TSG RAN Meeting #25 **RP-040320**
Palm Springs, CA USA, 7 - 9 September 2004

Title **CRs (Rel-6 Category F) to TR 25.899**
Source **TSG RAN WG1**
Agenda Item **8.10.1**

RAN1 Tdoc	Spec	CR	Rev	Phase	Cat	Curren Version t	Subject	Workitem	Remarks
R1-041056	25.899	1	1	Rel-6	F	6.0.0	Implementation complexity of ACK/NACK performance improvement	RInImp-RIperf	
R1-041055	25.899	2	-	Rel-6	F	6.0.0	Effect of PRE/POST scheme on HSDPA cell coverage	RInImp-RIperf	

3GPP TSG-RAN WG1 Meeting #38 **Tdoc ⌘R1-041056**
Prague, Czech Republic, 16-20th August 2004

CR-Form-v7.1

CHANGE REQUEST

⌘	**25.899**	**CR**	**001**	⌘**rev**	**1**	⌘	Current version:	**6.0.0** ⌘

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Proposed change affects: UICC apps⌘ [ ] ME [ ] Radio Access Network [ ] Core Network [ ]

Title:	⌘	Implementation Complexity of ACK/NACK performance improvement		
Source:	⌘	RAN WG1		
Work item code:	⌘	RInImp-RIperf	***Date:*** ⌘	24/08/2004
Category:	⌘	**F** *Use one of the following categories:* ***F*** *(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.	***Release:*** ⌘	Rel-6 *Use one of the following releases:* *Ph2 (GSM Phase 2)* *R96 (Release 1996)* *R97 (Release 1997)* *R98 (Release 1998)* *R99 (Release 1999)* *Rel-4 (Release 4)* *Rel-5 (Release 5)* *Rel-6 (Release 6)* *Rel-7 (Release 7)*

Reason for change:	⌘	No evaluation of receiver implementation complexity is given within section 6.7 on “ACK/NACK Transmit Power Reduction for HS-DPCCH with preamble and postamble”
Summary of change:	⌘	New section 6.7.2.3A added containing evaluation of implementation complexity. Summary in section 6.7.2.4 extended.
Consequences if not approved:	⌘	The study item would remain incomplete.

Clauses affected:	⌘	New section 6.7.2.3A inserted; 6.7.2.4			
		Y	**N**		
Other specs affected:	⌘		**X**	Other core specifications	⌘
			X	Test specifications	
			X	O&M Specifications	
Other comments:	⌘	The numbering of Figures in the new section assumes that CR 002 is also accepted			

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6.7.2 Evaluation and Benefits

6.7.2.1 Simulation assumptions

The following simulation assumptions are used for this evaluation:

2GHz carrier frequency
Pedestrian A channel – Rayleigh fast fading, classical Doppler spectrum, no shadowing
Rx diversity at Node B: 2 uncorrelated antennas
Channel estimation: 3 slots up to 40km/h, 1 slot at higher speeds
4% error rate (AWGN) on DL TPC commands
UL power control step size 1dB, algorithm 1
UL DPCCH SIR target set to give 4% TPC error rate; same SIR target in SHO as for non-SHO.
Interference in UL modelled as AWGN
Static ACK/NACK decision threshold
Average HS-SCCH failure rate = 0.01.

6.7.2.2 Performance targets

We consider two sets of performance targets, referred to here for simplicity as the “Tight Requirements” and “Relaxed Requirements” as follows:

<u>Tight requirements without PRE/POST:</u>

P(ACK->NACK) ≤ 0.01
(where the notation “P(ACK->NACK)” refers to the probability that a transmitted ACK is decoded as a NACK.)
P(NACK->ACK) ≤ 0.0001
P(DTX->ACK) ≤ 0.01

<u>Tight requirements with PRE/POST:</u>

P(ACK -> (NACK or PRE or POST)) ≤ 0.01
P(NACK -> ACK) ≤ 0.0001
P((PRE or POST or DTX) -> ACK) ≤ 0.01

<u>Relaxed requirements without PRE/POST:</u>

P(ACK->NACK) ≤ 0.01
P(NACK->ACK) ≤ 0.001
P(DTX->ACK) ≤ 0.1

<u>Relaxed requirements with PRE/POST:</u>

P(ACK -> (NACK or PRE or POST)) ≤ 0.01
P(NACK -> ACK) ≤ 0.001
P((PRE or POST or DTX) -> ACK) ≤ 0.1

The Relaxed Requirements are generally considered sufficient for “difficult” radio conditions such as high speeds or SHO.

6.7.2.3 Simulation Results

6.7.2.3.1 Soft Handover

Figure 37 shows simulation results for SHO with N_acknack_transmit = 2 for the Relaxed Requirements. For the PRE/POST scheme, two different HS-DSCH traffic loadings (20% and 80%) are shown, as this affects the ratio between packets which are first in a burst and those which are immediately preceded by other packets. The traffic model used specifies the probability of a packet being sent to the UE in any given sub-frame. No correlation is assumed between packet transmissions.

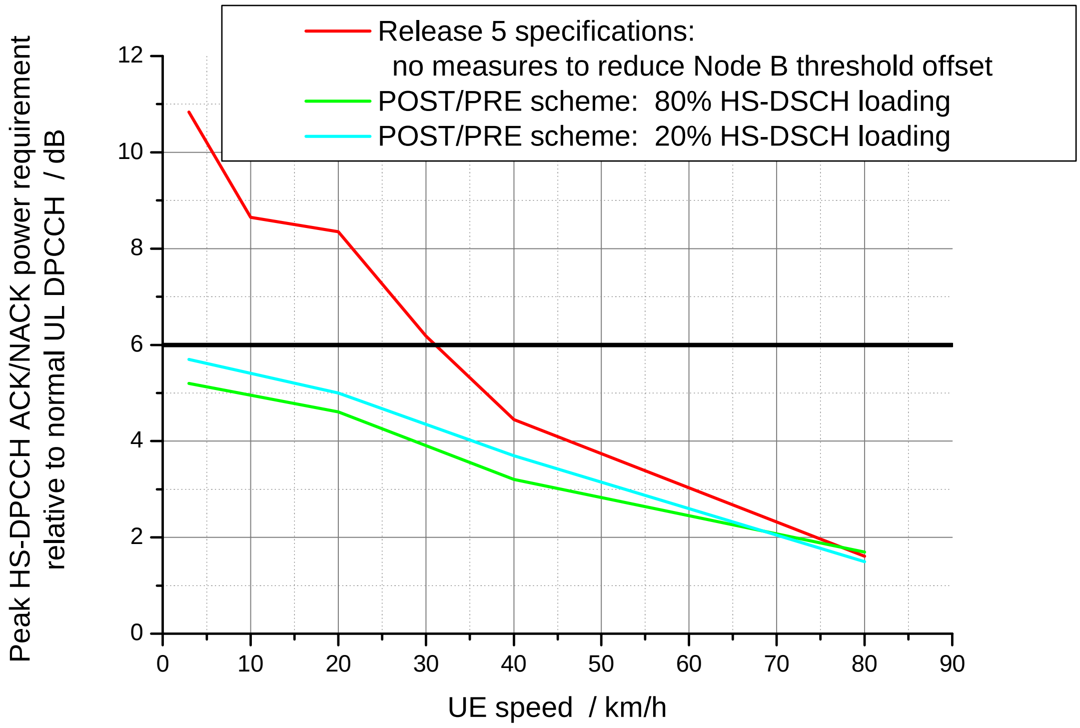

Figure37: SHO, Relaxed Requirements, N_acknack_transmit = 2

It can be seen from Figure 37 that the PRE/POST scheme meets the Relaxed Requirements at all UE speeds and at both high and low loadings, without requiring a larger HS-DPCCH power offset than can be signalled according to the Release 5 specifications (where the maximum offset is 6dB).

