TSG-RAN Working Group 1 meeting #18
Boston, U.S.A.

TSGR1-01-0087

January 15 – 18, 2001

Agenda Item: **WI 36: RAN Small Technical enhancements and improvements**

Source: **Siemens AG**

Title: **CR for Power Control at Power Limits**

Document for: **Approval**

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1. Abstract

At the last meeting in Stockholm we presented simulation results referring the proposed improvement for power control at power limits [5]. In the plenary it was concluded to present an CR at the next meeting in Boston. In this paper we present an appropriate CR clarifying the power control at power limits and answer some questions raised since the last meeting. Additional some more simulation results we carried out are presented.

2. Introduction

Accurate power control is one of the basic requirements for the high WCDMA system capacity. The transmit power must be kept as low as possible in order to minimise interference, and just high enough to ensure the required quality of service [8]. Looking at the current Rel. 99 specification there are some decisive deficits in the power control behaviour close to the power limits. The CR we provide in this paper counteracts these deficits and yields an accurate power control situation we are used to get in the "normal" power level cases.

3. Answers to questions raised in the WG1#17 meeting

At the last meeting in Stockholm some questions were raised which for example should be clarified with WG4. Thus we present all questions we received and give an appropriate answer:

- What are the reasons for this significant 3 dB gain, how can this be achieved?
  Due to the current Specifications the power is too low after leaving the maximum power limit and the power has to be ramped up to the appropriate value. This disturbed power control causes a coding degradation.
  When we use the proposed improvement we get two effects: coding gain and an appropriate power level immediately after leaving the power limits.
  We get a coding gain since the disturbance of the power control is reduced and the BS receives almost a constant power. But the major part of the indicated 3 dB gain is reached because of the appropriate power level immediately after leaving the power limit. Looking at the simulation results in figure 1 (we already presented in Stockholm) you can recognise that our proposal approaches to the ideal undisturbed power control curves (yellow).
- What is the expected time period for that indicated gain?
  This depends on the amount of power control disturbance. That means the greater the deviation from the appropriate power level the greater the period of gain, which is achieved by using our proposed method. Furthermore the period of gain depends also on the power control algorithm i. e. emulated steps size or normal step size. If emulated step sizes are applied then the time period will be 5 times longer than in the PCA=1 case.
  Conclusion: In general a few slots up to some frames can be affected by the gain.
  The gain projected to the entire link depends on the frequency of occurrence.
  The achieved gain we presented in the simulation results refers to a certain time period and not permanently to an entire link. The same is encountered in case of power control during compressed mode. There some additions for power control are also introduced in order to reduce and mitigate the power control disturbance immediately after the gap. This enhancements are referred to the period of some slots after the gap and not to the entire link.
- TS 25.133 section 6.4 and 6.4.1: Does this section prevents a UE from increasing or decreasing data rate when a

UE operates at maximum or minimum power limit?

It is stated when the UE reaches the maximum transmit power it shall limit the usage of transport format combinations for the assigned transport format set. Section 6.4.1 presents more detailed information: A requested exceeding is not excluded. Moreover a parameter T1, which is still to be specified, counts the period of the UE output power requested by UTRAN to be higher than the UE maximum transmit power in order to reduce the data rate after a period of T1.

Conclusion: A restriction of possible TFC due to reaching the maximum power limit is foreseen. A requested exceeding of the maximum power due to a request from UTRAN is considered. After a certain time T1 of exceeding the data rate should be reduced (block certain TFC), but the power control behaviour at that point is not clarified yet. That is exactly what our proposal intends to clarify.

- Release '99 compatibility

  There are no issues with respect to R99 backward compatibility. 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 the enhanced algorithm and its gain.

4. Simulation results

As already depicted in [5] we consider a UE operating close to the maximum power limit. The UE conveys data with a rate of 8 kbit/sec (DPDCH). After 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 data rate increase the transmit power is requested to exceed the maximum power limit specified in [7]. Corresponding to section 5.1.2.6 of TS 25.214 scaling is applied and after 10 ms the higher data rate should be released and the previous data rate is applied again. In TS 25.133 a time period [T1] is scheduled. This time period [T1] counts the period of the UE output power requested to be higher than the UE maximum transmit power in order to reduce the data after the latest period T1.

