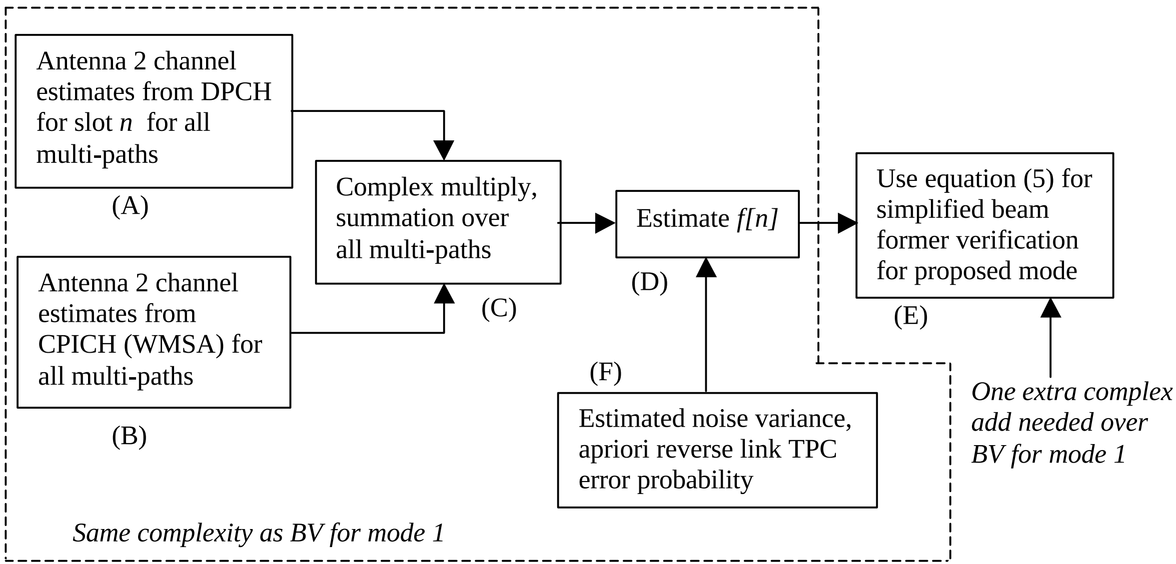


*Figure (2): A block diagram for the simplified beam former verification (SBV) for the proposed mode. The SBV requires only one extra complex add per beam slot as compared to the BV for the current mode 1 implying that the complexity of SBV is about the same as BV for current mode 1.*

A detailed description of the block diagram in figure (2) and SBV procedure follows:

(a) Blocks (A), (B), (C) are exactly the same as the BV for mode 1 and involves the summing of the antenna 2 channel estimates from DPCH for slot *n* and antenna 2 channel estimates for slot *n* from the CPICH (using WMSA) over all the multi-paths.

(b) Block (D) consists of using equation (3) for *even n* and using the *real* part of the output of block (C) in figure (2) to implement a maximum-a-posteriori (MAP) detector the same way as BV for mode 1. Similarly for *odd n* the block (D) consists of using the *imaginary* part of the output of block (C) in figure (2) to implement a maximum-a-posteriori (MAP) detector the same way as BV for mode 1. Thus the output of block (D) is an estimate of the function *f[n]* based upon a MAP detector.

(c) The output of block (D) is now used by block (E) to estimate the $f_{Tx}[n]$ with a 1 slot delay.

(d) As shown in figure (2) the complexity of blocks (A), (B), (C), (D) and (F) is exactly the same the complexity for BV for current mode 1. The only added extra complexity for the SBV for the proposed mode is the one extra complex add needed in equation (5), per slot. But since this leads to a very small increase in complexity, we can say the SBV for the proposed mode and the BV for the current mode 1 have about the same complexity.

## 2.2 Beam former verification for current mode 2 (Nokia mode 2)

BV is also possible for current mode 2 proposed by Nokia in WG1#6. It involves a 8 hypothesis testing hence is more complex than the SBV for the proposed mode, but it performs better than the current mode 2 with no BV. *Hence we present the simulation results with/without BV for current mode 2 to show that the proposed mode with SBV always performs better than or equal to current mode 1 with BV and current mode 2 with/without BV.*

## 3.0 Simulation results

Simulations were performed to analyze the relative performance of current mode 1 with BV, current mode 2 with/without BV and the proposed mode with SBV. The simulations parameters are shown in the following table 4.