Figure 38 shows the power required to meet the Tight Requirements with N_acknack_transmit = 2.

It can be seen from Figure 38 that the PRE/POST scheme can even meet the Tight Requirements in SHO at UE speeds above about 45km/h (where the effect of time-diversity is greater relative to the fading rate), although this may not be a necessary requirement.

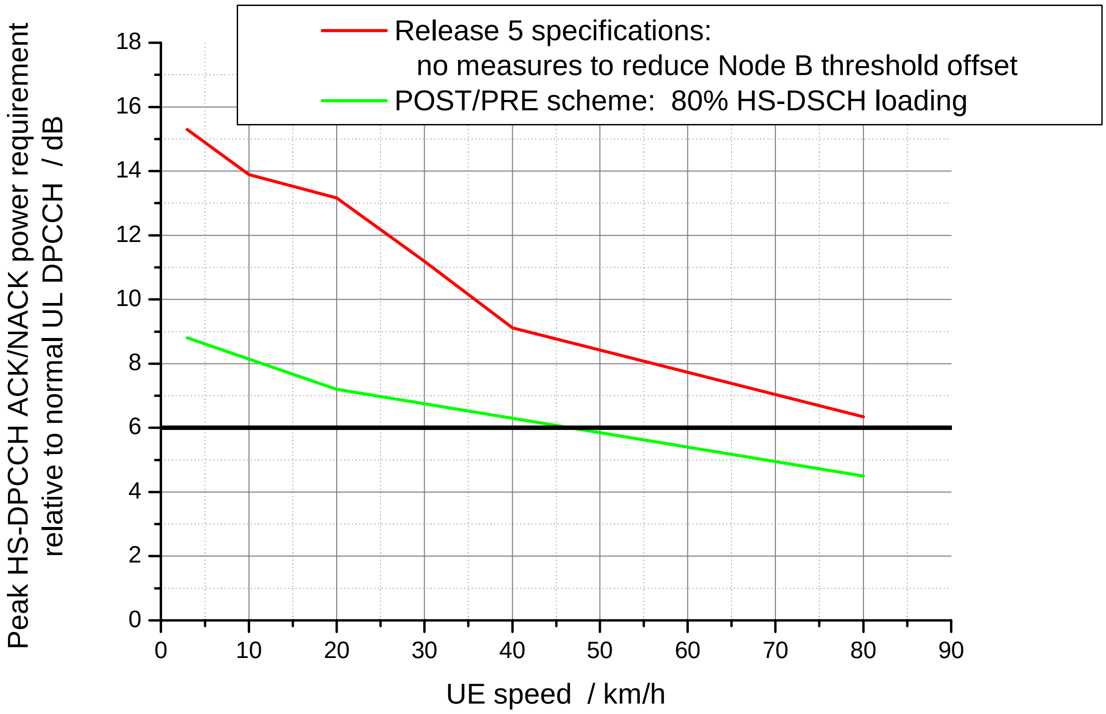

Figure 38: SHO, Tight Requirements, N_acknack_transmit = 2

6.7.2.3.2 Non Soft Handover

The PRE/POST scheme also gives benefit in non-SHO situations, as shown in Figure 39 for the Tight Requirements, with N_acknack_transmit set to 1.

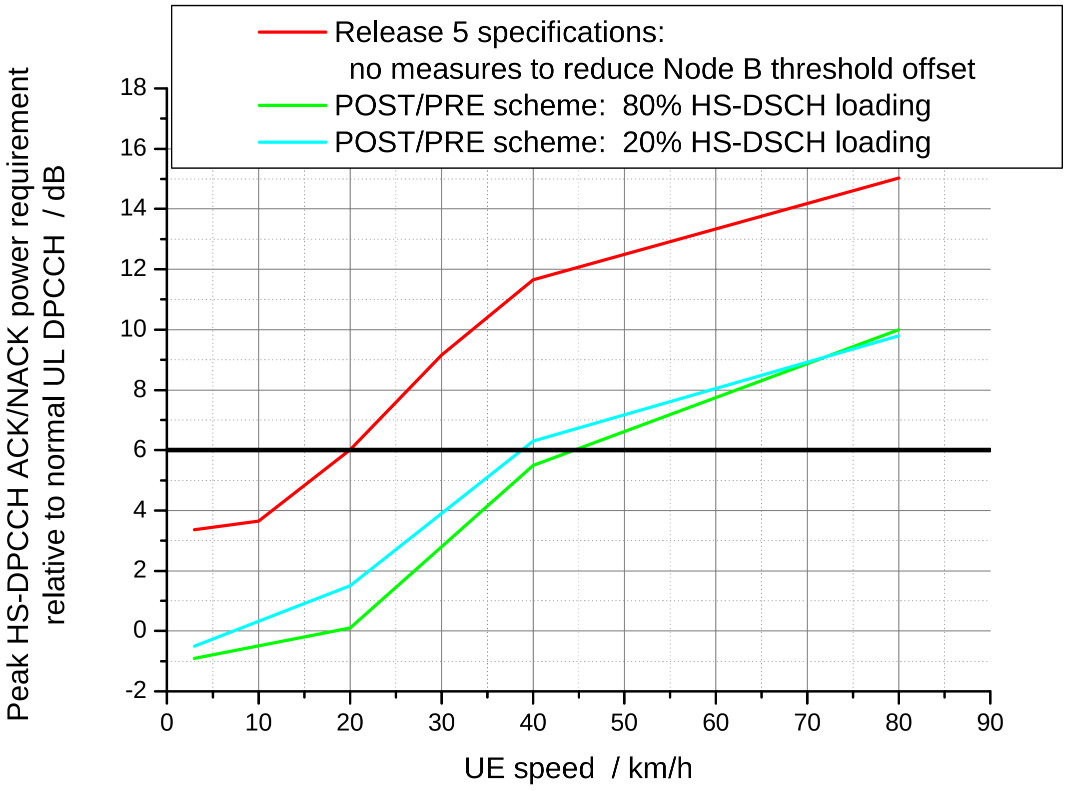

Figure 39: Non-SHO, Tight Requirements, N_acknack_transmit = 1

It can be seen from Figure 39 that the PRE/POST scheme enables the Tight Requirements to be met at speeds up to 40km/h, instead of only 20km/h with the Release 5 specifications.

Figure 40 shows the power requirements for the Relaxed Requirements. It can be seen that the PRE/POST scheme enables the Relaxed Requirements to be met at all UE speeds, without requiring the use of repetition. (By contrast, the Release 5 specifications would need the use of repetitions at UE speeds higher than about 35km/h in order to meet the Relaxed Requirements).

