TSG-RAN Working Group 1 meeting #17 *TSGR1-00-1447*
Stockholm, Sweden

November 21 – 24, 2000

Agenda Item:

Source: **Siemens AG**

Title: **Improved Uplink Power Control at Power Limits (revision of R1-00-1359)**

Document for: **Discussion and Approval**

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1. Abstract

At the last meeting in Korea we presented a draft work item description [3], which aims to improve the uplink power control operation at maximum and minimum power limits. The conclusion in the plenary of WG1 #16 was to postpone the decision how to proceed with this WI to the next meeting WG1 #17. Some more information regarding this topic should be provided, i.e. the expected impacts on the specifications and some simulation results indicating the achievable gain.
Thus, this paper shows a possible solution for the improvement of the power control behaviour at the power limits. In Section 4 simulation results are presented. Section 5 describes the anticipated changes and impacts on the Specifications and the compliance with the Release 1999 Specifications.

2. Introduction

The closed loop power control is an essential feature for the WCDMA system. Nevertheless some exceptions appear, for which this closed loop is interrupted during a certain time period. Compressed mode in the uplink and downlink is one example, which requests an extraordinary attention. Therefore the "Recovery Period power control mode" and the so called "Initial Transmit Power mode" are introduced obtaining a balanced power control after the gap as fast as possible.

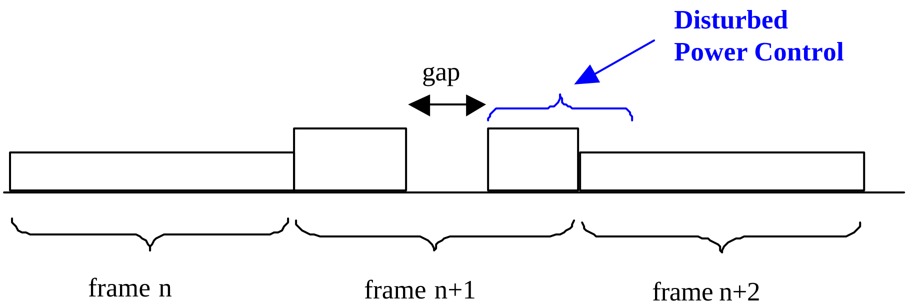

Figure 1: *Disturbed Power control due to Compressed mode*

In addition to the case of compressed mode the closed loop power control loop is also be interrupted when a UE is operating at the power limits as already depicted in [1], [3].

In the following case we consider a UE transmitting immediately below the maximum power limit.
In the case a higher data rate is requested the total transmit power will increase (date 1), but will also be scaled to the

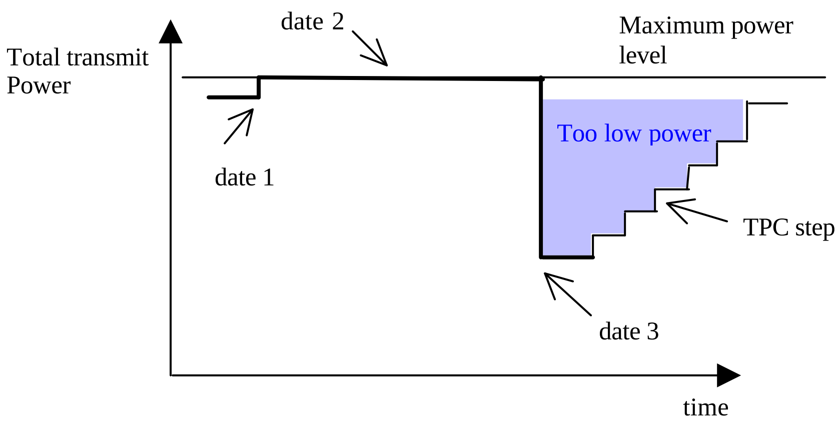

Figure 2: *Power behaviour scenario at the maximum power level*

maximum allowed transmit power according to section 5.1.2.6 of [5]. If the high data rate is released again (refer to date 3 of figure 2) and the UE has not moved remarkably, the channel and power condition should prevail unchanged. But according to the current specification the gain factor readjustment is performed using the maximum power level for reference. As the UE has not moved too far, the power attitudes would be ideally the same like before date 1. Due to the present procedure in the specification the UE commences always with too low power while leaving the maximum power limits due to gain factor readjustments.