The conducted simulations compare the achieved BER in the frame after releasing the higher data rate, since due to the current specifications the transmit power is expected to be too low. The x-axis represents the received E_b/N_0 (bit power to noise ratio) in the balanced power case. So, the x-axis represents the target E_b/N_0. The so called "Current scheme" in figure 1 and 2 represents the BER in the frame immediately after the higher data rate by using the current specified scheme in [6]. The curve "New Scheme" shows the BER in that frame by using the proposed scheme as presented in the CR. The yellow line "undisturbed PC" represents the BER of a power balanced frame.

Figure 1 shows the simulation results we already presented in [5] at the Stockholm meeting. Figure 1 applies PCA=1 and for comparison Figure 2 applies PCA=2. Please note if we use PCA=2 then the time period of that indicated gain will last at least 5 times longer than in the PCA=1 case. Comparing the two lines called "New Scheme" and "undisturbed PC" shows that the proposed scheme yields nearly the same performance as in the undisturbed and power balanced case. For simulation results engaging different speed assumptions please refer to [5].

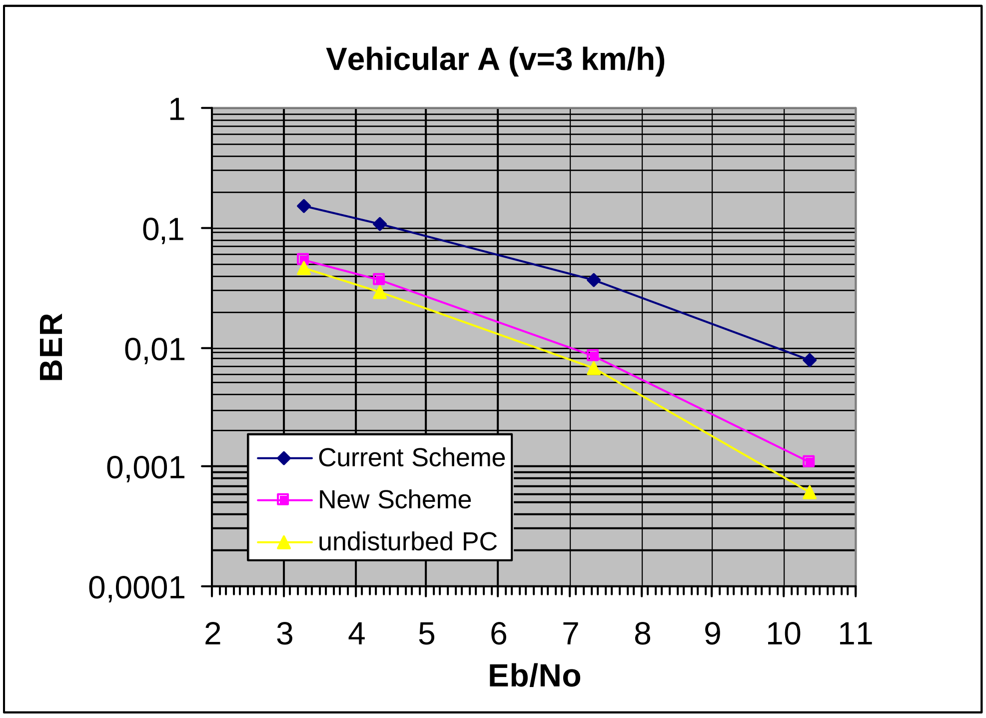

Figure 1: *BER after releasing higher data rates (speed: 3 km/h)*

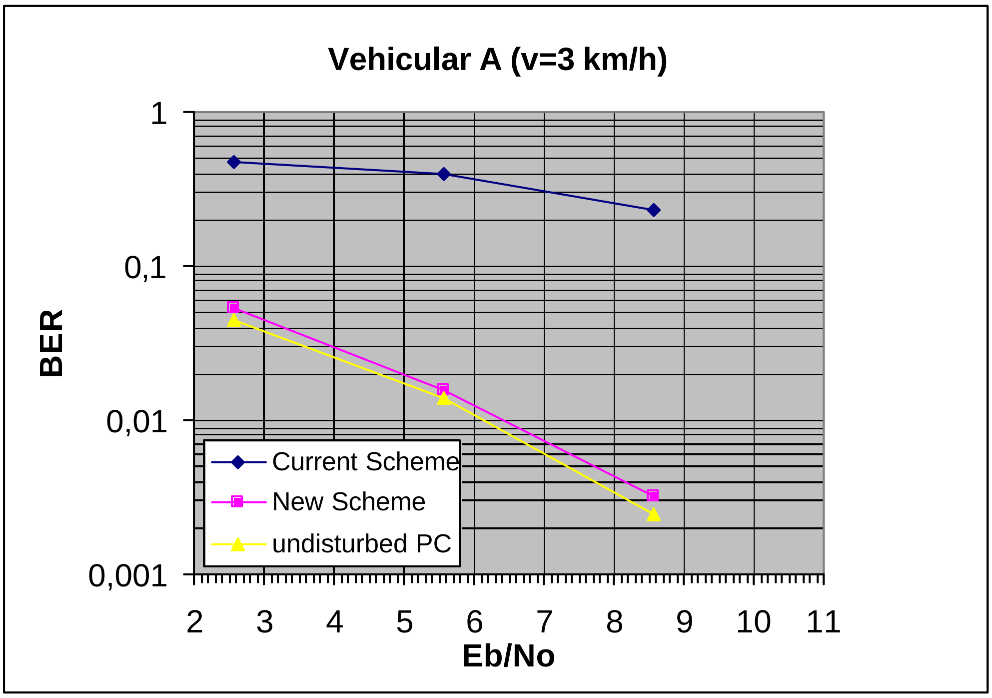

Figure 2: *BER after releasing higher data rates (speed: 3 km/h) by using emulated step sizes*

We also carried out simulations for the minimum power level case. We consider a UE, which operates close to the Base Station with a transmit power near the minimum power level. This UE conveys data with a rate of 8 + 384 kbit/sec (DPDCH). After a request for releasing the 384 kbit/sec service the DPCCH maintains the Spreading Factor (SF) of 256 and the DPDCH switches from SF 4 to SF 256. Due to data rate