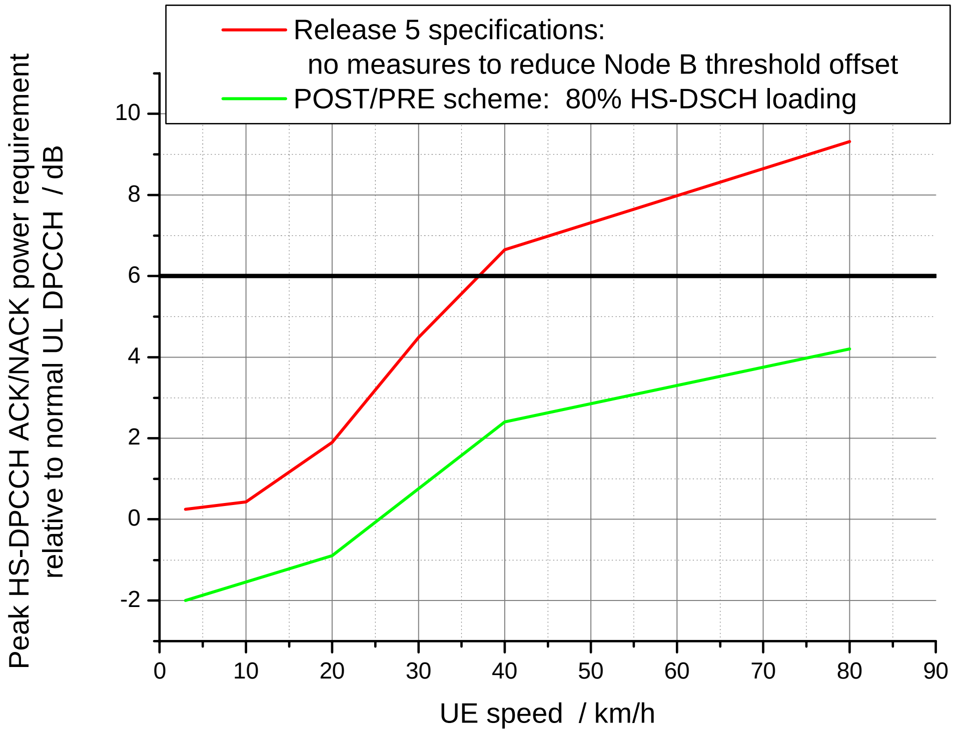

Figure 40: Non-SHO, Relaxed Requirements, N_acknack_transmit = 1

In addition to improving the decoding performance of the ACK/NACK signalling, the PRE/POST scheme enables the Node B to distinguish between the UE having failed to detect the HS-SCCH signalling and the UE having detected the HS-SCCH signalling but failed to decode the HS-DSCH packet.

If the UE has failed to detect the HS-SCCH signalling, the UE will transmit either POST, or PRE, or DTX in 2 consecutive slots, whereas a NACK (or PRE+NACK for the first packet in a burst) would be transmitted if the UE had detected but failed to decode the packet. If full IR is being used, the error rate between PRE/POST/DTX+DTX and NACK is of interest. In the simulations presented here, a maximum error rate of 0.03 is achieved in all circumstances, both for PRE/POST/DTX+DTX -> NACK and for NACK->PRE/POST/DTX+DTX.

This enables the Node B to select the best redundancy version with a high degree of confidence.

6.7.2.3A Implementation Complexity

6.7.2.3A.1 UE transmitter

The PRE/POST scheme would require implementation of a minor modification to the ACK/NACK transmission procedure at the UE, for which the increase in complexity is small and is not considered further here.

6.7.2.3A.2 Node B receiver

6.7.2.3A.2.1 Assumptions

This analysis considers the total node B processing which might be required under the following conditions:-

- Four HS-SCCH in the downlink
- 8 active users (monitoring HS-SCCH) = N_u

- 4 users receiving transmissions per subframe = N_{tx}
- CQI transmission in every subframe for each active user
- No repetition of ACK/NACK
- No repetition of CQI

Since despreading is a common requirement, and a basic function required in the Node B receiver, this aspect is not considered further in the complexity analysis.

The number of operations per subframe is evaluated, taking worst case assumptions, and applying some weighting factors to try and take into account the fact that some operations are relatively more complex than others.

We also consider the number of storage locations required. For the processing envisaged, resolution no more than 16 bita per location should be sufficient.

The complexity evaluations of Release 5 receivers for ACK/NACK and CQI are taken as references.

6.7.2.3A.2.2 Release 5 Complexity

According to the Release 5 specification for HS-DPCCH, a receiver at the Node B could be implemented by despreading of 1 slot, followed by a correlator matched to the bit sequence corresponding to ACK. This correlator output could then be compared with a couple of thresholds to determine whether the most likely transmission was ACK, NACK or DTX.

For comparison purposes it is of interest to consider the processing required to receive CQI at the Node B. This could be implemented by despreading of two slots, followed by correlators matched to each of the five basis sequences of the (20,5) code. Then comparison operations are needed to decide on the value of each bit in the CQI word.

It is assumed that the use of a 10 bit correlator matched to ACK is required for each packet which has been transmitted. Since the NACK signal is the inverse of that for ACK, the same correlator output can be used to detect NACK's.

Table 6: Processing for Rel 5 ACK/NACK

	Correlation operations	Compare operations	Total
	$10. N_{tx}$	$2.N_{tx}$	
Total	40	8	
Complexity weighting	1	2	
Weighted total	**40**	**16**	**56**

Table 7: Storage for Rel 5 ACK/NACK

Received ACK/NACK bit sequences	Correlation results	Total
$10. N_{tx}$	N_{tx}	
40	**4**	**44**

The CQI information is coded using a (20,5) code. Detection of each of the five basis sequences requires a separate 20 bit correlator for each user in each subframe. The complexity evaluation is carried out assuming 8 users sending CQI. In practice there may be many more than this. Note that this evaluation only includes CQI decoding, and does not include any of the further processing which would be required in the Node B scheduler.

Table 8: Processing for decoding Rel 5 CQI

	Correlation operations	Compare operations	Total
	$20.\ 5.N_u$	$2.5.N_u$	
Total	800	80	
Complexity weighting	1	2	
Weighted total	800	160	960

Table 9: Storage for Rel 5 CQI

Received CQI bit sequences	Correlation results	Total
$20.N_u$	$5.N_u$	
160	40	200

6.7.2.3A.2.3 Complexity of PRE/POST scheme

According to the state diagram shown in Figure 35, the following are pairs of possible codewords which may be transmitted in sub-frames *n*-1 and *n* respectively:

n*-1 *n
POST + DTX
POST + PRE
ACK + ACK
ACK + NACK
ACK + POST
NACK+ ACK
NACK+ NACK
NACK+ POST
DTX + DTX
PRE + ACK
PRE + NACK
ACK + PRE
NACK+ PRE
DTX + PRE

Some further restrictions can be identified depending on which sub-frames had packets transmitted:

- PRE can never be transmitted in sub-frame *n* if no packet was transmitted in sub-frame *n*+1;
- ACK and NACK can never be transmitted in sub-frame *n*-1 if no packet was transmitted in sub-frame *n*-1;
- POST can never be transmitted in sub-frame *n*-1 if no packet was transmitted in sub-frame *n*-2;

- POST can never be transmitted in sub-frame *n* if no packet was transmitted in sub-frame *n*-1.

The receiver algorithm can be designed to make use of this information. For example the results presented in section 6.7.2.3, assumed a procedure as outlined below:

(1) Determine which of five possible variants of the processing procedure is to be used, based on whether packets were sent in the next sub-frame and the previous two subframes, and the decoded signals from the previous two subframes.

