Techniques to Reduce the Fading Effect in 3G Mobile Communications Systems

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***Abstract* –Detailed methods used in mobile radio communications sistems WCDMA 3G, to improve the performance of the system working in a fading environement are presented. For system efficiency are used RRM algorithms. To reduce the interference level and provide quality of service (QoS) in criticall situations (interference, fading), was used a power control algorithm. To handle the mobility of the Ms across cell boundaries the handover protocol needed in cellular systems. Was drawn some conclusions about third generation WCDMA air interface in interaction with the fading.**

***Keywords:* fast power control, RRM, diversity, soft handover, drifting.**

I. INTRODUCTION

A few algorithms are responsible for efficient utilization of the air interface resources. One of them the RRM (Radio Resource Management) is needed to guarantee QoS, to maintain the planned coverage area, and to offer high capacity. The RRM family algorithms can be divided into handover control, power control, admission control, load control, and packet scheduling functionalities [1]. Power control is needed to keep the interference levels at minimum in the air interface and to provide the required quality of service QoS.

II. RADIO RESURCE MANAGEMENT ALGORITHMS

The RRM algorithms can be based on the amount of hardware in the network or on the interference levels in the air interface. The difference between hard blocking and soft blocking is described below. Hard blocking is defined as the case where the hardware limits the capacity before the air interface gets overloaded. Soft blocking is defined as the case where the air interface load is estimated to be above the planned limit. It is shown that soft blocking based RRM, being a proactive method, gives higher capacity than hard blocking based RRM, which is a reactive method. If soft blocking based RRM is applied, the air interface load needs to be measured. These measurements of the air interface load are very important.

Typical locations of the RRM algorithms in a WCDMA (Wideband Code Division Multiple Acces) network are shown in Fig. 1.

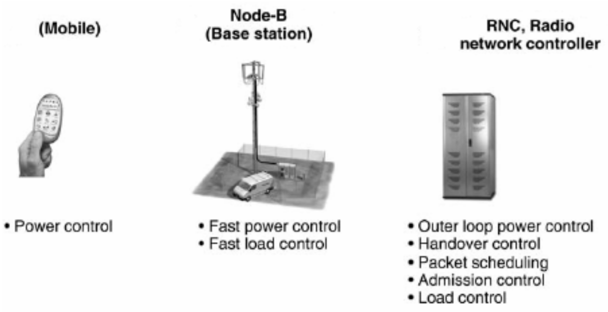

Fig. 1. RRM algorithms locations in a WCDMA network

III. POWER CONTROL

In this section important aspects of WCDMA power control are covered. Some of these issues are not present in existing second generation systems, such as GSM and IS-95, but are new in third generation systems, 3G, and therefore require special attention. In subsection A. is presented a fast power control and in subsection B power control and diversity are analyzed. Two special aspects of fast power control are presented in detail: the relationship between fast power control and diversity, and fast power control in soft handover. In WCDMA, fast power control with 1.5 kHz frequency is supported in both uplink and downlink. In GSM, only slow (frequency approximately 2 Hz) power control is employed. In IS-95, fast power control with 800 Hz frequency is supported only in the uplink.

A. *Fast power control*

In this section, are presented examples of the benefits of fast power control.

The experimented service is 8 kbps with BLER ¼ 1% and 10 ms interleaving. Simulations are made, with and without fast power control with a step size of 1 dB. Slow power control assumes that the average power is kept at the desired level and that the slow power control would be able to ideally compensate for the effect of path loss and shadowing, whereas fast power control can compensate also for fast fading. Two-branch receive diversity is assumed in the Node B. Vehicular is a five-tap channel with WCDMA resolution, and Pedestrian is a two path channel where the second tap is very weak [2]. Required E_b / N_0 with and without fast power control are shown in Table 1 and the required average transmission powers Table 2.