reduction the transmit power is requested to fall below the minimum power limit specified in [7]. Corresponding to section 5.1.2.6 of TS 25.214 scaling is applied so that the total transit power is scaled up to –50 dBm. In our simulation assumptions the higher data rate should be resumed again after 10 ms and thus the previous data rate is applied again. According to the current specification the UE transmits with too much power while the higher data rate is engaged again and therefore causes intra cell interference unnecessarily.

In order to get a feeling of the impact of this caused intracell interference to the other UEs residing in the same cell, we conducted simulations. Therefore we consider besides this interfering UE a second UE, which is exemplary observed in order to get the suffered impact. Please note this impact can be extracted to all other UEs of this cell. This second UE uses a low bit rate service of about 8 kbit/sec.

The conducted simulations compare the BER of the second UE at that time when the interfering UE resumes the higher data rate. The x-axis represents the received $E_b/(N_0+I)$ (bit power to noise ratio plus interference). The so called "Current scheme" in figure 3 represents the BER of the second UE when the first UE obeys to the current specified scheme in [6]. The curve "New Scheme" shows the BER achieved when the first UE uses the proposed scheme as presented in the CR. The "New Scheme" line is shifted to the right because the unnecessary interference caused by the first UE is avoided. Additionally you can recognise that the proposed scheme achieves besides this shift of the curve a better BER performance. This gain, which is achieved for this second UE as an example, can be extracted to all other UEs camp ing in that cell. This means by using the proposed method the cell capacity is increased and the BER is optimised.