(2) Excecute the first stage of detection, which requires comparison of up to three correlator outputs (for ACK, PRE and POST waveforms)

(3) Execute the second and final stage of detection which depends on the results of step (2) and may require another comparison of up to three correlator outputs.

(4) Based on the results from steps (2) and (3), determine whether ACK/NACK/ DTX/PRE/POST has been received.

However, the receiver implementation is not restricted to using this approach, and a variety of alternatives are possible. One alternative approach with a simpler structure (but not necessarily lower complexity) is as follows:

(1) Based on the known sequence of packet transmission, determine the possible transmitted signals in the current and previous subframe (e.g. using the scheme in Figure 45).

(2) Derive in each subframe the likelihood values for each of the possible transmissions: ACK/NACK/ DTX/PRE/POST (based on correlator outputs for each signal).

(3) Multiply the likelihoods for each signal in each possible signal pair and pick the largest as the detected signal (e.g. using the scheme in Figure 46). (Note that this operation is not necessary for the signal pairs which are detemined as “not possible” in step (1).)

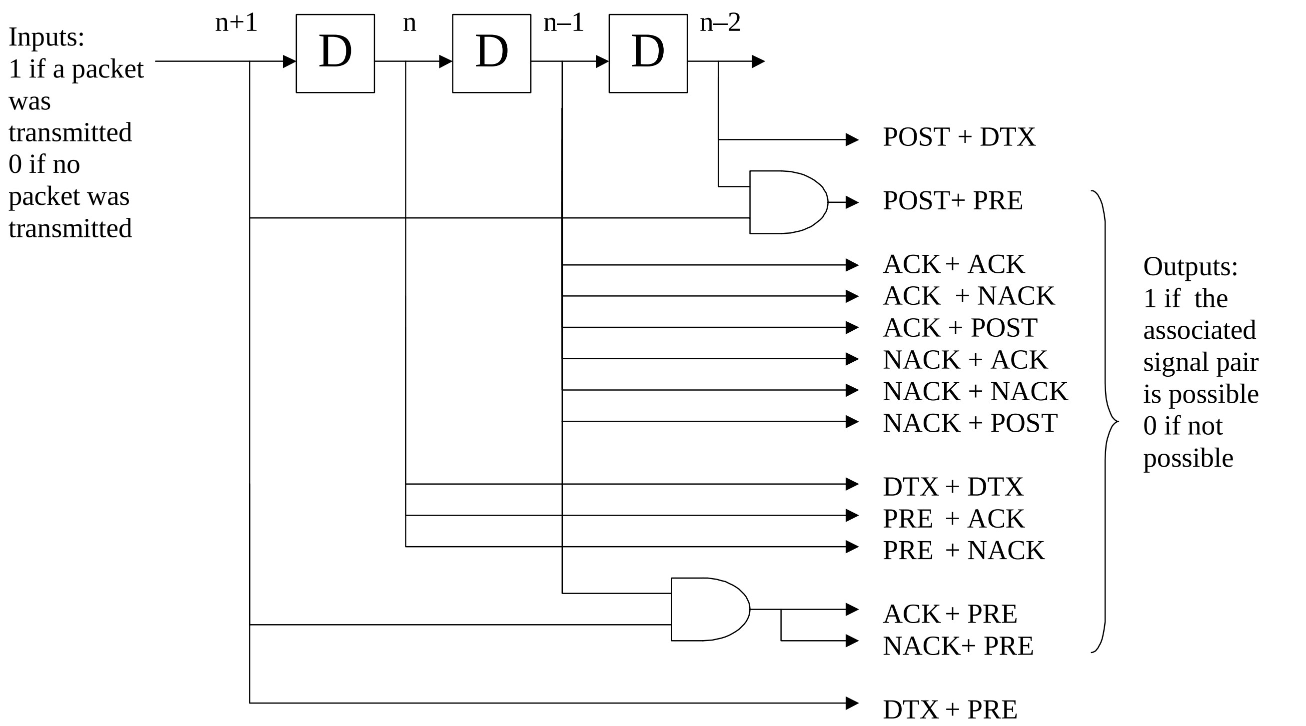

Figure 45: Derivation of possible signal pairs for previous and current subframes

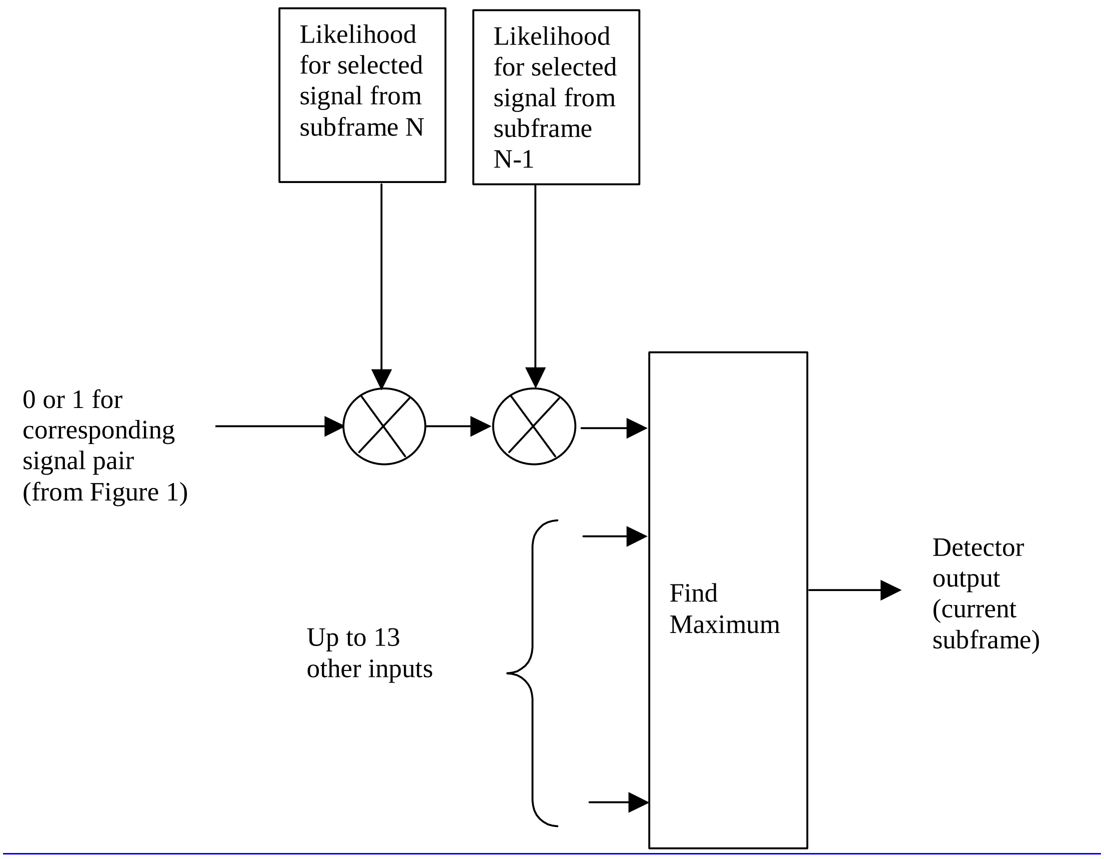

Figure 46: Derivation at the receiver of most likely transmitted signal

In practice the likelihood metric could be replaced by log-likelihood or a distance-based metric, in which case the processing in Figure 46 could be modified appropriately.