TABLE 1. Required E_b / N_0 with and without fast power control

	Slow power control (dB)	Fast 1.5 power control (dB)	Gain from fast power control (dB)
ITU Pedestrian A 3Km/h	11.3	5.5	5.8
ITU Vehicular A 3Km/h	8.5	6.7	1.8
ITU Vehicular A 20km/h	7.7	6.9	1.2
ITU Vehicular A 50Km/h	6.8	7.3	- 0.5

TABLE 2. Required relative transmission powers with and without fast power control

	Slow power control (dB)	Fast 1.5 power control (dB)	Gain from fast power control (dB)
ITU Pedestrian A 3Km/h	11.3	7.8	3.5
ITU Vehicular A 3Km/h	8.5	7.4	1.0
ITU Vehicular A 20Km/h	7.7	7.4	- 0.1
ITU Vehicular A 50Km/h	6.8	7.5	- 0.7

Fast power control gives clear gain, which can be seen from Tables 1 and 2. We can see that the gain from the fast power control is larger in the next cases:

-for low UE speeds than for high UE speeds;

-in required E_b / N_0 than in transmission powers;

-for those cases where only a little multipath diversity is available, as in the Pedestrian channel.

The relationship between fast power control and diversity is analysed in subsection B.

In Tables 1 and 2 the negative gains at 50 km/h indicate that an ideal slow power control would give better performance than the realistic fast power control. The negative gains are due to inaccuracies in the SIR estimation, power control signaling errors, and the delay in the power control loop. The gain from fast power control, from Table 1, can be used to estimate the required fast fading margin in the link budget. The fast fading margin is needed in the Ms (Mobile station) transmission power for maintaining adequate closed loop fast power control. The maximum cell range is obtained when the Ms is transmitting with full constant power, i.e. without the gain of fast power control. Typical values for the fast fading margin for low mobile speeds are 2–5 dB.

B. Power control and diversity

In this section the importance of diversity is analyzed together with fast power control. At low Ms' speed the fast power control can compensate for the fading of the channel and keep the received power level fairly constant. The main sources of errors in the received powers arise from inaccurate SIR (Signal to Interference Ratio) estimation, signaling errors and delays in the power control loop.

The compensation of the fading causes peaks in the transmission power. The received power and the transmitted power are shown as a function of time in Fig. 1 and 2 with an Ms speed of 20 km/h. These experimental results include realistic SIR estimation and power control signaling.

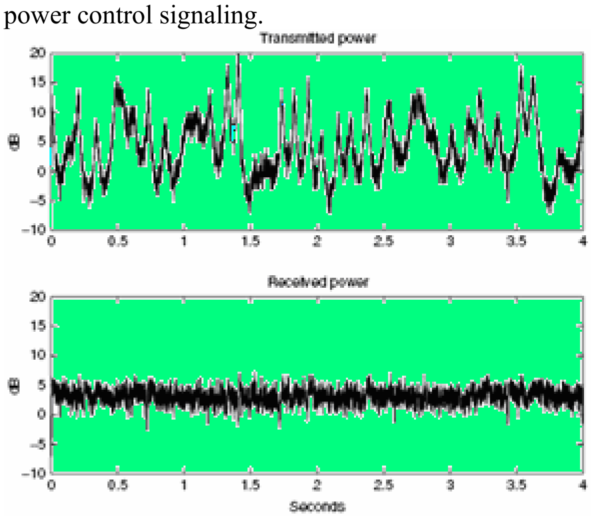

Fig. 1. Transmited and received power (average tap powers 0dB, -10dB) in Rayleigh fading channel at 20km/h

A power control step size of 1.0 dB is used. In Fig. 1 very little diversity is assumed, while in Fig. 2 more diversity is assumed in as it can observe variations in the transmitted power are higher in Fig. 1 than in Fig.

2, this is due to the difference in the amount of diversity. The diversity can be obtained with, for example, multipath diversity, receive antenna diversity, transmit antenna diversity or macro diversity.

With less diversity there are more variations in the transmitted power, but also the average transmitted power is higher. Here we define power rise to be the ratio of the average transmission power in a fading channel to that in a non-fading channel when the received power level is the same in both fading and non-fading channels with fast power control.

