ANALYSIS OF CLOSED LOOP POWER CONTROL MODES IN UTRA-FDD UNDER TIME VARYING MULTIPATH CHANNELS

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Abstract - Fast power control is perhaps the most important aspect in a WCDMA system like UTRA-FDD. In this paper, closed loop power control procedures in UTRA-FDD are studied. A physical layer simulator, which has been implemented in the C language from the standard of the UTRA-FDD mode [1]-[4], has been the tool to get the results included in this research. Simulations have been made for different mobile speeds (3, 30, 50 and 120Km/h) getting very different results. Power control gets worse quickly as the mobile speed grows. The implementation of an adaptive algorithm to predict the received power to try to improve the power control has been studied, but large improvements have not been obtained. Probability distribution of the power control error and influence of SIR estimation error have also been studied.

Keywords – Power control, WCMA, UTRA-FDD

I. INTRODUCTION

Fast power control is perhaps the most important aspect in a WCDMA system like UTRA-FDD [5]-[7]. Without it, a single mobile that arrives at a base station with a very high power can block the whole cell. In a WCDMA system, all the mobiles transmit at the same frequency and at the same time. They are separated at the base station thanks to their spreading codes. These codes are not completely orthogonal, and there is an interference due to the cross-correlation between the codes. The higher the power received, the higher the interference produced. This is the well-known near-far problem of CDMA. The capacity of the cell is maximized when all the mobiles reach the base station with the same power.

Open loop power control mechanisms are too inaccurate to make all the mobiles reach the base station with the correct power. The reason is that fast fading is uncorrelated between uplink and downlink, due to the large frequency separation of uplink and downlink bands in UTRA-FDD. However, open loop power control is used in UTRA-FDD, but only for the access at the beginning of a connection. Closed loop power control is the solution to this problem. Closed loop power control is also used in the downlink, although in this case the targets are different: there is no near-far problem, but it is suitable to provide additional power to mobile stations at the cell edge, because they suffer from increased other-cell interference.

Simulations about closed loop power control have been carried out to get results about the efficiency of this method.

II. CLOSED LOOP POWER CONTROL

Closed loop power control only exists in dedicated channels [4]. It is divided into inner-loop and outer-loop. Inner-loop has almost the same structure in both links.

The **uplink inner-loop** power control adjusts the base station transmit power in order to keep the received uplink signal to interference ratio (SIR) at a given SIR target, SIR_{target}. The base station (or stations if the mobile is in soft handover) should estimate signal to interference ratio SIR_{est} of the received uplink DPCH and then generate TPC commands and transmit the commands once per slot according to the following rule:

If $SIR_{est} > SIR_{target}$, TPC command to transmit is "0"

If $SIR_{est} < SIR_{target}$, TPC command to transmit is "1"

Upon the reception of one or more TPC commands in a slot, the mobile shall derive a single TPC command, TPC_cmd, for each slot. There are two algorithms supported by the mobile for deriving a TPC command. Higher layers determine which of these two algorithms is used.

The step size Δ_{TPC} can take two values, 1dB and 2dB. Higher layers also determine these values. After deriving of the combined TPC command TPC_cmd using one of the two supported algorithms, the mobile shall adjust the transmit power of the uplink DPCCH with a step of Δ_{DPCCH} (in dB) which is given by:

$$\Delta_{DPCCH} = \Delta_{TPC} \times TPC\_cmd$$

This study is focused on when only one TPC command is received in each slot, that is to say, when the mobile is not in soft handover. In this case, the algorithms are the following:

Algorithm 1

- If the received TPC command is equal to 0, then TPC_cmd for that slot is –1

- If the received TPC command is equal to 1, then TPC_cmd for that slot is 1

Algorithm 2

This algorithm makes it possible to emulate smaller step sizes than nominal step size. The mobile shall process received TPC commands on a 5-slot cycle. The value of TPC_cmd shall be derived as follows:

- For the first 4 slots of a set, TPC_cmd = 0.
- For the fifth slot of a set, the mobile uses hard decisions on each of the 5 received TPC commands as follows:

  - If all 5 hard decisions within a set are 1, then TPC_cmd = 1 in the 5^{th} slot

  -If all 5 hard decisions within a set are 0, then TPC_cmd = -1 in the 5^{th} slot

  -Otherwise, TPC_cmd = 0 in the 5^{th} slot

The downlink inner-loop power control also adjusts the mobile transmit power in order to keep the received downlink signal to interference ratio (SIR) at a given SIR target, SIR_{target}. TPC commands are also generated according to the following rule:

- If $SIR_{est} > SIR_{target}$, the TPC command to transmit is “0”
- If $SIR_{est} < SIR_{target}$, the TPC command to transmit is “1”

In the downlink there are two power control modes:

DPC_MODE = 0

The mobile sends a unique TPC command in each slot and the TPC command generated is transmitted in the first available TPC field in the uplink DPCCH.

The base station shall estimate the transmitted TPC command TPC_{est} to be 0 or 1 and shall update the power every slot.

DPC_MODE = 1

The mobile repeats the same TPC command over 3 slots and the new TPC command is transmitted such that there is a new command at the beginning of the frame.

The base station shall estimate the transmitted TPC command TPC_{est} to be 0 or 1 and shall update the power every three slots.

After estimating the k:th TPC command, the base station shall adjust the current downlink power P(k-1) (dB) to a new power P(k) (dB) according to the following equation:

$$P(k) = P(k-1) + P_{TPC}(k)$$

Where $P_{TPC}(k)$ is the k:th power adjustment (similar to Δ_{DPCCH} in uplink) and is calculated according to the following.

$$P_{TPC}(k) = \begin{cases} +\Delta_{TPC} & \text{if } TPC_{est}(k) = 1 \\ -\Delta_{TPC} & \text{if } TPC_{est}(k) = 0 \end{cases}, \text{[dB]}.$$

The power control step size Δ_{TPC} can take four values: 0.5, 1, 1.5 or 2 dB. It is mandatory for all the base stations to support Δ_{TPC} of 1 dB, while support of other step sizes is optional.

In the downlink, **outer-loop** power control adjusts the target SIR set up in the base station according to the needs, usually defined as a certain target bit error rate (BER) or block error rate (BLER). In the uplink, there is also another procedure, which is not specified, but open to the manufacturers optimisation. In this research, outer-loop mechanisms have not been included. The SIR target has been a simulation parameter.

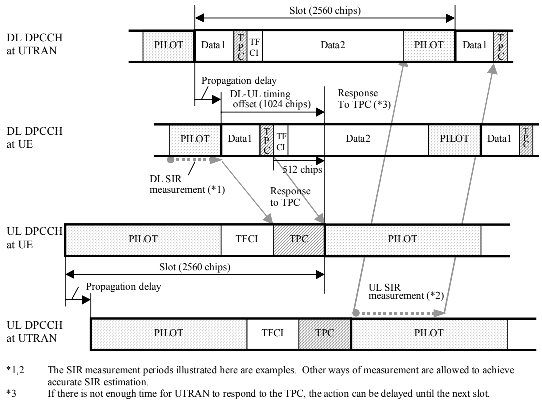

Fig. 1. Transmitter power control timing

Figure 1 shows the transmitter power control timing [4]. The frame timing of an uplink DPCH is delayed 1024 chips from that of the corresponding downlink DPCH measured at the mobile antenna. Thanks to this delay, in the uplink there is no delay between the slot whose power is estimated and the slot where the power is updated, as it is shown in the figure. However, in the downlink there is one-slot delay, but in this case closed loop power control does not need to be so accurate.

An adaptive algorithm has been implemented to predict the power that is going to be received in the next slot, in order to improve the closed loop power control. The key idea is closed loop power control uses the received power in a slot to update the transmitted power of the next slot. If the received power of that next slot (without updating) could be estimated, the updating could be more accurate. The algorithm that has been used is the Normalized LMS, whose expressions are [9]:

$$\mathbf{w}_{n+1} = \mathbf{w}_n + \beta \frac{\mathbf{x}(n)}{\| \mathbf{x}(n) \|^2} e(n)$$

$$y(n) = \mathbf{w}_n \, \mathbf{x}(n)$$

$$e(n)=d(n)-y(n)$$

Where $\mathbf{x}(n)$ is the input power vector, $\mathbf{w}_n$ is the coefficient vector, y(n) the estimated power, d(n) the real power and β is a normalized step size.