At the minimum power level an equivalent problem occurs (see figure 3). Looking at a UE residing immediately next to the base station, the total transmit power could be very low. In the case of reducing the data rate the UE is not forced to reduce the transmit power below its minimum power level.

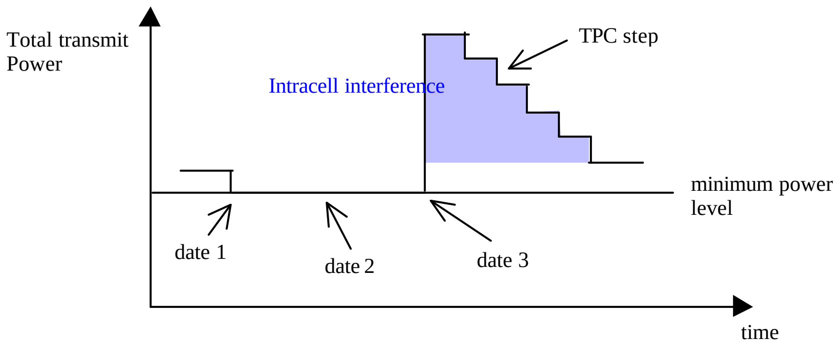

Figure 3: *Power behaviour scenario at the minimum power level*

If the UE has to increase the total data rate again (date 3), the power adjustment due to gain factor readjustment would increase the power in the conventional way i.e. adding the power amount to the actual transmitted power and not to the previously requested transmit power. That means the UE commences always with too much power when leaving the minimum power limit due to gain factor readjustments. This wrong transmit power value must be corrected and adapted to a suitable attitude by the inner loop power control. During this adaptation phase the UE causes intra cell interference (see the blue hatched field in figure 3).

3. Proposed modified Power Control Algorithm

We propose to exploit the information of the power control commands and gain factor readjustments immediately before reaching the power limits. We therefore introduce P^{trace} to maintain an estimate of the ideally required power level, if this ideal power exceeds the UE capabilities. P^{trace} is initialised when the requested power exceeds the UE capabilities (either due to a PC step or gain factor readjustment or both). It will be maintained and be further updated following power adjustments due to gain factor readjustments while the UE is transmitting at the maximum power level and TPC_cmd is equal to 1. In the minimum power level case P^{trace} is initialised at the first requested falling below the minimum power limit and also traces power adjustments due to gain factor readjustments while the UE is transmitting at minimum power level and TPC_cmd is equal to –1. Figure 4 and 5 present the improvement in comparison to figure 2 and 3.