| Parameter | |
|---|---|
| Chip rate | 4.096 Mcps |
| Data rate | 8 Kbps speech service |
| Modulation | QPSK |
| Physical channel rate | 32 KSPS |
| Interleaving | 24X16, 10 ms |
| Convolutional coding rate | 1/3, K = 9 |
| Pilot/TPC/TFI | 8/2/0 |
| CPICH power | 10 % of the total BTS power |
| PC feedback rate | 1.6 Kb/s |
| TxAA feedback rate | 1.6 Kb/s |
| PC/TxAA feedback errors | 4% |
| PC/TxAA delay | 1 slot |
| PC step | 1 dB |
| PCCPH channel estimation for channel measurement | 1 slot |
| DPCH channel estimation | WMSA, 4 slots [0.4 1.0 1.0 0.4] |
| CPICH channel estimation for beam former verification | WMSA, 4 slots [0.4 1.0 1.0 0.4] |

*Table 4: Main simulation parameters*

The different simulation conditions and the results are summarized in table (5) below:

| Simulation condition | Current mode 1 with BV (Mode 1 CPICH-BV) | Current mode 2 without BV (Mode N2 DPCH) | Current mode 2 with BV (Mode N2 CPICH-BV) | Proposed mode with SBV (Proposed Mode CPICH-SBV) |
|---|---|---|---|---|
| Single path 5 Km/h | | | *Best performance* | *0.2 dB worse* |
| Pedestrian A, 5 Km/h | | | *Best performance* | *0.2 dB worse* |
| Pedestrian A, 10 Km/h | | | *Best performance* | *0.1 dB worse* |
| Vehicular B, 20 Km/h | | | | *Best performance* |
| Vehicular B, 40 Km/h | | | | *Best performance* |
| Vehicular B, 56 Km/h | | | | *Best performance* |

*Table 5: The different simulation conditions and the simulation results are given*

Figures (3), (4), (5), (6), (7) and (8) show the performance for the different simulation conditions namely single path 5 Km/h, Pedestrian A 10 Km/h, Pedestrian A 10 Km/h, Vehicular B 20 Km/h, Vehicular B 40 Km/h and Vehicular B 56 Km/h respectively.


*Figure 3: The performance the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for single path channel for a mobile velocity of 5 Km/h. We can see that the current mode 2 with BV has the best performance. The proposed mode with SBV is less than 0.2 dB away.*


*Figure 4: The performance of the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for Pedestrian A channel for a mobile velocity of 5 Km/h. We can see that the current mode 2 with BV has the best performance. The proposed mode with SBV is less than 0.2 dB away.*


*Figure 5: The performance of the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for Pedestrian A channel for a mobile velocity of 10 Km/h. We can see that the current mode 2 with BV has the best performance. The proposed mode with SBV is less than 0.1 dB away.*

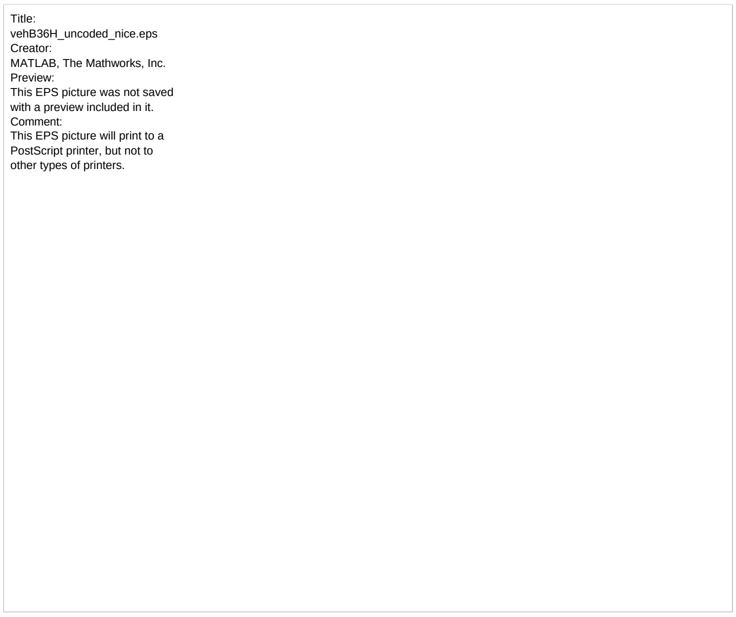


*Figure 6: The performance of the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for Vehicular B channel for a mobile velocity of 20 Km/h. We can see that the proposed mode with SBV has the best performance.*

