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Source:	NOKIA
Title:	UE maximum power reduction when HS-DPCCH is transmitted
Agenda item:	**7.5.2**
Document for	Discussion and approval

1 Introduction

In order to support fast ACK/NACK transmission and CQI reporting from UE to Node B, a separate uplink code channel called HS-DPCCH has been introduced. The main reason for using a separate code channel was to ensure backwards compatibility with Release'99 base stations for the cases where HSDPA is not deployed in all cells in the system. Introduction of third uplink code channel HS-DPCCH increases the PAR (Peak-to-Average Ratio) and modifies the shape of output power probability function and sets more stringent linearity requirements for UE transmitter. PAR issue has been discussed in the recent RAN WG1 and WG4 meetings. Several companies have presented contributions showing that in order not to create more stringent linearity requirements than in R99 terminals, about 2dB reduction of maximum power is needed with worst case gain factor combination when HS-DPCCH is transmitted [1, 2, 3, 4, 5].

An idea of gain factor dependent power reduction when the UE is transmitting close to or at the maximum power has been presented and impacts of power reduction to HSDPA system performance have been analyzed [10, 11, 12, 13, 14, 15]

2 Discussion

2.1 UL PAR increase and UE maximum power reduction need

PAR increase with all allowed $?_c$, $?_d$ and $?_{hs}$ combinations are shown in figure 1 below. On the left in the figure 1, PAR increase is shown when $?_d > ?_c$, which is the case in all UL reference channels, and on the right hand side PAR increase is shown when $?_d < ?_c$. It's easy to see that PAR increase on the right hand side is significantly higher than on the left hand side where maximum PAR increase is ~0.6dB with parameter setting $?_c/?_d/?_{hs}$ is equal to 15/15/19. On the right, in the figure 1 one can also find PAR increase for one special case where $?_d$ is 0 (DTX state). The worst-case PAR increase in DTX state is according to simulations just above 1dB when $?_c/?_d/?_{hs}$ is equal to 15/0/15.

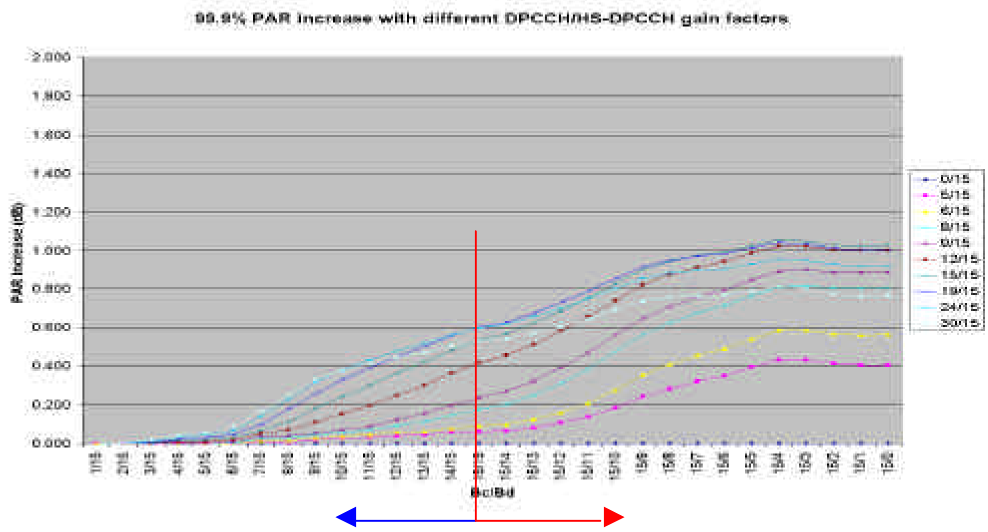

Figure 1. 99.9% PAR increase with HS-DPCCH with different $?_{hs}$ gain factors

Mapping between the PAR increase and needed power reduction in order to reach the same linearity is very implementation specific issue but simulation results in [1 and 5] show that 1:1 is not enough but that 1:2 relation in dB domain is closer to reality. This can be explained with higher probability of output power exceeding the average power as explained in [1]. Power reduction needed for meeting existing ACLR and SEM (spectrum emission mask) requirements with R99 implementations has been simulated with all allowed ?$_{c}$, ?$_{d}$ and ?$_{hs}$ combinations, using simplified model for UE transmitter, and results are shown in figure 2 below.