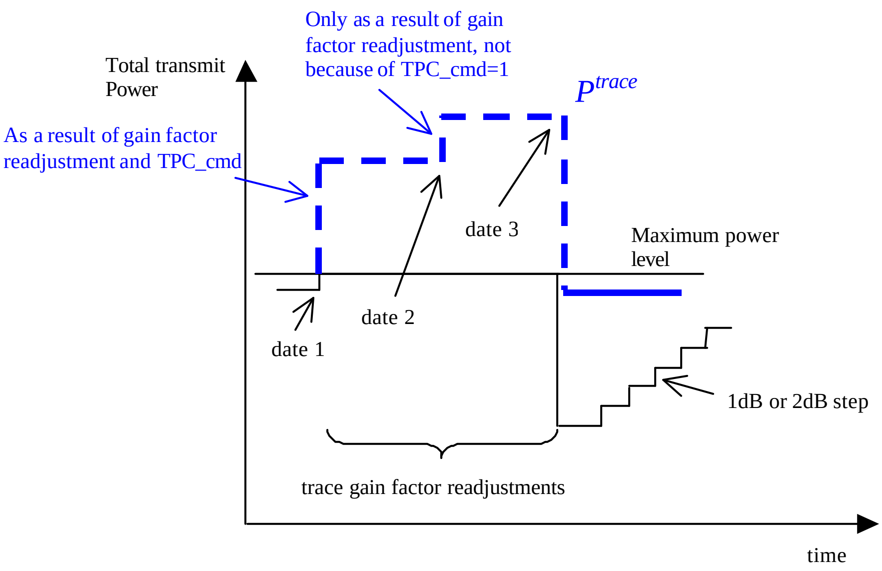

Figure 4: *Improved power control at the maximum power level*

The blue coloured line in figure 4 presents the proposed changes for the power control algorithm at the power limits. After date 3 the advantage of the proposal is obvious as the UE uses the most likely power amplitude. According to the current description the UE uses always a too low power level.

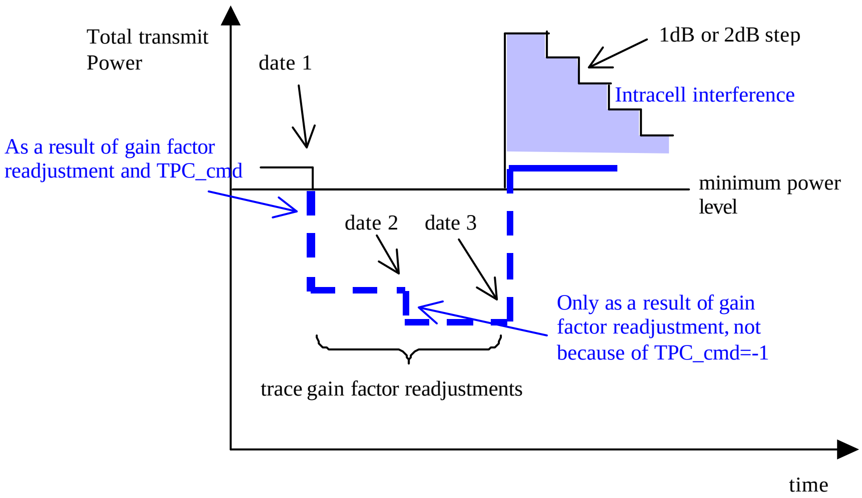

Figure 5: *Improved power control at the minimum power level*

Figure 5 demonstrates the proposed power control applied to a UE operating at the minimum power level. The intra cell interference is avoided.

4. Simulation results

In order to investigate the benefit of the proposed method at the maximum power limit we had to determine some representative parameters. So we consider a UE operating close to the maximum power limit while conveying data with a rate of 8 kbit/sec (DPDCH). A fter a request for an additional data rate of about 384 kbit/sec the DPCCH maintains the Spreading Factor (SF) of 256 and the DPDCH uses the SF 4. The convolutional 1/3 coder with an adequate rate matching scheme is applied. Due to the data rate increase the transmitted power would (in most of the cases) exceed the maximum power limit specified in [6]. Scaling is applied and after 10 ms the higher data rate should be released again and the previous data rate is applied again. In figure 6 we consider a UE having a speed of 3 km/h in the Vehicular A model.

The conducted simulations compare the achieved BER in the first frame after releasing the higher data rate. The x-axis represents the received bit power E_b of the second frame after releasing the higher data rate in relation to the prevailing noise power N_0. This is done since in the second frame the power control is balanced again. So, the x-axis represents a target E_b/N_0. The so called "Current Scheme" in figure 6 represents the BER in the first frame after releasing the higher data rate by using the currently specified scheme in [5]. The curve "New Scheme" shows the BER in the first frame by using the proposed scheme as presented in chapter 3. The yellow line "Next Frame" represents the BER of the second frame.

The achieved gain is about 3 dB by using the proposed method. Comparing the two lines called "New Scheme" and "Next Frame" shows that the proposed scheme yields nearly the same performance as in the undisturbed and balanced power control case.