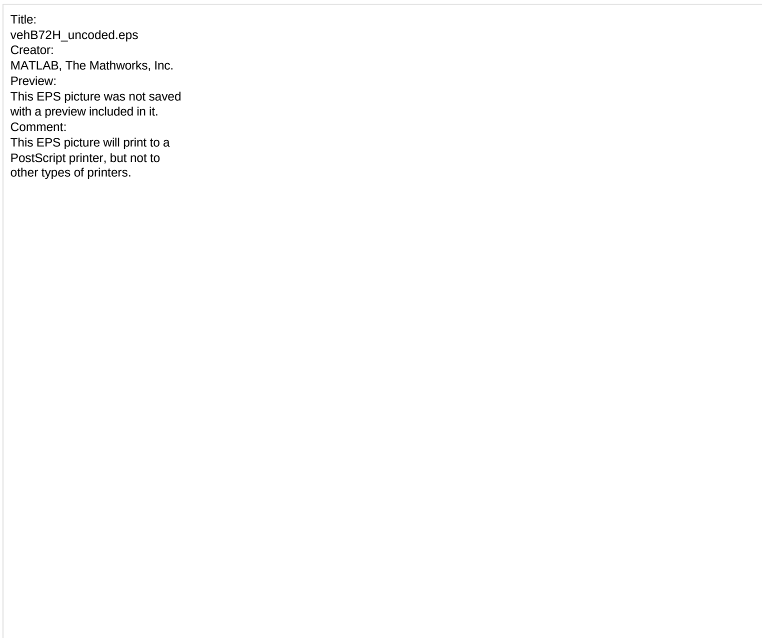


*Figure 7: The performance of the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for Vehicular B channel for a mobile velocity of 40 Km/h. We can see that the proposed mode with SBV has the best performance.*

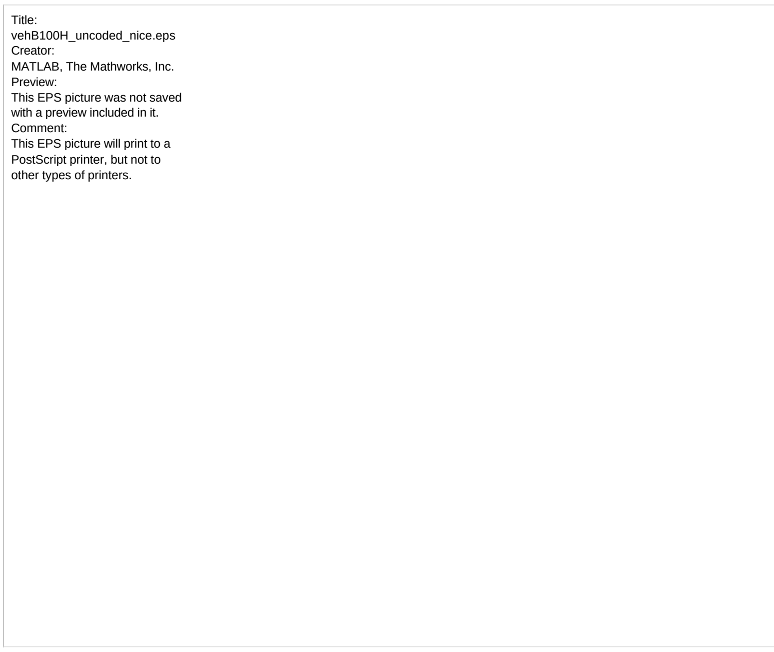


*Figure 8: The performance of the current mode 1 with BV, current mode 2 with/without BV and proposed mode with SBV is shown for Vehicular B channel for a mobile velocity of 56 Km/h. We can see that the proposed mode with SBV has the best performance*

**4.0 Conclusions**

We propose to make a small modification by merging the current mode 1 and the current mode 2 into a single mode with beam former verification. The proposed mode with BV performs better than or equal to the best of current mode 1 with BV and current mode 2 with/without BV. The proposed mode is very similar to the current mode 2 proposed by Nokia in the last WG1 meeting, making it a very small change to the standard. The advantages of the proposed mode are:

(1) Further reducing the total number of closed loop modes by 1
(2) Giving the best performance at all Dopplers where current mode 1 or mode 2 will be used
(3) There is no increase in mobile complexity to implement the SBV over the complexity of current mode 1 with BV.

*Hence we propose that the current mode 1 and mode 2 be merged into a single mode similar to current mode 2, except with a rotation of* $N\frac{\pi}{2} \bmod 2\pi$ *in each slot.*