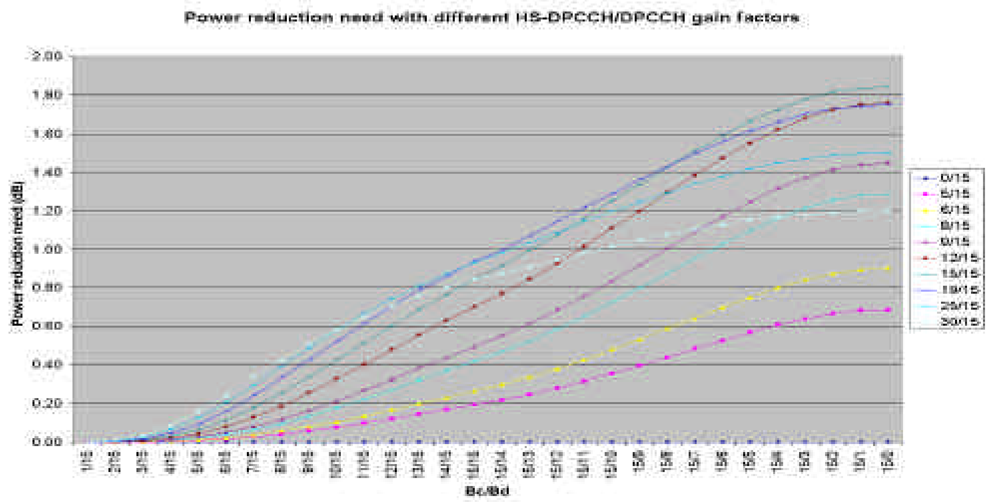

Figure 2. Power reduction need with HS-DPCCH with different ?$_{hs}$ gain factors

2.2 System impacts of UE maximum output power reduction

Output power of the UE increases when HS-DPCCH is transmitted unless the UE is in power-limited situation and uses scaling as specified in TS 25.214. Power increase and need to reduce maximum transmit power due to PAR increase are shown in Figure 3. These graphs include all possible ?$_{hs}$ values for UL reference channels mentioned in 25.104. Power increase and required maximum power reduction due to PAR increase with ?$_{hs}$=24 are shown in the Table 1. This equals to maximum HS-DPCCH/DPCCH ratio of 4dB, and based on the analysis done in RAN4 it is quite typical power offset for HS-DPCCH.

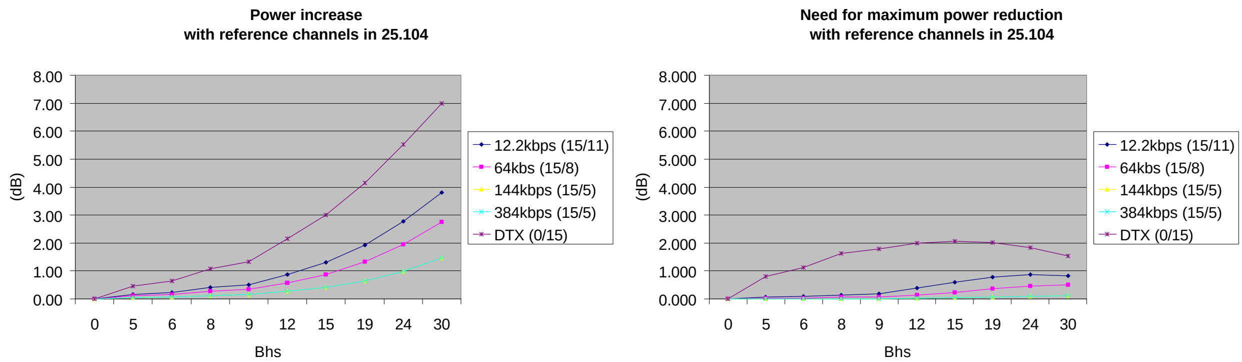

Figure 3. Power increase and need for maximum power reduction when HS-DPCCH is transmitted

Table 1. Power increase and need for maximum power reduction when HS-DPCCH is transmitted with B_{hs}=24

#	Info bit rate	DPCCH/DPDCH power ratio	DPDCH	DPCCH	HS-DPCCH Bhs/Bc= 24/15	Power increase with HS-DPCCH	Need for max. power reduction (2x simulated PAR increase)	Power increase + power reduction needed due PAR increase
1	12.2kbps	-2.69	15	11	18	2.78	0.86	3.64
2	32kbps	-3.52	15	10	16	2.52	0.76	3.28
3	64kbps	-5.46	15	8	13	1.95	0.46	2.41
4	144kbps	-9.54	15	5	8	0.99	0.09	1.08
5	384kbps	-9.54	15	5	8	0.99	0.09	1.08
6	DTX	-	0	15	24	5.51	1.84	7.36

From the table 1 above some observations can be made.

