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Title: **Downlink Power Balancing: Additional Slow Loop**

Document for: **Discussion & Decision**

Preface

The issue of DL power balancing in case of soft handover with different Node Bs has been addressed several times in this working group.

The basic problem: When cells of at least two Node Bs are involved in a soft handover situation with a UE, then all these cells receive the same TPC command from the UE. Consequently, under ideal conditions they will always change their transmit powers in the same direction. However, due to errors in the detection of TPC bits, the transmit power levels of the cells will drift relative to each other in the sense of a random walk. This drift is only limited by the finite range of the transmit powers.

It seems clear, that the resulting imbalance of the transmit powers reduces the DL macrodiversity gain, not only in SSDT mode. In fact, system level simulations (see Annex A) confirm this statement: The power imbalance increases the overall power that needs to be transmitted in DL for the UE to attain a certain quality (block error rate). Consequently, the overall downlink interference increases, and a decrease of capacity/range is the result.

1 Introduction

This contribution compares different strategies for counteracting the power imbalance problem, referred to as “options 1 to 4”, and concludes that one of these options should be included in the standard. Amongst others, the power re-sync method (here: “option 1”) and the NEC proposal of an adjustment loop as proposed in R3-99b46 (here: special case of “option 4”) are considered.

It will be pointed out (see § 4.1), that the algorithm for DL power balancing needs to be standardised in any case, mainly for the following reasons:

- Two Node Bs that apply different power balancing algorithms achieve sub-optimum performance.
- Even if two Node Bs perform the same power balancing algorithm, they might use a different set of parameters characterising this algorithm. Again, this can result in sub-optimum performance.
- Different power balancing algorithms require different messages to be signalled via Iub and Iur/Iub.

According to the current standard, only a message called “reference power” is specified for power balancing purposes, which is sent from RNC to NodeBs. This is certainly not enough information for optimum power balancing performance. Sub-optimum performance will be the result, unless all Node Bs in a soft handover situation belong to the same manufacturer (like behaviour of different Node Bs is desireable to achieve best results). But even then, performance will be sub-optimum, unless the RNC comes from the same manufacturer as well and some manufacturer-dependent measurements and messages on Iub are implemented.

This is against the philosophy of an open interface, hence the need for standardising the DL power balancing algorithm and its messages between Node B and SRNC. A text proposal for TS25.214 is given.

1.1 Overview

In section 2, four different options to counteract the power imbalance are introduced, and their advantages and disadvantages w.r.t. computational effort/signalling overhead are outlined. All these options have one thing in common: They maintain a power control cycle of 1 slot.

Section 3 decribes the scheme according to option 4 (“Additional Slow Loop”) in more detail.

Section 4 draws conclusions from the analysis of the different options and the simulation results of annex A. It proposes to include “option 4” (“Additional Slow Loop”) in the standard and to define messages between NodeB and SRNC such that option “4” can be supported by UTRAN in an optimum way.

Annex A provides simulation results for the different options and different scenarios.

Annex B provides a text proposal for TS25.214.

2 Discussion: Different Power Balancing Options

Several strategies to counteract the power imbalance are described in the following, some of which have already been proposed in other Tdocs (e.g. R3-99b46 by NEC). Mind the different interpretations of the term "reference power" in option 1/2 on the one hand and in option 4 on the other hand.

2.1 Option 1: Periodical Simultaneous Power Resets

In regular time intervalls (eg. 1^{st} slot of every n^{th} frame), all cells being in the active set of the UE simultaneously reset their transmit powers (w.r.t. DPCCH of respective UE) to a certain value, the “reference power”.

Assumptions:

- The parameter “n” (power reset rate) is set by the SRNC.
- The “reference power” is set by the SRNC, based on feedbacks from each cell on its actual transmit power (w.r.t. DPCCH of respective UE), possibly averaged over an appropriate time period.

Benefits:

\+ Perfect power balance among the cells is established directly after each power reset.

Drawbacks:

\- Each reset of the transmit powers disrupts the fast power control process. After each adjustment, the fast power control process needs some time to converge to its optimum value. In the meantime, reception conditions might be bad.

2.2 Option 2: Event Triggered Simultaneous Power Resets

By means of reports from the Node Bs every “n” frames, the SRNC continuously monitors the instantaneous transmitted powers (w.r.t. DPCCH of respective UE) of the different cells being in the active set of the UE. When SRNC detects an unwanted imbalance, then it sets the transmit powers (w.r.t. DPCCH of respective UE) of all these cells to a certain value (corresponding to the “reference power” in option 1). All cells set their transmit powers to this value synchronously (in the same slot of the same frame).

Assumptions:

- The parameter “n” (power report rate) is set by the SRNC.

Benefits:

\+ Perfect power balance among the cells is established directly after each adjustment.

\+ Adjustments only take place when a power imbalance has been detected, hence disruptions of the fast power control process are less frequent than in option 1.