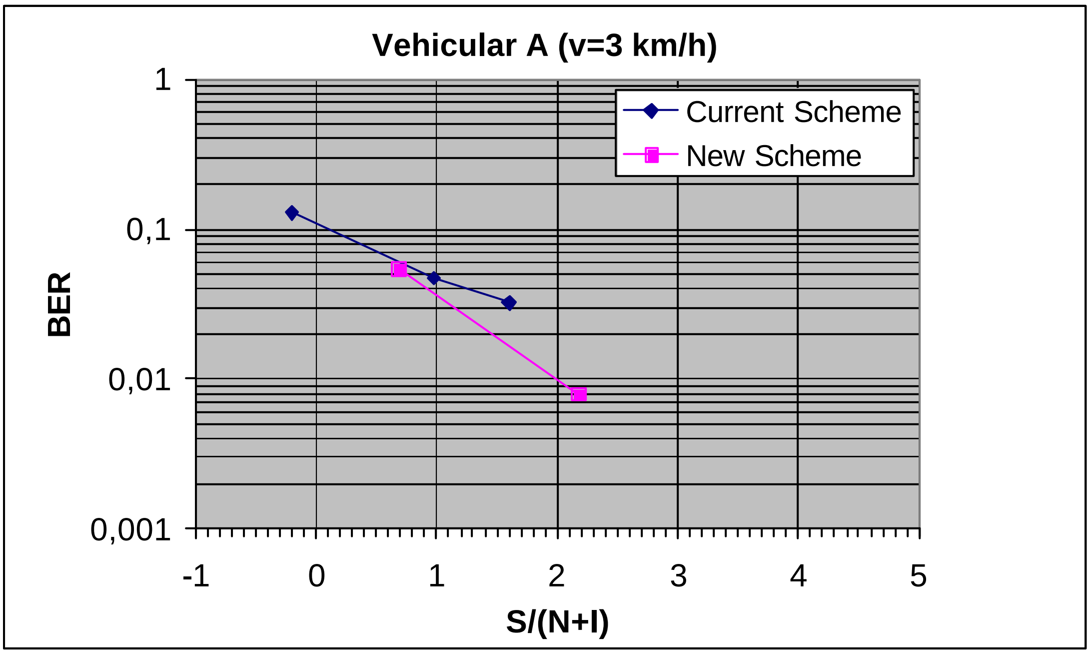

Figure 3: *BER of UE encountering the interference of another UE operating at minimum power level*

5. Some words to the change request

[5] already depicts the basic idea of the proposed method for power control at power limits. In the appendix (section 7) of this paper an algorithm is attached in order to give an extensive description. The description is divided into two algorithms, i. e. the algorithm for the introduced variable P^{trace} (figure 4) and the algorithm for the total transmit power (figure 5). In figure 4 and 5 the following abbreviations are applied:

$P_{Tx}(i)$: UE total transmit power (DPCH) of the current slot

$P_{Tx}(i-1)$: UE total transmit power (DPCH) of the previously transmitted slot

? $_{DPCH}(i)$: current UE total power adjustments due to TPC commands

? $P_{Gain}(i)$: current UE total power adjustments due to gain factor readjustments

$y=\{x\}_{min}^{max}$: min ? y ? max

Please see the Rel. 4 Change Request below. Three cases are distinguished:

1. The total transmit power is within the allowed power limits.
2. An overstep of the power limits is required
3. An overstep of the power limits was already requested in the previous slot and new power changes should be adopted to the total transmit power.

In case 3 if PCA=1, then we combine the current and the previous TPC_cmd together before a TPC_cmd is executed. This counteracts the impacts of TPC bit errors.

6. 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] TSGR1#17(00)1447; Stockholm, Sweden; 11-2000; Siemens; Improved Uplink Power Control at Power Limits

[6] TS 25.214 V3.5.0: "Physical layer procedures (FDD)"

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

[8] Sipilä, K., Laiho-Steffens, J., Wacker, A. and Jäsberg, M., `Modelling the Impact of the Fast Power Control on the WCDMA Uplink´, *Proceedings of VTC'99 Spring*, Houston, TX, 16-19 May 1999, pp. 1266-1270.