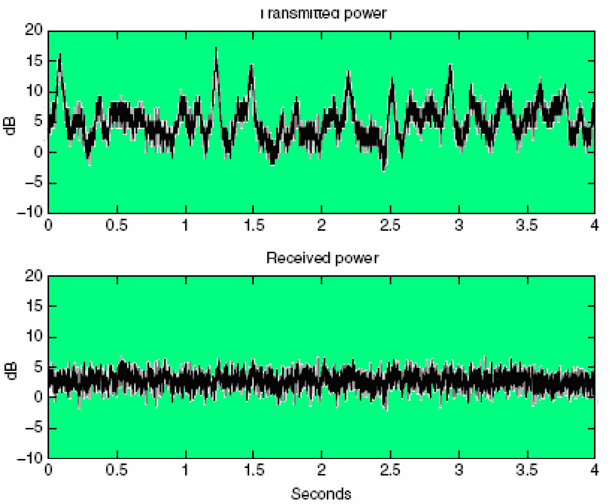

Fig. 2. Transmitted and received powers in Rayleigh fading channel, with (equal taps power) at 20km/h

The power rise after analyzed Fig.1 and 2 is depicted in Fig. 3.

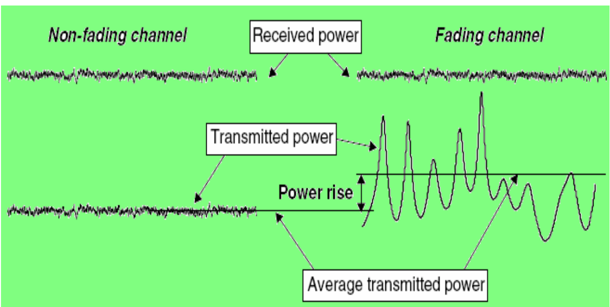

Fig. 3. Power rise in fading channel, with fast power control

The link level results for uplink power rise we presented in Table 3. The simulations are performed at different Ms speeds in a two-path Pedestrian channel with average multipath component powers of 0.0 dB and -12.5 dB. In the simulated conditions the received and transmitted powers are collected slot by slot. In case of ideal power control, the power rise would be 2.3 dB. A comprehensive treatment of the topic can be found in [3].

TABLE 3. Power rise in multipath channel ITU pedestrian A anntena diversity assumed

Ms speed (km/h)	Average power rise (dB)
3	2.2
5	2.1
10	2
20	1.6
35	1.4
45	1.1
50	0.8
100	0.5
120	0.2

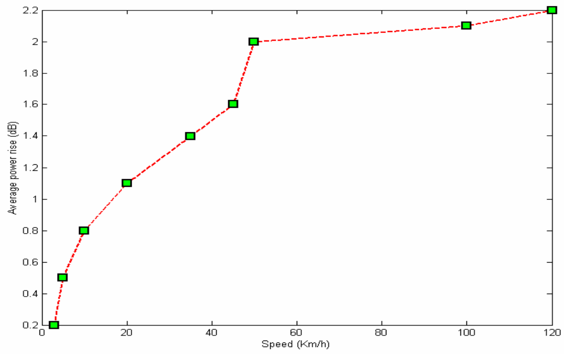

Fig. 4. Graphical corespondation of Table 3 values

The WCDMA system performance depends of the power rise parameters in both uplink and downlink connections. In the downlink, the air interface capacity is directly determined by the required transmission power, since that determines the transmitted interference. Thus, to maximize the downlink capacity the transmission power needed by one link should be minimized. In the downlink, the received power level in the Ms does not affect the capacity.

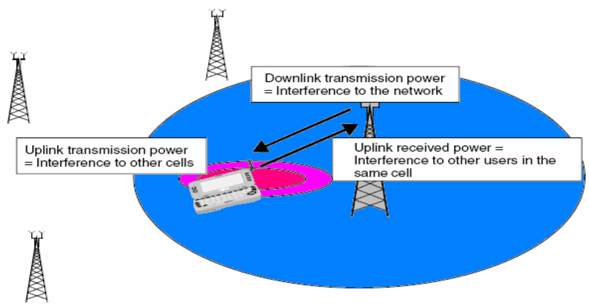

Fig. 5. Effect of received and transmission powers on interference levels.

In the uplink, the transmission powers determine the amount of interference to the adjacent cells, and the received powers determine the amount of interference to other Ms in the same cell. If, for example, there were only one WCDMA cell in one area, the uplink capacity of this cell would be maximized by minimizing the required received powers and the power rise would not affect the uplink capacity.