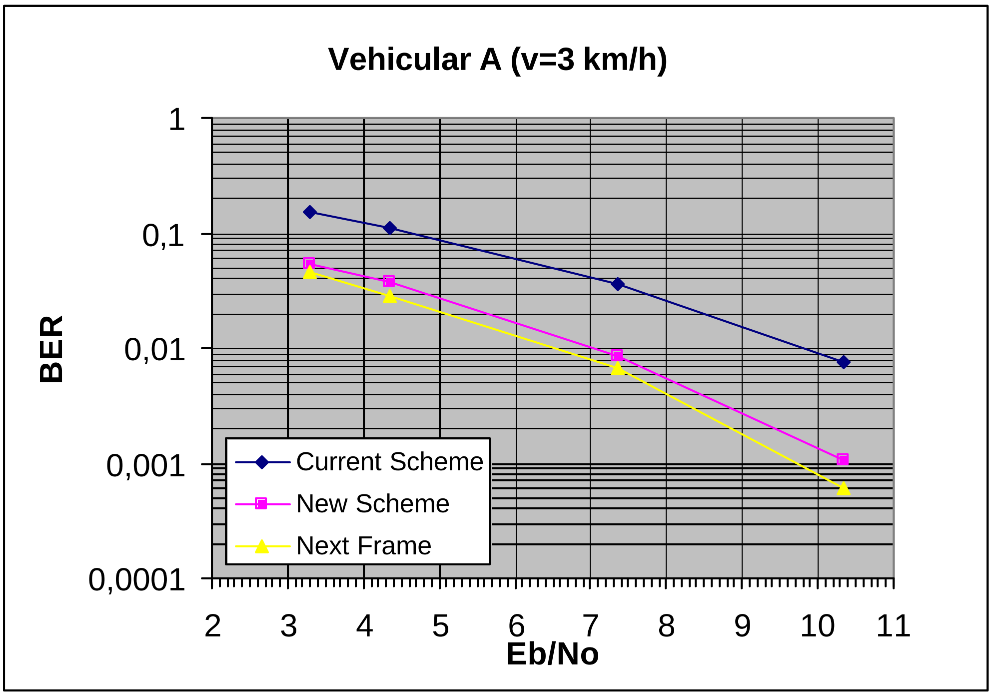

Figure 6: *BER after releasing higher data rates (speed: 3 km/h)*

In figure 7 the same simulation assumptions are done but the speed is switched to 30 km/h. The gain which can be reached is slightly smaller than in the previous case of v=3 km/h. The reason is that the power control is disturbed in such a way that the estimated value P^{trace} is not correlated to the power setting after the release of the higher data rate. The information content of P^{trace} decreases slightly with increasing speed. But with the current scheme the start value of the power setting after the higher data rate is always too low and not favourable.

At higher velocity a further effect occurs.