?? Since the gain factor of HS-DPCCH is dependent on DPCCH gain factor, the power increase due to introduction of HS-DPCCH is higher with lower information bit rate channels having power ratio of DPCCH/DPDCH close to 1 (11/15 vs. 10/15 DPCCH/DPDCH ratio).

?? For 12.2kbps channel the need for maximum power reduction is 0.86dB where only 0.09dB is needed with 144 kbps and 384kbps channels.

?? With all UL reference channels and in DTX the required maximum power reduction needed due PAR increase is significantly lower than power increase that is caused by the introduction of new code channel.

?? In the last column the two previously mentioned parameters (power increase and back-off due PAR) have been added together. The column shows how much power margin the UE should have (i.e. how far from the maximum power the UE is operating) when it does not transmit HS-DPCCH in order to be capable of transmitting all three code channels, DPCCH, DPDCH and HS-DPCCH without degradation in ACLR performance.

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In figure 4 the information from table 1 is in graphical form.

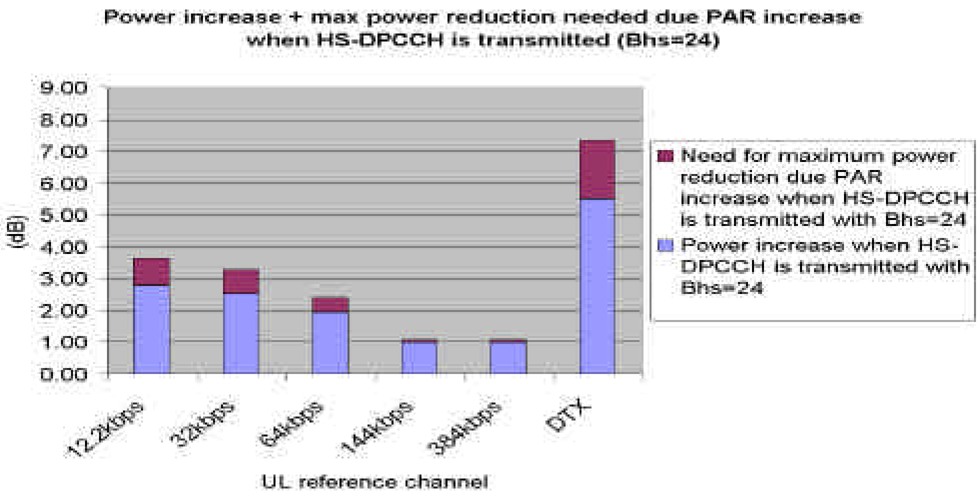

Figure 4. Power increase + need for maximum power reduction when HS-DPCCH is transmitted with B_{hs}=24

UL cell planning in the existing networks is done based on DPCH (DPDCH&DPCCH) coverage. Simplified link budget calculations for UL reference channels listed in TS 25.104 are shown in Table 2 and it can be seen that link budget is not determined by 12.2kbps service or by DTX but by higher information bit rate services. The last row in Table 2 shows the difference between the link budgets of different information bit rate services.

Table 2. Simplified link budget calculations for UL

Case 1 (3km/h)	12.2kbps	32kbps	64kbps	144kbps	384kbps	DTX	
Eb/No (TS 25.104)	11.9	9.2	9.2	8.4	8.8	-	dB
DPDCH Ec/No	-15.0	-13.2	-9.7	-6.3	-1.7	-	dB
DPCCH Ec/No	-17.6	-16.7	-15.1	-15.9	-11.2	-11.2	dB
UE output power	21	21	21	21	21	21	dBm
UE DPDCH channel power	18.1	19.4	19.8	20.5	20.5	-	dBm
UE DPCCH channel power	16.4	15.9	14.5	11.0	11.0	21	dBm
BS Noise Floor (NF=5dB)	-103.0	-103.0	-103.0	-103.0	-103.0	-103	dBm
Required DPDCH_Ec	-117.8	-116.1	-112.8	-109.3	-104.8	-	dBm
Required DPCCH_Ec	-120.6	-119.7	-118.1	-118.8	-114.2	-114.2	dBm
Link budget	137.0	135.5	132.5	129.8	125.2	135.2	dB
Delta to minimum	**11.9**	**10.4**	**7.4**	**4.7**	**0.0**	**10.0**	dB