III. SIMULATION

Simulations have been carried out in C, with an UTRA-FDD physical layer simulator previously implemented. The simulator consists of a single base station connecting with a single mobile station. The aim of the simulations is to measure the power control error in terms of standard deviation in different conditions. The main parameters that have been used in the simulations are included in table 1.

Table 1
Simulation parameters.

Parameter	Value (for both links)	
Propagation Model	28.6 + 35log10(d) dB, d in metres	
BS Antenna Gain	14 dB	
MS Antenna Gain	0 dB	
Noise+Interference Power	-84 dBm	
Fast Fading Model (*)	3, 30, 50 and 120Km/h	
	Relative Delay [ns]	Average Power [dB]
	0	0
	976	-10
MS Power Class	Class 4: 21 dBm	
Transmission Rate	240 Kbps (SF_u=16 and SF_d=32)	
SIR_{target}	-8.6 dB	
RAKE receiver	5 branches one-chip delayed	
Transmitted Frames	400	

The distance between the mobile and the base station has been fixed at 200 metres. A parallel research has been made for different mobile speeds. The analysis has been carried out for the two step sizes that are allowed in both links: 1dB and 2dB. For 1dB, the normalized LMS algorithm has been simulated. The results obtained in the uplink and downlink are shown in figure 2 and figure 3 respectively.

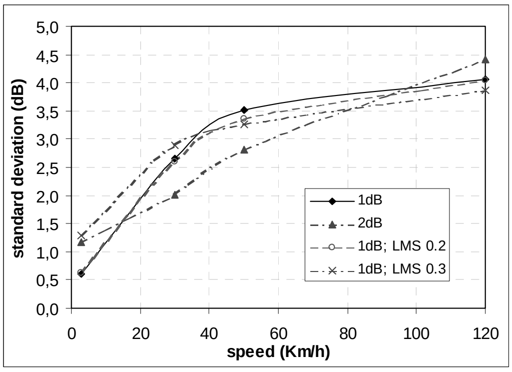

Fig. 2. Power control error vs. speed in the uplink.

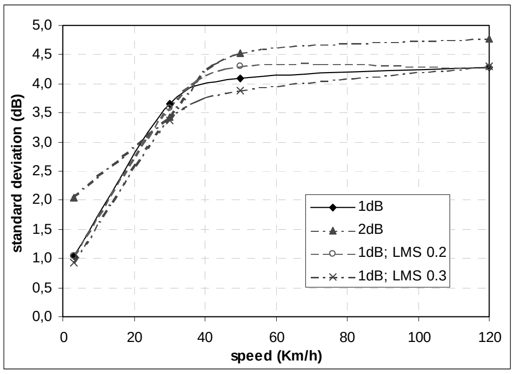

Fig. 3. Power control error vs. speed in the downlink.

With 1dB the error is pretty reduced at 3Km/h. If the step size is increased up to 2dB, the error grows. 1dB is enough to keep on channel variations at this speed, and this increase just introduces additional noise. However, as the mobile speed grows, the results are better with 2dB because higher variations can be followed with higher steps. When channel variations are too high, there are many mistakes in the power control, and this make the error be again smaller with 1dB. This happens at lower speed in the downlink because of the delay in the downlink power control.

No results of Algorithm 2 and DPC_MODE=1 are included in the figures. These algorithms are suitable for almost static conditions when the propagation channel varies slowly, since they are able to emulate smaller step sizes than nominal step size. The error standard deviation in the uplink with Algorithm 2 and in the downlink with DPC_MODE=1 (both with nominal step size of 1dB) at 3Km/h are 1.20dB and 2.05dB in that order, both higher than with Algorithm 1 and DPC_MODE=0. Logically, the results will be worse at higher speeds.