We are, however, interested in cellular networks where the design of the uplink diversity schemes using special software [4], has to take into account both the transmitted and received powers. The effect of received and transmission powers on network interference levels is illustrated in Fig. 5.

C. *Power control in soft handover*

Fast power control in soft handover has two major issues that are different from the single link case: power drifting in the Node B powers in the downlink, and reliable detection of the uplink power control commands in the UE. These aspects are illustrated in Fig. 6. and 7 and described in more detail, and a solution for improving the power control signaling quality is also presented.

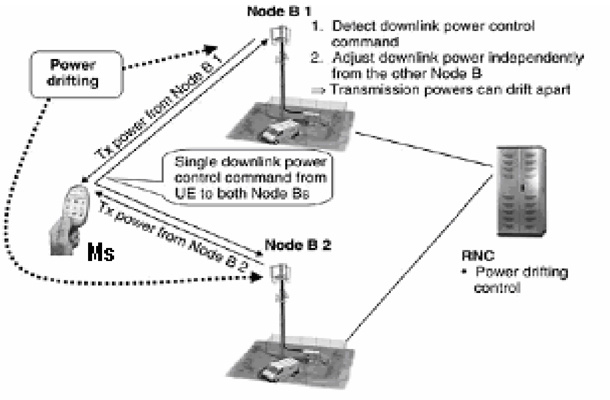

Fig. 6. Downlink power drifting in soft handover

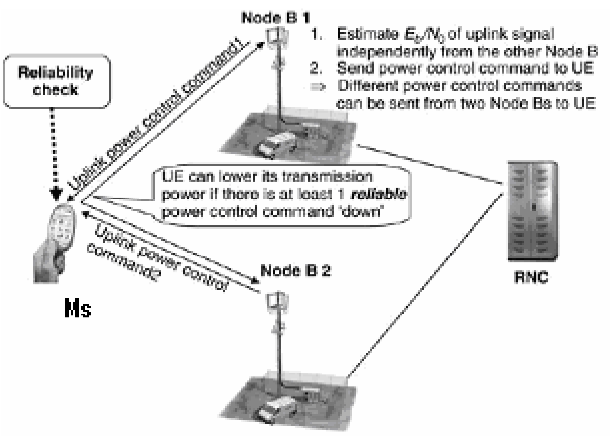

Fig. 7. Reliability check of uplink power control commands in Ms in soft handover

The Ms sends a single command to control the downlink transmission power, this is received by all Node Bs in the active set. The Node Bs detect the command independently, since the power control commands cannot be combined in RNC because it would cause too much delay and signaling in the network. Due to signalling errors in the air interface, the Node Bs may detect this power control command in a different way. It is possible that one of the Node Bs lowers its transmission power to that Ms while the other Node B increases its transmission power. These behaviors lead to a situation where the downlink powers start drifting apart; this is referred to here as power drifting [5]. If strict limits are established for the downlink power control, these power limits apply to the Mss specific transmission powers. Naturally, the smaller the allowed power control dynamics, the smaller the maximum power drifting. Another way to reduce power drifting is as follows. RNC (Radio Network Core) can receive information from the Node Bs concerning the transmission power levels of the soft handover connections. These levels are averaged over a number of power control commands, e.g. over 500 ms ore equivalently over 750 power control commands. Based on those measurements, RNC can send a reference value for the downlink transmission powers to the Node Bs. The soft handover Node Bs use that reference value in their downlink power control for that connection to reduce the power drifting. The idea is that a small correction is periodically performed towards the reference power. The size of this correction is proportional to the difference between the actual transmitted power and the reference power. This method will reduce the amount of power drifting. Power drifting can happen only if there is fast power control in the downlink.

IV CONCLUSION

From Fig. 4 some conclusions result. At low Ms' speed, the simulated power rise values are close to the theoretical value of 2.3 dB, indicating that fast power control works efficiently to compensate the fading.

At high Ms' speed (over 100 km/h) it is only very little power rise since the fast power control cannot compensate for the fading.

Also one the other point of wiev, the power drifting fenomenon is not desirable, since it mostly degrades the downlink soft handover performance. That can be controlled via RNC, by setting relatively strict limits for the downlink power control. A large power control dynamics typically improve power control performance, as shown in Table 2.

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