Let's assume that network has been dimensioned for 384kbps information bit rate i.e. that 384kbps service can be supported over the whole network. If it's further assumed that HSDPA must be supported over the whole network as well without degradation in UL information bit rate and that 4dB power offset between HS-DPCCH and DPCCH is required, we can see from the Table 1 that 1.08dB power margin in UL is needed (0.99dB due HS-DPCCH and 0.09dB due PAR increase). If this is taken into account in network dimensioning, we can discover by comparing the Table 1 and Table 2, that HSDPA can be supported over the whole network area with lower information bit rate services and with DTX. The link budget increase with lower bit rate services is always higher than additional power needed by HS-DPCCH plus power reduction needed due to PAR increase.

Similar calculation can be done assuming that the original network dimensioning was done for 64kbps information bit rate. In this case 2.41dB power margin is needed (1.95dB due to HS-DPCCH and 0.46dB due to PAR increase) but if this has taken into account, HSDPA can also be supported with lower information bit rate services.

Link budgets can be converted to radius of the cell using macro cell path loss formula from TR 25.942 [16]. The relative cell radius with 12.2, 32 and 64kbps information bit rate has been shown in Table 3. For HSDPA 64kbps UL, the cell radius shrinks from 112.7% to 100% since power must be divided between all three-code channels. However 32kbps service can cover the whole 100% even with 1dB reduction in maximum output power, similarly 2dB maximum output power reduction can be allowed for 12.2kbps service. It should be further noticed that cell radius with 32kbps and 12.2kbps service, with 1 and 2dB reduction in maximum power respectively, almost equals to Rel-99 cell radius of 64kbps service.

Table 3. Relative cell radius

#	Info bit rate	Nominal Pout without HSDPA	Nominal Pout with HSDPA	1dB maximum power reduction	2dB maximum power reduction
1	12.2kbps	148.4	125.2	117.8	110.8
2	32kbps	135.5	116.1	109.2	102.7
3	64kbps	112.7	100.0	94.1	88.5

2.3 Gain factor dependent reduction of UE maximum output power

Analysis done in previous chapters shows that if no power reduction is allowed for 64kbps service and 1dB and 2dB reductions are allowed for 32kbps and 12.2kbps services the system impacts in network dimensioned for 64kbps service are minimal. Analysis was however done using gain factors of reference measurement channels in 25.104 [7] and input from operators [15] show that wider range of ?$_c$/?$_d$ is in practice needed in order to operate the network efficiently. It's therefore proposed that two-breakpoint solution that was earlier presented in [13] is used to solve the problem but breakpoint are set in a way that they allow effective network operation with different information bit rate services and their combinations.

When UE transmit HS-DPCCH, its maximum output power during the DPCCH time slots shall be the value specified in table below depending on the gain factors of DPCCH and DPDCH.

Table 4. UE maximum output power with HS-DPCCH

Region	Ratio of DPCCH and DPDCH gain factors	Maximum output power
1	1/15 ? $?_c/?_d$? 11/15	Power class 3: +24dBm+1/-3dB
		Power class 4: +21dBm+2/-2dB
2	12/15 ? $?_c/?_d$? 15/15	Power class 3: +23dBm+2/-3dBm
	15/14 ? $?_c/?_d$? 15/9	Power class 4: +20dBm+3/-2dB
3	15/8 ? $?_c/?_d$? 15/0	Power class 3: +22dBm+3/-3dB
		Power class 4: +19dBm+4/-2dB