Drawbacks:

\- There are still disruptions of the fast power control process, see option 1.

\- A lot of regular measurement reports from Node B to SRNC are necessary. Assuming a TPC detection error rate of 5% for each cell and 1dB TPC stepsize, the mean power drift between two cells is 3.14 dB per 10 frames (=150 slots) and even 9.76 dB per 100 frames. The actual drift can be much higher. Hence, the reports have to be sent on a basis of 'n' frames, where n is a small integer number. This means there will be a considerable additional signalling overhead (in-band signalling) on Iub/Iur in uplink and additional processing load.

\- Since power drifts might occur quite often (see above), frequent power adjustment commands need to be sent (also in-band). This means a lot of signalling overhead on Iub/Iur in downlink and additional processing load.

2.3 Option 3: Event Triggered Power Corrections

By means of reports from the Node Bs every “n” frames, the SRNC continuously monitors the instantaneous transmitted powers (w.r.t. DPCCH of respective UE) of the different cells being in the active set of the UE. When SRNC detects an unwanted imbalance, then it sends a power alignment command to at least one of the cells. This alignment command is a value (in dB) which is *relative* to the cells actual transmit power (w.r.t. DPCCH of respective UE). A cell that receives such an alignment command shall adjust its transmit power (w.r.t. DPCCH of respective UE) by the given amount (in dB).

Assumptions:

- The parameter "n" (power report rate) is set by the SRNC.

Benefits:

+ Disruptions of the fast power control as in option 1 or 2 are eliminated.
+ Adjustments only take place when a power imbalance has been detected.

Drawbacks:

- There is a delay of typically at least 1 frame between detection of an imbalance and correction of the imbalance (transfer delays on Iub or Iub/Iur, periodicity of frame protocol PDUs).
- A lot of regular measurement reports from Node B to SRNC are necessary, see "option 2". Hence, the reports have to be sent on a basis of 'n' frames, where n is a small integer number. This means there will be a considerable additional signalling overhead (in-band signalling) on Iub/Iur in uplink and additional processing load.
- Since power drifts might occur quite often (see "option 2"), frequent power adjustment commands need to be sent (also in-band). This means a lot of signalling overhead on Iub/Iur in downlink and additional processing load.

2.4 Option 4: Additional Slow Loop

Each cell performs a slow power adjustment procedure in superposition to the fast power control process. While the fast power control is determined by the received TPC commands, the slow power adjustment process is determined by the instantaneous transmit power relative to a "reference power" value (different meaning than in options 1 and 2!). The reference value is set by SRNC based on feedbacks from the cell on its average (in dB) transmit power level (w.r.t. respective UE).

Assumptions:

- The "reference power" is set by the SRNC, based on feedbacks from each cell on its average (in dB) transmit power level (w.r.t. respective UE)
- The aforementioned averaging period for averaging the transmit power is set by the SRNC.
- All Node Bs use the same set of parameters α, β, γ (see § 3) that specify the "additional slow loop".

Benefits:

+ No disruptions of the fast power control process.

Drawbacks:

- The number of parameters involved in option 4 is higher than in option 1.
- Some additional (but simple) processing on Layer 1 inside Node B.

2.5 Summary:

Advantages (+) and disadvantages (-) of the respective options are summarised in the table below:

	Without power balancing ↓	**Option**			
	w/o	**1**	**2**	**3**	**4**
Processing/Signalling:					
Signalling and processing effort UL	++[1]	+[3]	-[2]	-[2]	+[3]
Signalling and processing effort DL	++[1]	+[3]	-[2]	-[2]	+[3]
Radio Performance:					
Disruption of fast power control process ('+' = no, '-' = yes)	++	--	-	+	+
Power balancing performance	?	?	?	?	?
Overall DL Interference minimisation	?	?	?	?	?

Legend: ← worse ---, --, -, o, +, ++, +++ better →

Simulations have been performed to be able to compare the radio performances, see annex.

[1] No signalling.
[2] In-band, one message every few frames.
[3] One message every few seconds, e.g. by dedicated NBAP/RNSAP.

3 Description of Option 4 ("Additional Slow Loop")

What follows is a more detailed description of "option 4".

3.1 The Principle:

- Each cell performs a continuous transmit power adjustment in superposition to the fast power control. The direction of this additional power adjustment is determined by a reference power.
- The reference power is set by the SRNC and may be changed in relatively large time intervals (e.g. seconds). The SRNC calculates the reference power based on messages received from the cells indicating their time averaged (in dB) transmit power level (w.r.t. DPCCH of respective UE).