7. Appendix

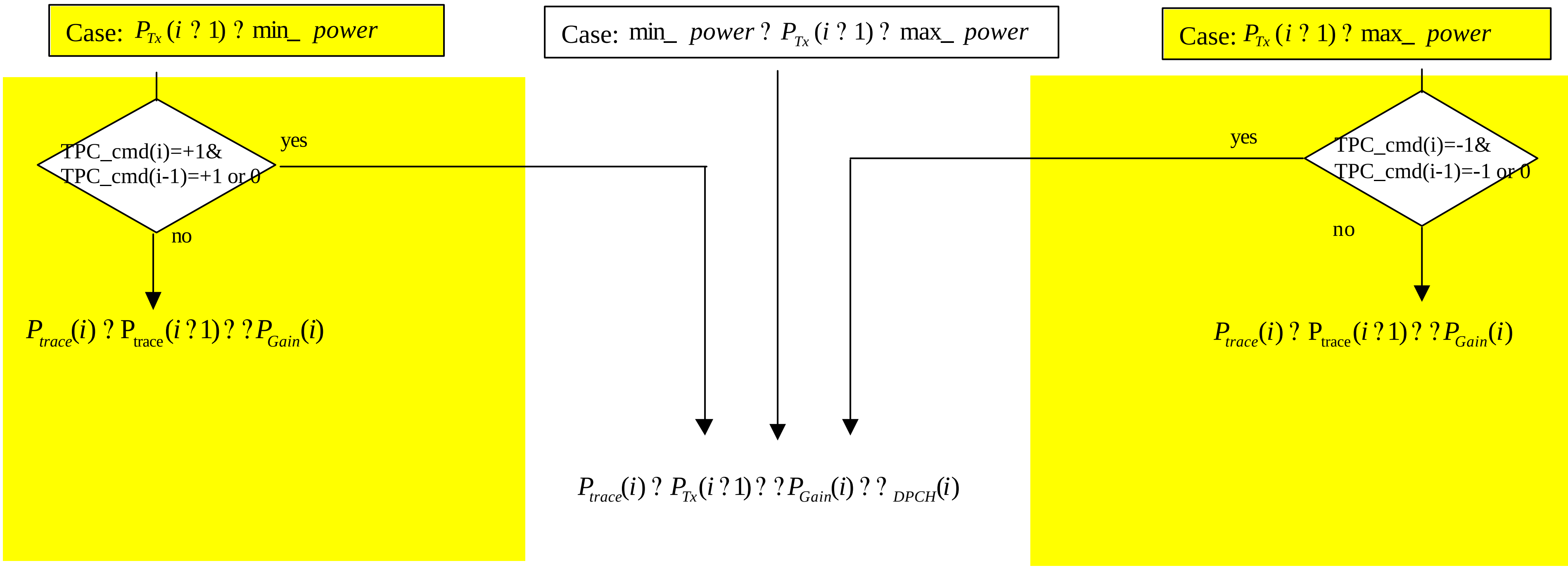

Figure 4: *Algorithm for* P_{trace}

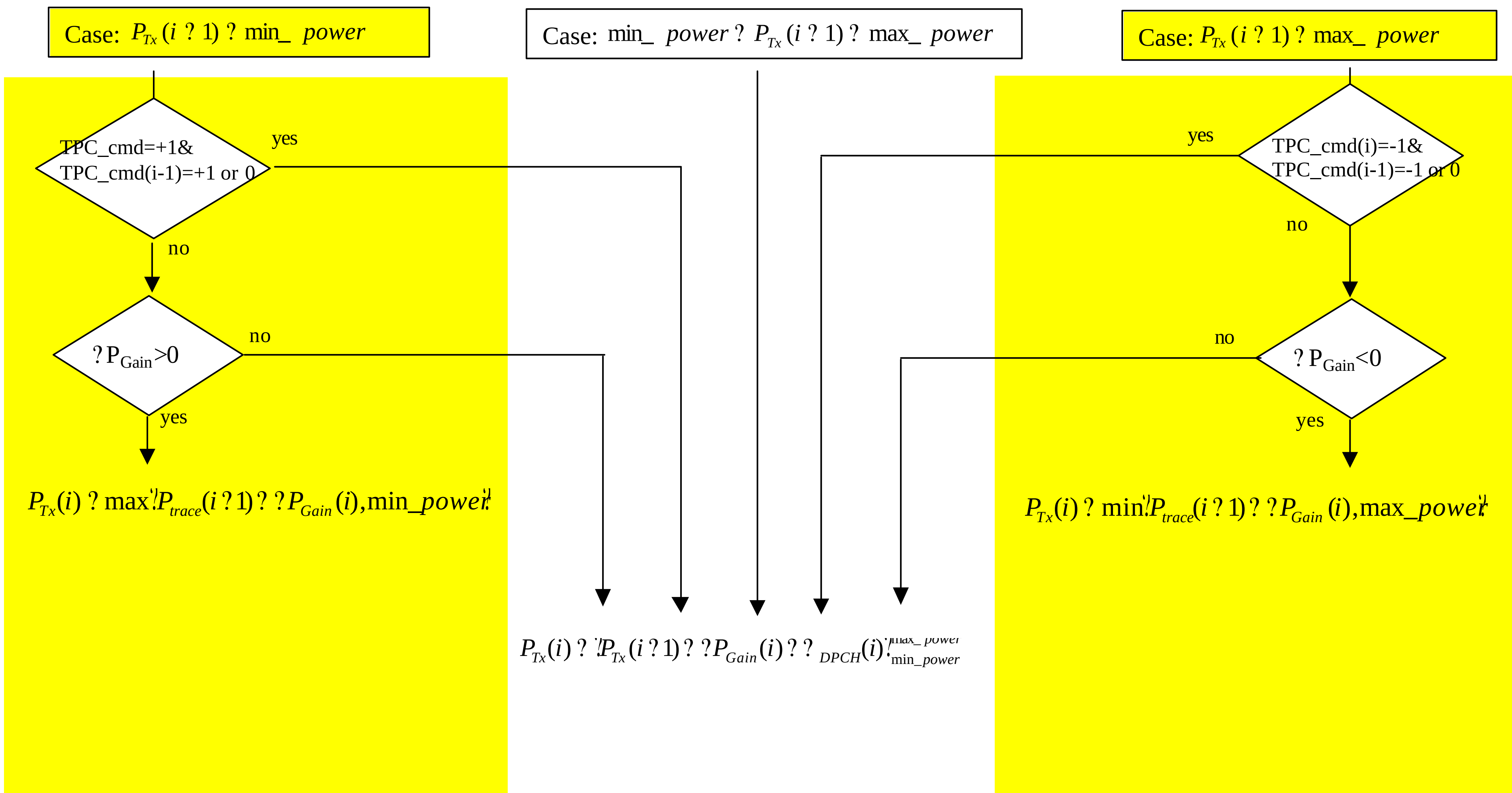

Figure 5: *Algorithm for total transmit power P(i)*

The yellow coloured fields show the changes to the current Rel. 99 Specification.

3GPP TSG-RAN WG1 Meeting #18
Boston, U. S. A., 15-18 January 2001

Tdoc R1-01-0087

CR-Form-v3

CHANGE REQUEST

✍ **25.214** CR **147**	✍ rev **-**	✍	Current version: **3.5.0**	✍

*For **HELP** on using this form, see bottom of this page or look at the pop-up text over the ✍ symbols.*

Proposed change affects: ✍ (U)SIM [ ] ME/UE [X] Radio Access Network [ ] Core Network [ ]

Title: ✍	Improved Uplink Power Control		
Source: ✍	Siemens AG		
Work item code: ✍	WI 36: RAN small technical improvements and enhancements	***Date:*** ✍	20.12.00
Category: ✍	**C**	***Release:*** ✍	REL-4
	Use one of the following categories: ***F*** *(essential correction)* ***A*** *(corresponds to a correction in an earlier release)* ***B*** *(Addition of feature),* ***C*** *(Functional modification of feature)* ***D*** *(Editorial modification)* Detailed explanations of the above categories can be found in 3GPP TR 21.900.		*Use one of the following releases:* *2 (GSM Phase 2)* *R96 (Release 1996)* *R97 (Release 1997)* *R98 (Release 1998)* *R99 (Release 1999)* *REL-4 (Release 4)* *REL-5 (Release 5)*

Reason for change: ✍	Power Control at power limits needs an improvement
Summary of change: ✍	Ptrace for power control at power limits is introduced
Consequences if not approved: ✍	If the UE reaches its power limits the uplink quality cannot be maintained and the intracell interference is increased unnecessarily.

Clauses affected: ✍	5.1.2.6	
Other specs affected: ✍	[ ] Other core specifications [ ] Test specifications [ ] O&M Specifications	✍
Other comments: ✍		

How to create CRs using this form:

Comprehensive information and tips about how to create CRs can be found at: http://www.3gpp.org/3G_Specs/CRs.htm. Below is a brief summary:

1) Fill out the above form. The symbols above marked ✍ contain pop-up help information about the field that they are closest to.

2) Obtain the latest version for the release of the specification to which the change is proposed. Use the MS Word "revision marks" feature (also known as "track changes") when making the changes. All 3GPP specifications can be downloaded from the 3GPP server under ftp://www.3gpp.org/specs/ For the latest version, look for the directory name with the latest date e.g. 2000-09 contains the specifications resulting from the September 2000 TSG meetings.