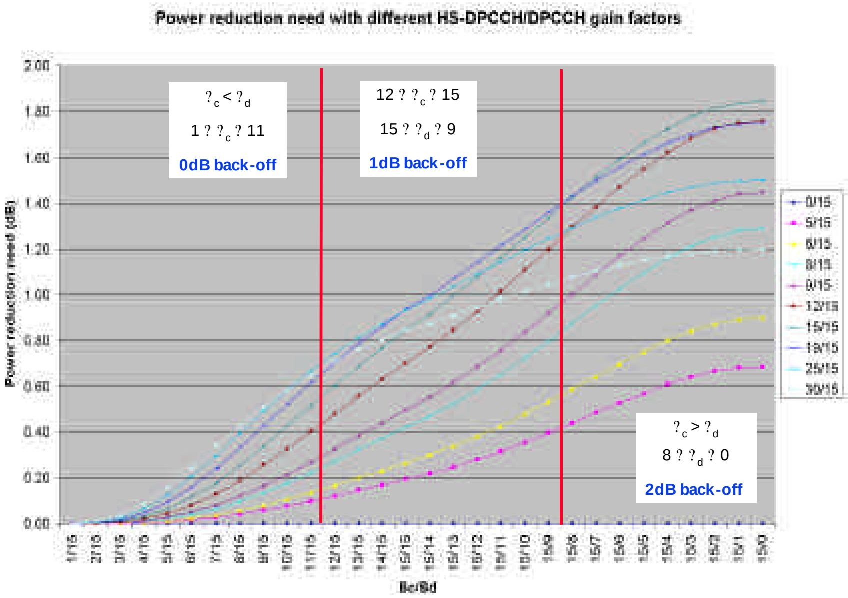

Figure 5. Gain factor dependent reduction of UE maximum output power

2.4 UE behavior in time domain

Power reduction should be allowed only during the DPCH slots where HS-DPCCH is transmitted in order to minimise the impact on system performance. In practice this would mean that UE would reduce the maximum output power if the total output power would be close or equal to maximum output power. If the output power with HS-DPCCH results in exceeding the maximum output power, UE uses output power scaling as specified in [8].

Three different ways to make power reduction has been discussed.

1.) Rel-99 TTI based method
   - ?? UE would evaluate the need for power reduction in the beginning of each Rel-99 TTI. This could be in practice impossible, since UE might not know at TTI-boundary if the network will schedule data to UE during next TTI.

2.) HSDPA TTI based method
   - ?? UE evaluates the need for power reduction in the beginning of HSDPA TTI. In practise the evaluation needs to be done in the beginning of a DPCCH slot where HSDPA TTI begins, since HS-DPCCH slots are not time aligned with DPCCH slots.
   - ?? UE calculates the power reduction need based on the maximum $?_{hs}$ during the HSDPA TTI.

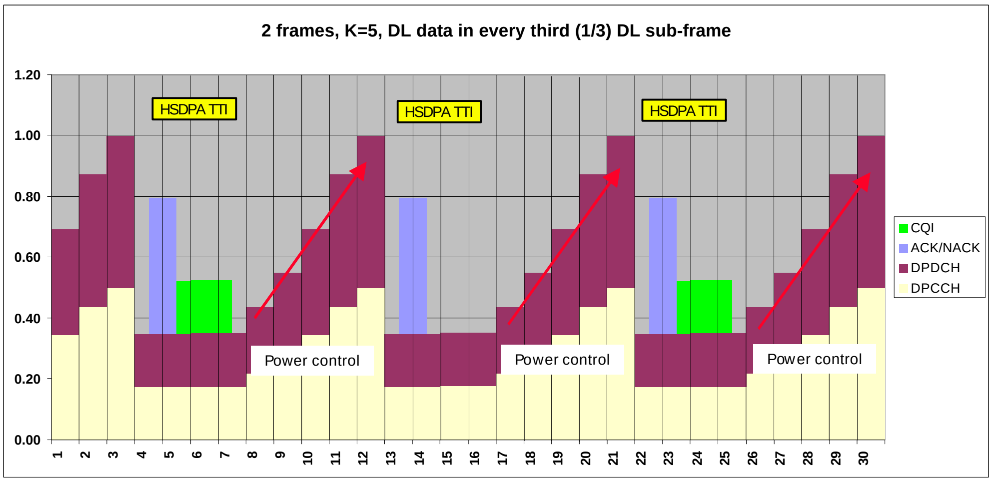

Figure 6. HSDPA TTI based method, 1dB maximum power reduction, 1dB UL power control step

(?$_c$=15, ?$_d$=15, ?$_{ACK/NACK}$=24 and ?$_{CQI}$=15)

3.) Slot based method

- ?? Since HS-DPCCH slots are not time aligned with DPCCH slots, the evaluation of the required power reduction needs to be done in the beginning of a DPCCH slot where HS-DPCCH is also transmitted.
- ?? UE calculates the power reduction need based on the maximum ?$_{hs}$ during the DPCCH slot.
- ?? This option is in line with the current RAN4 working assumption for the TFC selection criteria with HS-DPCCH.