Table 10: Processing for PRE/POST scheme

	Operations to determine possible signal pairs	Correlation operations	Table lookups to get likelihood values	Processing of likelihood values (multiplications)	Compare operations	Total
	2. N_{tx}	10.3.N_u (1)	5.N_u (1)	2.14.N_{tx}	14.N_{tx}	
Total	8	240	40	112	56	
Complexity weighting	1	1	3	1	2	
Weighted total	8	240	120	112	112	592

(1) In practice, depending on the transmission duty cycle not all these operations may be required. These figures are upper limits based on transmission of a packet to a given user in every other subframe.

Table 11: Storage for PRE/POST scheme

Storage to determine possible signal pairs	Received ACK/NACK bit sequences	History of Correlation Results	Total
$4. N_u +14. N_{tx}$	$10.N_u$	$2.5.N_u$	
88	80	80	248

6.7.2.3A.3 Summary of complexity evaluation

Table 12: Summary of complexity evaluation

	Release 5 ACK/NACK	Release 5 CQI	ACK/NACK enhancement
Processing operations per subframe (weighted)	56	960	592
Memory locations	44	200	248

Under the assumptions made here, the implementation complexity of the receiver for the proposed ACK/NACK enhancement is approximately an order of magnitude greater than the very simple Release 5 ACK/NACK receiver. However, the complexity is less than that which would be required for detection of CQI (from 8 continuously active users).

6.7.2.4 Summary

Simulation results presented here show that the PRE/POST scheme achieves the following:

- "Relaxed Requirements" met at all UE speeds in SHO, without needing more than 1 ACK/NACK repetition;
- "Tight Requirements" met in SHO at UE speeds above 45km/h;
- When not in SHO, "Tight Requirements" met with no repetitions at all speeds up to 40km/h (compared to only 20km/h with Release 5 specifications);
- "Relaxed Requirements" met without repetitions at speeds higher than 40km/h when not in SHO.
- Worst-case error rate of 0.03 achieved for distinguishing between failed HS-SCCH detection and failed HS-DSCH CRC.

Evaluation of complexity shows that for 8 users the additional receiver complexity at the Node B for the PRE/POST scheme is less than that required by a Release 5 receiver for decoding CQI from the same number of users.

3GPP TSG-RAN WG1 Meeting #38 **Tdoc ⌘R1-041055**
Prague, Czech Republic, 16-20th August 2004

CR-Form-v7.1

CHANGE REQUEST

⌘	**25.899**	**CR**	**002**	⌘ **rev**	**-**	⌘	Current version:	**6.0.0** ⌘

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Proposed change affects:	UICC apps⌘ [ ]	ME [ ]	Radio Access Network [ ]	Core Network [ ]

Title:	⌘	Effect of PRE/POST scheme on HSDPA cell coverage
Source:	⌘	RAN WG1
Work item code:	⌘	RInImp-RIperf ***Date:*** ⌘ 24/08/2004
Category:	⌘	**F** ***Release:*** ⌘ Rel-6

Use one of the following categories:
- ***F*** *(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:
- *Ph2 (GSM Phase 2)*
- *R96 (Release 1996)*
- *R97 (Release 1997)*
- *R98 (Release 1998)*
- *R99 (Release 1999)*
- *Rel-4 (Release 4)*
- *Rel-5 (Release 5)*
- *Rel-6 (Release 6)*
- *Rel-7 (Release 7)*

Reason for change:	⌘	No evaluation of effect on cell coverage is given within section 6.7 on “ACK/NACK Transmit Power Reduction for HS-DPCCH with preamble and postamble”
Summary of change:	⌘	Evaluation of cell coverage added to section 6.7.2.3. Summary in section 6.7.2.4. extended.
Consequences if not approved:	⌘	The study item would remain incomplete.

Clauses affected:	⌘	6.7.2.3; 6.7.2.4			
		Y	**N**		
Other specs Affected:	⌘		**X**	Other core specifications	⌘
			X	Test specifications	
			X	O&M Specifications	
Other comments:	⌘	If this CR is implemenented in addition to CR 001, then the new text added to section 6.7.2.4 should precede that added by CR 001.			

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<u>Tight requirements with PRE/POST:</u>

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<u>Relaxed requirements with PRE/POST:</u>

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The Relaxed Requirements are generally considered sufficient for "difficult" radio conditions such as high speeds or SHO.

6.7.2.3 Simulation Results

6.7.2.3.1 Soft Handover

Figure 37 shows simulation results for SHO with N_acknack_transmit = 2 for the Relaxed Requirements. For the PRE/POST scheme, two different HS-DSCH traffic loadings (20% and 80%) are shown, as this affects the ratio between packets which are first in a burst and those which are immediately preceded by other packets. The traffic model used specifies the probability of a packet being sent to the UE in any given sub-frame. No correlation is assumed between packet transmissions.

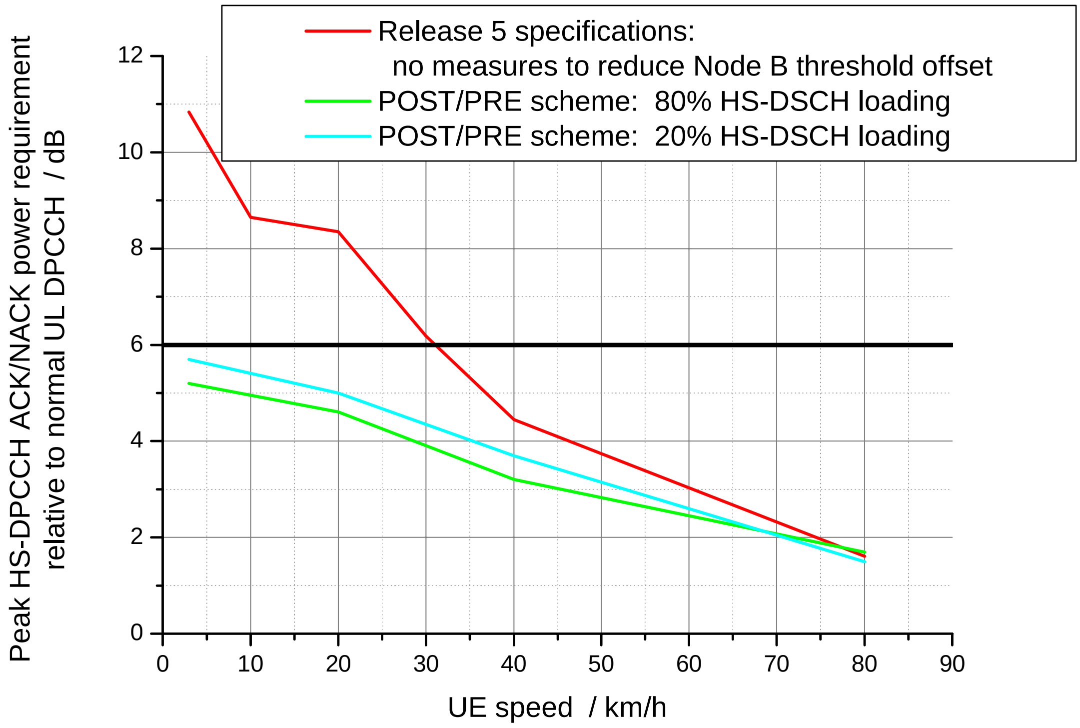

Figure37: SHO, Relaxed Requirements, N_acknack_transmit = 2

It can be seen from Figure 37 that the PRE/POST scheme meets the Relaxed Requirements at all UE speeds and at both high and low loadings, without requiring a larger HS-DPCCH power offset than can be signalled according to the Release 5 specifications (where the maximum offset is 6dB).