With regard to the use of an adaptive algorithm to predict the received power, there is not a great improvement. According to the mobile speed and the link, the results are better with β=0.2 or with 0.3, but the improvement in relation to not to use it is never over 0.3dB.

There is another effect over the power control, which has not been taken into account in the previous simulations. This is the error in the SIR estimation. In this study, no estimation algorithms have been implemented, but their effect has been simulated through an additive gaussian error. Simulations have been made at different speeds for both links (figures 4 and 5). At high speeds, this error hardly has influence, because the errors due to the large channel variations are much more important. On the other hand, at low speeds, this error is more significant in relation to the channel variations, although it goes on being fairly reduced.

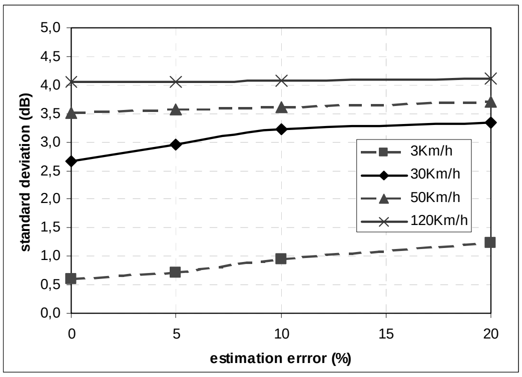

Fig. 4. Standard deviation vs. estimation error in the uplink

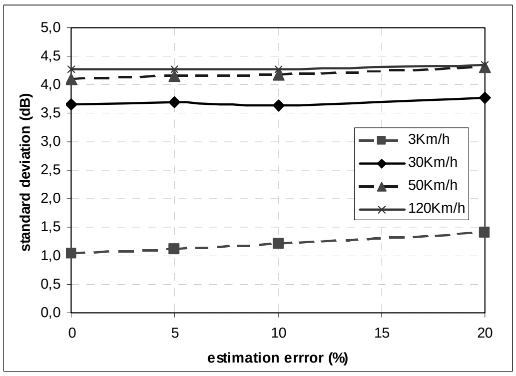

Fig. 5. Standard deviation vs. estimation error in the downlink

Another important aspect has been to demonstrate that closed loop power control error has a lognormal distribution. In figure 6, power control error and lognormal probability function are represented. This allows to introduce the error in simulations of higher layers without including the power control.

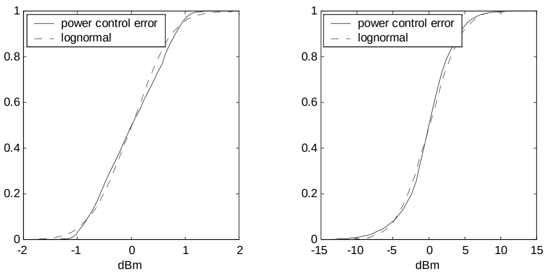

Fig. 6. Power control error vs. lognormal probability function. Δ_{TPC}=1dB; Algorithm 1.On the left, at 3Km/h and on the right at 50Km/h.

IV. CONCLUSIONS

In this paper, closed loop power control methods in UTRA-FDD have been analysed. According to the channel environment, different algorithms and step sizes are the most suitable to reduce power control error. These methods work properly at low mobile speeds. However, the error grows when the mobile moves at higher speeds, since the power control can not follow channel variations at these speeds. This error increase will reduce the capacity of the cell. In order to calculate this reduction, a study with several mobile stations would be necessary.

Although no SIR estimation algorithms have been studied in detail, a fairly error about 5 or 10% does not seem to have a very important influence in the power control according to the results obtained.

In relation to the LMS algorithm, a little improvement has been obtained. At low speeds, the error is so low that it can be hardly reduced and at high speeds, because of the low correlation in the channel characteristics for consecutives slots, there can not be a great improvement. Its use does not seem to be a good solution, because the little improvement does not compensate for the complexity of the algorithm and the risk of divergence.

ACKNOWLEDGEMENTS

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