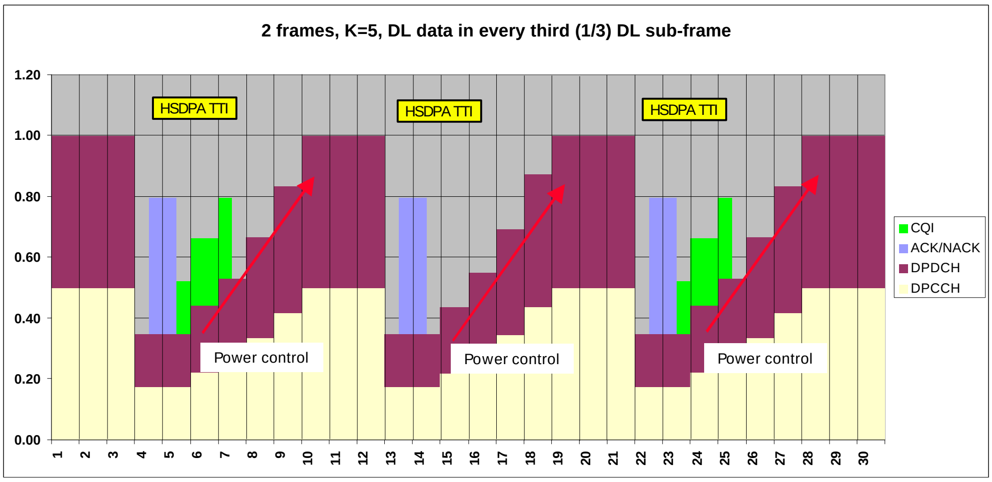

Figure 7. DPCCH slot based method, 1dB maximum power reduction, 1dB UL power control step

(?$_c$=15, ?$_d$=15, ?$_{ACK/NACK}$=24 and ?$_{CQI}$=15)

As stated above it may be possible that option 1.) does not work at all. What comes to options 2.) and 3.), the difference between them is not that big as can be seen from figures 7 and 8. However, the UE recovers from power scaling faster with option 3.) and option 3.) is in line with the current RAN4 assumption for the TFC selection criteria with HS-DPCCH. It's therefore proposed to proceed with this option.

2.5 TFC selection

When UE reaches power-limited situation and it cannot support the transmission of a given TFC, the UE has to change to another TFC it can support, unless the UE is already using a minimum set of TFC. This procedure has been described in TS 25.133 and 25.321, but some clarifications to the requirements together with HS-DPCCH are needed in TS 25.133. RAN4 has already made a principle agreement on how the clarification should be made to the TFC selection requirements, but final agreement of a CR should still be made.

If a certain TFC would require using maximum power or more (without power reduction), it is considered as a "hit" in the TFC selection criteria. Furthermore, once this power reduction concept is agreed, a situation, where the UE would be allowed to reduce its transmission power although the given TFC does not require the maximum UE transmission power, should also be taken into account in the TFC selection criterion. In this way reduced maximum power due to increased PAR should not affect the TFC selection procedure.

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 and also DPCCH and HS-DPCCH remains unchanged.

Since SHO regions may be problematic areas for HS-DPCCH, the network has to be prepared to deactivate the HSDPA service for a UE that cannot support HS-DPCCH transmission in uplink with the required power. Otherwise the UE may end up in a situation where critical RRC control messages on DPCH cannot be sent to the network. In most case this situation can, however, be avoided by a proper network planning.

If the network does not react to the situation of such a UE and does not deactivate DL HS-DSCH for that UE, this UE cannot transmit HS-DPCCH with a power it should (due to L1 scaling at the maximum power) causing an increased probability that the network will receive ACK, NACK or CQI incorrectly. If the network has not configured proper triggers for out of HSDPA service, HSDPA scheduler in the network keeps repeating the same data to the UE until the maximum number of repetitions is reached. Hence, there is an increased risk that network reserves resources for a UE that cannot benefit from them and therefore network resources are clearly wasted.