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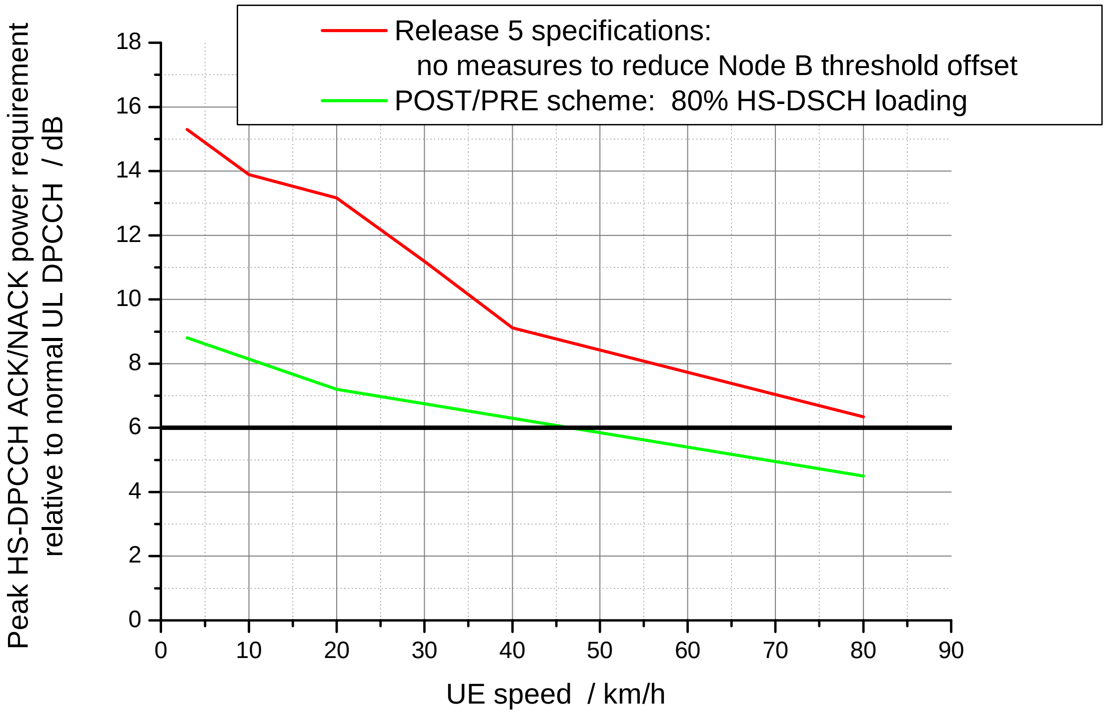
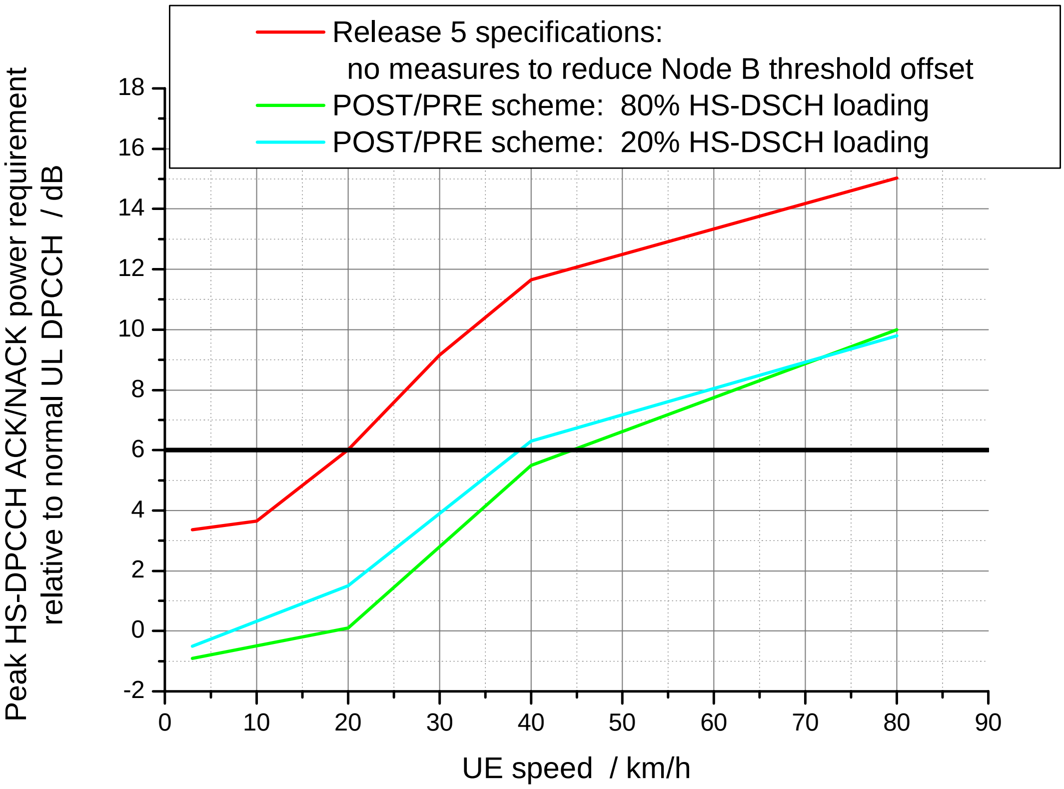


Figure 38: SHO, Tight Requirements, N_acknack_transmit = 2

6.7.2.3.2 Non Soft Handover

The PRE/POST scheme also gives benefit in non-SHO situations, as shown in Figure 39 for the Tight Requirements, with N_acknack_transmit set to 1.



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It can be seen from Figure 39 that the PRE/POST scheme enables the Tight Requirements to be met at speeds up to 40km/h, instead of only 20km/h with the Release 5 specifications.

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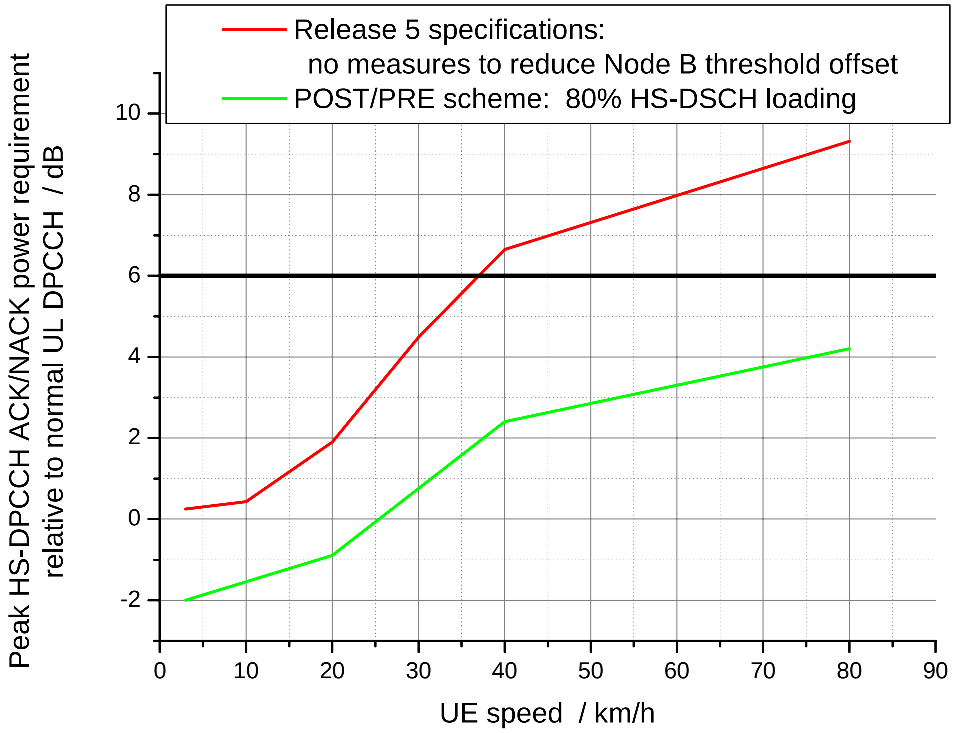