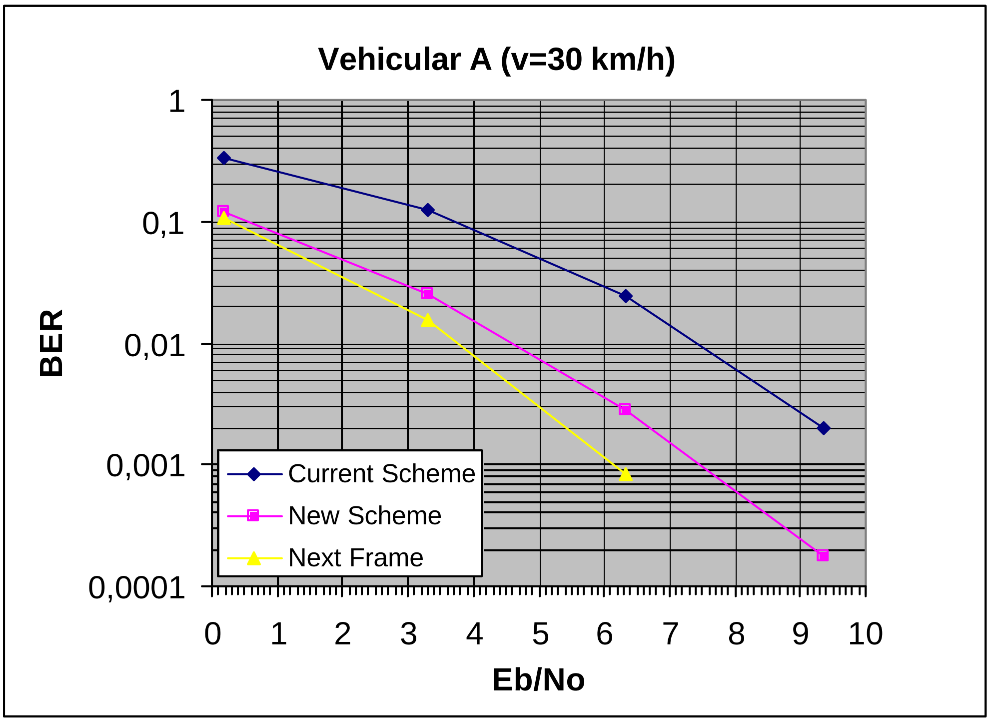

Figure 7: *BER after releasing higher data rates (speed: 30 km/h)*

Also, we expect a gain at 120 km/h, which will correspond to figure 6. The reason is, the fast power control cannot follow the fast fading but is able to adjust to the slow lognormal fading. P^{trace} as well cannot follow the fast fading but is a good measure for the expected lognormal fading after reducing the data rate so that the power after the higher data rate period can rely on the value of P^{trace}.

5. Anticipated Impacts on Physical layer Specifications

The proposed method would only have some impacts on section 5.1.2.6 of [5], which would be an appropriate place to introduce P^{trace} (a text proposal can be seen in [1]). These changes would be full backwards compatible to Release 1999. No changes are foreseen for the Technical Specifications of WG 4.

Note that there are no issues with respect to backward compatibility with R99. The R4 UE will use a more appropriate power level after the change of data rates and the connection will enjoy a better quality. The network can know which algorithm the UE uses (the network knows whether the UE is a R99 or R4 UE), however, the network does not have to know the exact PC behaviour of the UE. Therefore it is even possible to use this enhanced algorithm when a R4 UE is communicating with a R99 Node B. For the same reason it is possible to use R99 UEs in a R4 network, of course without using enhanced algorithm and its gain.

WG 4 Specifications don't consider the fact described in chapter 2. In [6] WG 4 gives the minimum requirements referring to the wind up effect, which takes place when then Node B reaches the maximum downlink power and the UE has to stop to increase the target SIR despite an insufficient BER is received. But this applies only for the downlink. The way how the UE has to react after leaving its power limits is not specified in the WG 4 Specifications.

6. Gained Advantages

The simulation results confirm that the proposed uplink power control method yields an advantage at low UE's velocities and also at higher ones.

At the minimum power level the intra cell interference can be reduced in any cases, since the proposed method adjust a favourable power attitude in comparison to the current method, which predicts a too high power after releasing the lower data rate.

We see the advantage in the fact that this demonstrated gain is achieved without any actual complexity increase. This proposal is only deemed as a correction of a problem of the current method when the present method uses wrong power level as the reference power, i.e. the power after applying a scaling if the UE capabilities are exceeded.

We therefore propose to refine the PC behaviour like presented above.

7. References

[1] TSGR1#15(00)1056; Berlin, Germany; 8-2000; Siemens AG; Clarification of power control at maximum and minimum power

[2] TSGR1#15(00)1125; Berlin, Germany; 8-2000; Siemens AG, Philips; Proposal for work item on improved power control at maximum and minimum power

[3] TSGR1#16(00)1222, Pusan, Korea; 10-2000; Siemens AG, Philips; Draft Work Item: Improved power control at power limits

[4] TSGR1#14(00)0973; Oulu, Finland;7-2000; Philips; CR 25.214-118r2: Clarification of power control at maximum and minimum power

[5] TS 25.214 V3.4.0: "Physical layer procedures (FDD)"

[6] TS 25.101 V3.3.1: "UE Radio transmission and Reception (FDD)"