3) With "track changes" disabled, paste the entire CR form (use CTRL-A to select it) into the specification just in front of the clause containing the first piece of changed text. Delete those parts of the specification which are not relevant to the change request.

where RM_i is the semi-static rate matching attribute for transport channel *i* (defined in [2] subclause 4.2.7), N_i is the number of bits output from the radio frame segmentation block for transport channel *i* (defined in [2] subclause 4.2.6.1), and the sum is taken over all the transport channels *i* in the reference TFC.

Similarly, define the variable

$$K_j ? \underset{i}{?} RM_i ? N_i ;$$

where the sum is taken over all the transport channels *i* in the *j*:th TFC.

The variable A_j, called the nominal power relation is then computed as:

$$A_j ? \frac{?_{d,ref}}{?_{c,ref}} ? \sqrt{\frac{L_{ref}}{L_j}} \sqrt{\frac{K_j}{K_{ref}}} .$$

The gain factors for the *j*:th TFC are then computed as follows:

- If $A_j > 1$, then $?_{d,j} ? 1.0$ and $?_{c,j}$ is the largest quantized $?$ -value, for which the condition $?_{c,j} ? 1 / A_j$ holds. Since $?_{c,j}$ may not be set to zero, if the above rounding results in a zero value, $?_{c,j}$ shall be set to the lowest quantized amplitude ratio of 1/15 as specified in [3].

- If $A_j ? 1$, then $?_{d,j}$ is the smallest quantized $?$ -value, for which the condition $?_{d,j} ? A_j$ holds and $?_{c,j} ? 1.0$.

The quantized ?-values are defined in [3] subclause 4.2.1, table 1.

5.1.2.5.4 Setting of the uplink DPCCH/DPDCH power difference in compressed mode

The gain factors used during a compressed frame for a certain TFC are calculated from the nominal power relation used in normal (non-compressed) frames for that TFC. Let A_j denote the nominal power relation for the *j*:th TFC in a normal frame. Further, let $?_{c,C,j}$ and $?_{d,C,j}$ denote the gain factors used for the *j*:th TFC when the frame is compressed. The variable $A_{C,j}$ is computed as:

$$A_{C,j} ? A_j ? \sqrt{\frac{15 ? N_{pilot,C}}{N_{slots,C} ? N_{pilot,N}}} ;$$

where $N_{pilot,C}$ is the number of pilot bits per slot when in compressed mode, and $N_{pilot,N}$ is the number of pilot bits per slot in normal mode. $N_{slots,C}$ is the number of slots in the compressed frame used for transmitting the data.

The gain factors for the *j*:th TFC in a compressed frame are computed as follows:

If $A_{C,j} > 1$, then $?_{d,C,j} ? 1.0$ and $?_{c,C,j}$ is the largest quantized $?$ -value, for which the condition $?_{c,C,j} ? 1 / A_{C,j}$ holds. Since $?_{c,C,j}$ may not be set to zero, if the above rounding results in a zero value, $?_{c,C,j}$ shall be set to the lowest quantized amplitude ratio of 1/15 as specified in [3].

If $A_{C,j} ? 1$, then $?_{d,C,j}$ is the smallest quantized $?$ -value, for which the condition $?_{d,C,j} ? A_{C,j}$ holds and $?_{c,C,j} ? 1.0$.

The quantized ?-values are defined in [3] subclause 4.2.1, table 1.

5.1.2.6 Maximum and minimum power limits

In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would exceed the maximum allowed value, the UE shall apply additional scaling to the total transmit power so that it is equal to the maximum allowed power. This additional scaling shall be such that the power ratio between DPCCH and DPDCH remains as required by sub-clause 5.1.2.5.

The variable P^{trace} stores the information of the requested total UE transmit power, which is lost owing to the applied scaling.
Thus, the variable P^{trace} traces each exceeding of the maximum allowed total transmit power value (before applying additional scaling). P^{trace} also traces power adjustments due to gain factor readjustments while the UE is transmitting at maximum power level and
- TPC_cmd of either the current or the previous slot is equal to 1 (in case of PCA=1)
- TPC_cmd of the current slot is not equal to –1 (in case of PCA=2).
P^{trace} is equal to the total transmit power, if the total transmit power is below the maximum allowed value.