Figure 40: Non-SHO, Relaxed Requirements, N_acknack_transmit = 1

In addition to improving the decoding performance of the ACK/NACK signalling, the PRE/POST scheme enables the Node B to distinguish between the UE having failed to detect the HS-SCCH signalling and the UE having detected the HS-SCCH signalling but failed to decode the HS-DSCH packet.

If the UE has failed to detect the HS-SCCH signalling, the UE will transmit either POST, or PRE, or DTX in 2 consecutive slots, whereas a NACK (or PRE+NACK for the first packet in a burst) would be transmitted if the UE had detected but failed to decode the packet. If full IR is being used, the error rate between PRE/POST/DTX+DTX and NACK is of interest. In the simulations presented here, a maximum error rate of 0.03 is achieved in all circumstances, both for PRE/POST/DTX+DTX -> NACK and for NACK->PRE/POST/DTX+DTX.

This enables the Node B to select the best redundancy version with a high degree of confidence.

6.7.2.3.3 Effect on Cell Coverage

It is possible to estimate the uplink cell coverage for an HSDPA UE by considering the power available to the uplink DPDCH channel when the UE is transmitting at maximum power, after allocating a sufficient value of β_{HS} to achieve the required ACK/NACK error rate.

Link budget calculation shows that a 1dB reduction in peak power capability reduces coverage area by 14% (7% radius). The following assumptions on beta factors are used here as a reference:-

UL DTCH data rate	16kbps	32kbps	`64kbps
DPCCH/DPDCH amplitude ratio β_c/β_d	14/15	11/15	8/15
H-ARQ Ack/DPCCH amplitude ratio β_{hs}/β_c	24/15	24/15	24/15
CQI/DPCCH amplitude ratio β_{hs}/β_c	15/15		

The use of PRE/POST means that the peak power could be reduced by reducing the power of the ACK/NACK field, provided that ACK/NACK error performance is sufficient. Note that reducing the ACK/NACK power below that of CQI gives no further benefit in terms of peak power. This is shown in Figure 41(a). Then the power of all uplink channels could then be increased back to the peak power limit (see Figure 41(b)). This would lead to a coverage improvement, since the DPDCH is now transmitted at a higher power.

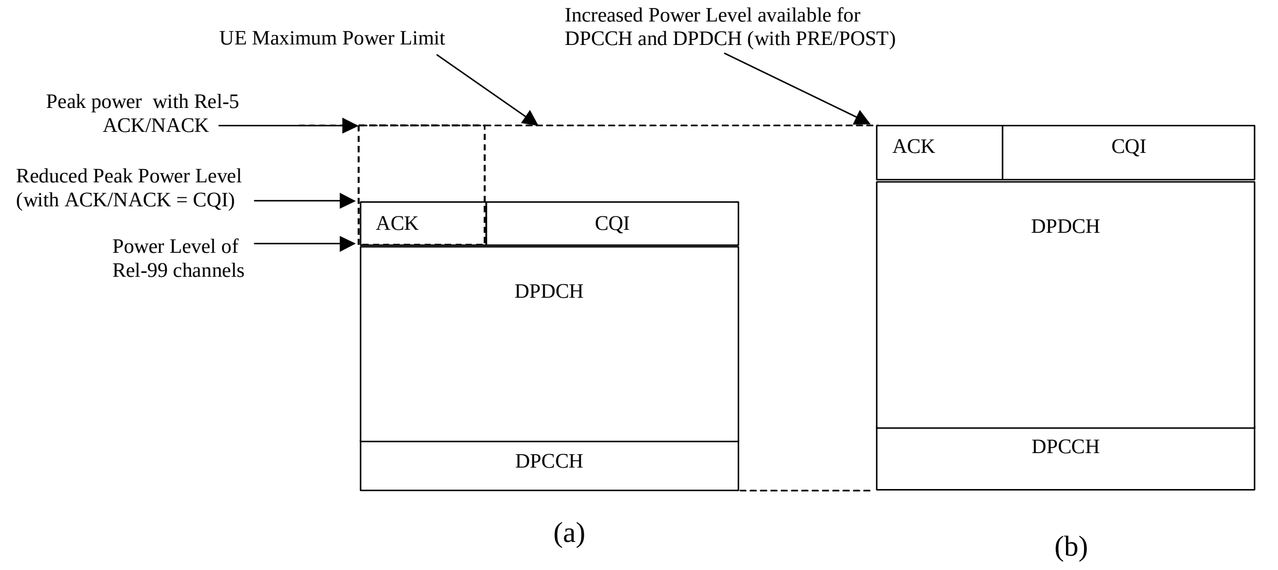

Figure 41: Relative power levels of uplink channels with and without PRE/POST scheme

Taking the case of 64kbps, reducing β_{hs}/β_c from 24/15 to 15/15 and then scaling the peak power back to its original value (as shown in Figure 41(b)) has the overall effect of reducing the ACK/NACK power by 3dB, while increasing the DPCCH and DPDCH powers by 1.1dB.

For the corresponding coverage improvement to be realised, the PRE/POST scheme must achieve the required ACK/NACK error rates with 3dB less power than the Rel-5 HS-DPCCH.

This is confirmed by the simulation results shown in Figures 37 – 40 above. In addition, further simulation results are given below for other channel models: AWGN, Case1 and Case3. Apart from the channel models, general simulation assumptions are as given in section 6.7.2.1, with the addition of the following:

- 80% packet loading per UE on HS-DSCH
- P(PRE or POST or DTX->ACK) $\leq$ 0.01 for AWGN and Case1
- P(PRE or POST or DTX->ACK) $\leq$ 0. 1 for Case3
- β_{hs}/β_c = 24/15 for Rel-5 HARQ-ACK field
- β_{hs}/β_c = 15/15 for PRE/POST scheme HARQ-ACK field.