3 Conclusion

HSDPA system performance with gain factor dependent maximum power reduction has been analysed and it’s shown that with proper selection of the breakpoints the impact is small. Two-breakpoint solution for maximum power reduction is proposed in Table 4.

It is on our understanding that the reduction in the maximum UE TX power is likely to happen in the areas where HSDPA cannot anyway be supported. Some coverage reduction for HSDPA service, when compared to Rel-99, may though happen but it is not significant compared to the benefits that the power reduction provides. We also believe that the reduction of the maximum UE transmission power does not add any complexity in the network.

Three different ways to do maximum power reduction in time domain has been shown. It is proposed that DPCCH slot based method, depicted as option 3.) in this document, is chosen. It is also in-line with RAN WG4 working assumption for the TFC selection criteria with HS-DPCCH.

Once power reduction scheme has been agreed it’s rather straightforward to agree on TFC selection criteria for 25.133 in the next RAN4 meeting as discussed in section 2.5.

4 References

[1] R4-031037, PAR increase of UE transmit signal with HS-DPCCH, Nokia
[2] R4-030989, Discussion paper on PAR aspects, Motorola
[3] R4-031066, PAR increase of UE TX signal with HS-DPCCH, Ericsson
[4] R4-031038, Additional Back off for HS-DPCCH, Panasonic
[5] R4-030796, ACLR requirements under HSDPA operation, Sony Ericsson
[6] TS 25.101, UE Radio Transmission and Reception (FDD) (Release 5)
[7] TS 25.104, BS Radio Transmission and Reception (FDD) (Release 5)
[8] TS 25.214, Physical layer procedures (FDD) (Release 5)
[9] R4-031081, LS on PAR increase with HS-DPCCH transmission, Source: RAN4, To: RAN1
[10] R1-040103, System impacts of maximum power reduction due to the increased PAR with HS-DPCCH, Nokia
[11] R1-040108, Effect on cell coverage of reducing UE maximum transmit power, NTT DoCoMo
[12] R1-040106, PAR and PA Backoff issues related to HS-DPCCH, Motorola
[13] R4-040102, HSDPA PA back-off, Motorola
[14] R4-040067, PAR of UE transmit signal with HS-DPCCH, Fujitsu
[15] R4-040071, Proposals for defining Beta Factors with respective power reduction values in HS-DPCCH transmission, NTT DoCoMo
[16] TR 25.942, RF System Scenarios (Release 5)

Appendix

CR proposal to Release-5 version of 25.101.

6 Transmitter characteristics

- NEXT MODIFIED SECTION –

6.2 Transmit power

6.2.1 UE maximum output power

The following Power Classes define the nominal maximum output power. The nominal power defined is the broadband transmit power of the UE, i.e. the power in a bandwidth of at least (1+a) times the chip rate of the radio access mode. The period of measurement shall be at least one timeslot.

Table 6.1: UE Power Classes

Operating Band	Power Class 1		Power Class 2		Power Class 3		Power Class 4	
	Power (dBm)	Tol (dB)	Power (dBm)	Tol (dB)	Power (dBm)	Tol (dB)	Power (dBm)	Tol (dB)
Band I	+33	+1/-3	+27	+1/-3	+24	+1/-3	+21	+2/-2
Band II	-	-	-	-	+24	+1/-3	+21	+2/-2
Band III	-	-	-	-	+24	+1/-3	+21	+2/-2

NOTE: The tolerance allowed for the nominal maximum output power applies even for the multi-code transmission mode.

6.2.2 UE maximum output power with HS-DPCCH

When UE transmits HS-DPCCH it's maximum output power, during the DPCCH time slots where it either fully or partially transmits also HS-DPCCH, shall be the value specified in table 6.1a depending on the gain factors of DPCCH and DPDCH.

Table 6.1a: UE allowed power reduction with HS-DPCCH

Region	Ratio of DPCCH and DPDCH gain factors	Maximum output power
1	1/15 ? $?_c/?_d$? 11/15	Power class 3: +24dBm+1/-3dB
		Power class 4: +21dBm+2/-2dB
2	12/15 ? $?_c/?_d$? 15/15	Power class 3: +23dBm+2/-3dB
	15/14 ? $?_c/?_d$? 15/9	Power class 4: +20dBm+3/-2dB
3	15/8 ? $?_c/?_d$? 15/0	Power class 3: +22dBm+3/-3dB
		Power class 4: +19dBm+4/-2dB