If the total UE transmit power in the previously transmitted slot is at the maximum power level and
- TPC_cmd of either the current or the previous slot is equal to 1 (in case of PCA=1)
- TPC_cmd of the current slot is not equal to –1 (in case of PCA=2)
and the total power shall be reduced due to gain factor readjustments, then the total UE transmit power value shall be computed on reference to P^{trace} of the previously transmitted slot and not on reference to the total UE transmit power of the previously transmitted slot, whereas also scaling will be applied if necessary.

When transmitting on a DPCH the UE is not required to be capable of reducing its total transmit power below the minimum level required in [7]. However, it may do so, provided that the power ratio between DPCCH and DPDCH remains as specified in sub clause 5.1.2.5. Some further regulations also apply as follows: In the case that the total UE transmit power (after applying DPCCH power adjustments and gain factors) would be at or below the total transmit power in the previously transmitted slot and also at or below the required minimum power specified in [7], the UE may apply additional scaling to the total transmit power, subject to the following restrictions:

- The total transmit power after applying any additional scaling shall not exceed the required minimum power, nor the total transmit power in the previously transmitted slot;
- The magnitude of any reduction in total transmit power between slots after applying any additional scaling shall not exceed the magnitude of the calculated power reduction before the additional scaling.

In the case that the total UE transmit power in the previously transmitted slot is at or below the required minimum power specified in [7] and the DPCCH power adjustment and gain factors for the current slot would result in an increase in total power, then no additional scaling shall be used (i.e. power control shall operate as normal).

In the case that the UE allows the total UE transmit power being below the minimum level, then P^{trace} is always equal to the total UE transmit power. If the UE is not capable of reducing its total transmit power below the minimum level required in [7], P^{trace} traces each first falling below the minimum power limit. P^{trace} also traces power adjustments due to gain factor readjustments while the UE is transmitting at the minimum power level and
- TPC_cmd of either the current or the previous slot is equal to –1 (in case of PCA=1)
- TPC_cmd of the current slot is not equal to 1 (in case of PCA=2).
P^{trace} is equal to the total UE transmit power, if the total transmit power is above the minimum allowed value.

If the total UE transmit power in the previously transmitted slot is at the minimum power level and
– TPC_cmd of either the current or the previous slot is equal to –1 (case of PCA=1)
– TPC_cmd of the current slot is not equal to 1 (in case of PCA=2)
and the total power shall be increased due to gain factor readjustments, then the total UE transmit power value shall be computed on reference to P^{trace} of the previously transmitted slot and not on reference to the total UE transmit power of the previously transmitted slot, whereas also scaling will be applied if necessary.

If the UE applies any additional scaling to the total transmit power as described above, this scaling shall be included in the computation of any DPCCH power adjustments to be applied in the next transmitted slot.

5.1.3 PCPCH

5.1.3.1 General

The power control during the CPCH access procedure is described in clause 6.2. The inner loop power control for the PCPCH is described in the following sub-clauses.

5.1.3.2 Power control in the message part

The uplink transmit power control procedure simultaneously controls the power of a PCPCH control part and its corresponding PCPCH data part. The relative transmit power offset between the PCPCH control part and the PCPCH data part is determined by the network and is computed according to sub-clause 5.1.2.5 using the gain factors signalled to the UE using higher-layer signalling, with the difference that:

- $?_c$ is the gain factor for the PCPCH control part (similar to DPCCH);
- $?_d$ is the gain factor for the PCPCH data part (similar to DPDCH).

The gain factors are applied as shown in sub clause 4.2.3.2 of [3].

The operation of the inner power control loop adjusts the power of the PCPCH control part and PCPCH data part by the same amount, provided there are no changes in gain factors.

Any change in the uplink PCPCH control part transmit power shall take place immediately before the start of the pilot field on the control part of the message part. The change in PCPCH control part power with respect to its value in the previous slot is derived by the UE and is denoted by $?_{PCPCH-CP}$ (in dB).

During the operation of the uplink power control procedure the UE transmit power shall not exceed a maximum allowed value which is the lower out of the maximum output power of the terminal power class and a value which may be set by higher layer signalling.

Uplink power control shall be performed while the UE transmit power is below the maximum allowed output power.

The provisions for power control at the maximum allowed value and below the required minimum output power (as defined in [7]) are described in sub-clause 5.1.2.6.

The uplink inner-loop power control adjusts the UE transmit power in order to keep the received uplink signal-to-interference ratio (SIR) at a given SIR target, SIR_{target}, which is set by the higher layer outer loop.