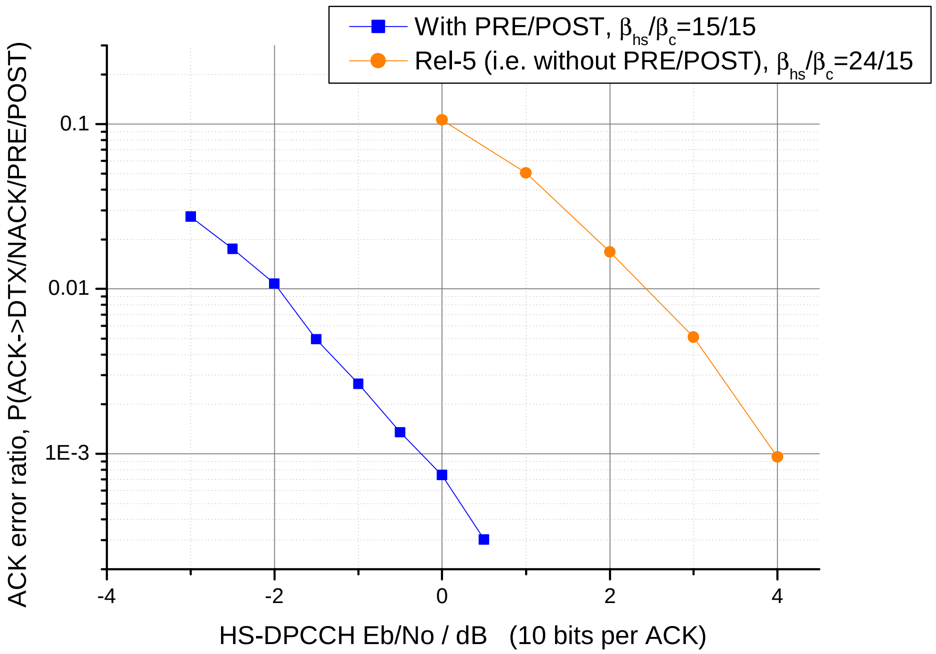

Figure 42: HARQ ACK performance in AWGN channel

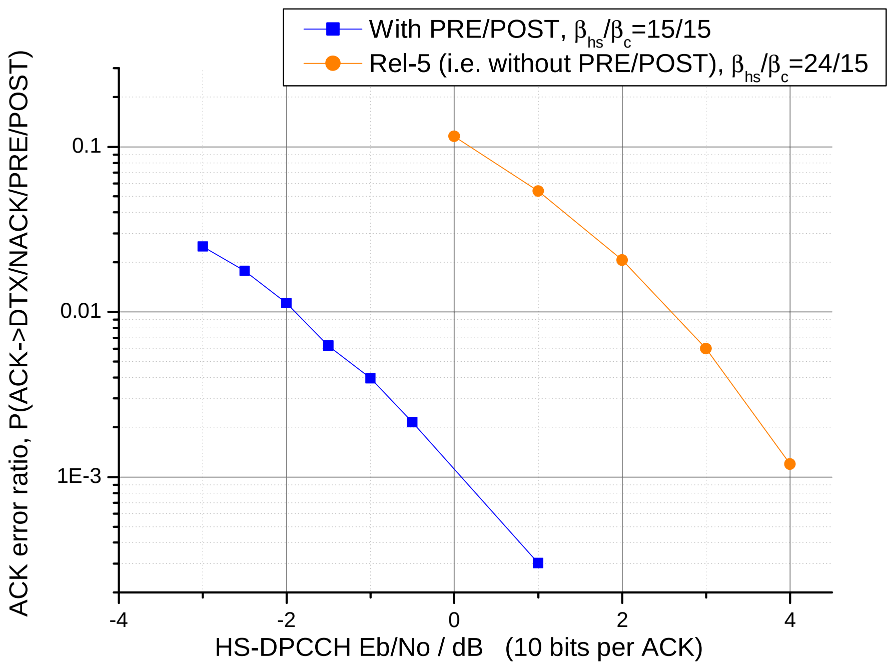

Figure 43: HARQ ACK performance in Case1 channel

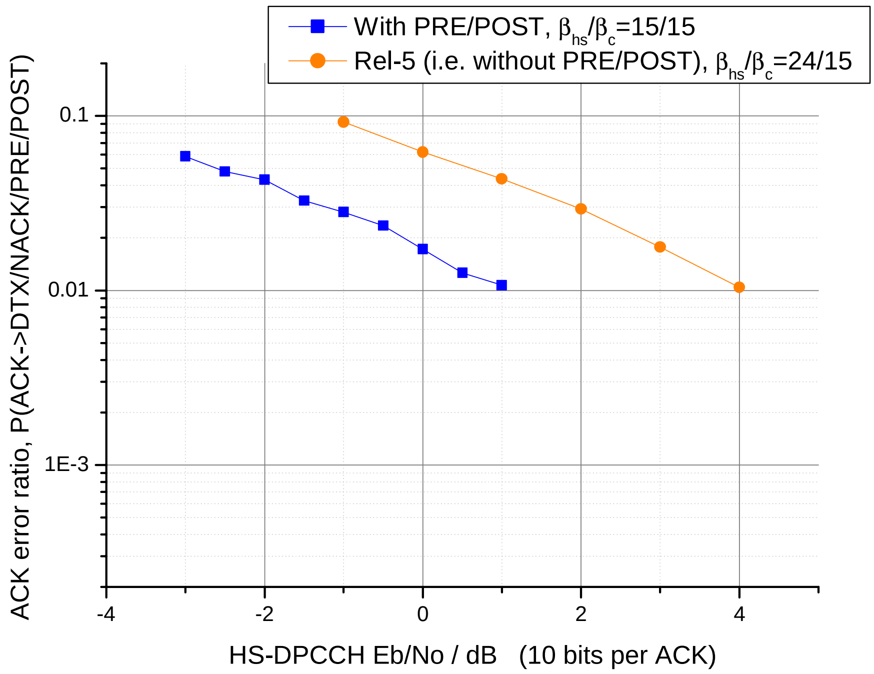

Figure 44: HARQ ACK performance in Case3 channel

It can be seen that in all 3 cases, the performance of the PRE/POST scheme is at least 3dB better in terms of HS-DPCCH required E_b/N_0 than the Rel-5 HS-DPCCH.

These results confirm that the PRE/POST scheme can meet the target of reducing the required ACK/NACK power by more than 3dB, and can therefore make available another 1.1dB transmit power for the DPCCH and DPDCH, which can increase coverage.

From link budget calculations, a 1.1dB increase in available UL transmit power corresponds to approximately a 14% increase in cell coverage area (7% increase in cell radius).

Similar calculations can be performed for other data rates, such as the 16kbps uplink. In this case, reducing β_{hs}/β_c from 24/15 to 15/15 and then scaling the peak power back to its original value (as shown in Figure 41(b)) has the overall effect of reducing the ACK/NACK power by 2.4dB, while increasing the DPCCH and DPDCH powers by 1.7dB, corresponding to approximately a 22% increase in cell coverage area (12% increase in cell radius).

6.7.2.4 Summary

Simulation results presented here show that the PRE/POST scheme achieves the following:

- “Relaxed Requirements” met at all UE speeds in SHO, without needing more than 1 ACK/NACK repetition;
- “Tight Requirements” met in SHO at UE speeds above 45km/h;
- When not in SHO, “Tight Requirements” met with no repetitions at all speeds up to 40km/h (compared to only 20km/h with Release 5 specifications);
- “Relaxed Requirements” met without repetitions at speeds higher than 40km/h when not in SHO.
- Worst-case error rate of 0.03 achieved for distinguishing between failed HS-SCCH detection and failed HS-DSCH CRC.

When the UE is at the cell edge, the power saved from the HS-DPCCH by using the PRE/POST scheme can enable at least 1dB more power to be allocated to the DPCCH and DPDCH, resulting in a cell coverage area improvement of 14% for 64kbps UL (or 22% for 16kbps UL).