In more detail, the procedure looks like this:

1. First of all, the SRNC sends the same set of parameters {tav, Δ_{TPC}, α, β, γ} to all cells that are in the active set of the UE. The parameter "tav" indicates the averaging period for the transmit power level reports by the Node B, Δ_{TPC} is the TPC stepsize in DL in dB and the parameters α, β and γ determine the way the additional slow loop behaves (see § 3.2).
2. After add branch, SRNC signals an initial reference power P_{ref} value to each cell being in the active set of the UE (in addition to tav, Δ_{TPC}, α, β and γ).
3. Each cell runs the fast power control as usual. <u>In superposition</u> to that, it adjusts its transmit power (w.r.t. respective UE) towards the reference value according to the parameters α, β and γ. These parameters have to be chosen such that these adjustments are slower than the fast power control steps. Otherwise the fast power control performance would be affected. For the exact meaning of α, β and γ refer to § 3.2.
   <u>Example</u> (here α=0.25, β=0 and γ=0.25): In every slot, when the instantaneous power is higher than the reference power, then the cell performs a +0.75 dB/–1.25 dB power adjustment (dpdt. on TPC command). When the instantaneous power is below the reference power, then it performs a +1.25 dB/–0.75 dB power adjustment. In other words, in this example there is a superposition of the fast power control loop (+/–1 dB, TPC driven) and the slow loop (+/- 0.25 dB, P_{ref} driven).
   <u>Remark</u>: If the digital resolution at Node B is not as fine as 0.25 dB, then Node B can instead approximate the behaviour described above as follows: It calculates the transmit power P_calc as indicated above (fine resolution). The actually transmitted power P is a rounded version of P_calc, where the resolution is dependant on the hardware.
4. Every tav (tav is large, e.g. 1 sec) the cells transfer the averaged (**averaged dB-values!**) power levels (w.r.t. respective UE) to the SRNC. The averaging period is tav.
   <u>Remark 1</u>: The message from the cells to the SRNC could be signalled via dedicated NBAP/RNSAP procedures (TS25.433/423).
   <u>Remark 2</u>: The power balancing works best when the actual transmit power is half of the time below the reference power and half of the time higher than the reference power. This is the reason why averaged dB values rather than linearly averaged power values shall be transmitted to the SRNC by the cells.
5. The SRNC compares the averaged values with each other and with the current reference values. The SRNC might then decide to send new reference values to some of the cells.
   <u>Remark 1</u>: The reference power can be either an absolute dBm-value, or a value relative to the CPICH power.
   <u>Remark 2</u>: The message from the SRNC to the cells could be signalled via NBAP/RNSAP (TS25.433/423).

Note that the reference power will not overrule the fast power control! For example, when the cell receives a 'TPC=UP', then the power <u>will</u> go up, even if P_{ref} is already much below the current transmit power. That means, the actual power might stay above the reference power for a long time, if the reference power is set unappropriately. Hence the need for feedbacks from Node B to SRNC about the averaged transmit power level.

3.2 *The Parameters a, b and g*

*Note: The setting **a**=0, **g**=infinity and **b**=1-r corresponds to the NEC proposal “R3-99b46”, where “r” is a parameter introduced in R3-99b46.*

The parameters α, β and γ determine the way the additional loop works. They are described in detail in the following.

Let P(k) be the transmit power of a cell (w.r.t. a certain UE) at slot k, and P_{ref} the reference power. Moreover, let P_{min} and P_{max} denote the minimum and maximum transmit power (power range), and let $SIGN_{TPC} \in \{-1, 1\}$ denote the direction of the transmit power due to the received TPC command.

Then the transmit power P(k+1) in the following slot 'k+1' will calculate as follows:

```
Δ_diff = (P(k)_dB - P_ref,dB);
Δ_slow_loop = -sign(Δ_diff) * Δ_TPC * min{α + β*|Δ_diff|, γ};
P_temp = P(k)_dB + SIGN_TPC*Δ_TPC + Δ_slow_loop;
// remark: SIGN_TPC*Δ_TPC due to TPC command; Δ_slow_loop due to P_ref.
IF P_temp > P_max THEN
   P(k+1)_dB = P_max
ELSEIF P_temp < P_min THEN
   P(k+1)_dB = P_min
ELSE P(k+1)_dB = P_temp;
```

The parameters α, β and γ should be chosen such that $\alpha \le \gamma < 1$ and $\beta > 0$ dB^{-1}, otherwise they do not make sense.

Some explanations for clarification:

- For $\beta = 0$ dB^{-1}, the value of γ has no relevance (as long as $\alpha \le \gamma$). In this case, the slow loop will always steer the transmit power towards the reference power with the fixed stepsize $\alpha * \Delta_{TPC}$.
- For $\beta > 0$ dB^{-1}, the slow loop will steer the transmit power towards the reference power with a stepsize which is larger, the larger the difference between current transmit power and reference power. Hower, the stepsize is limited by $\gamma * \Delta_{TPC}$ in order not to overrule the fast power control.
- For $\alpha = \gamma$, the value of β has no meaning.
- The condition $\gamma < 1$ ensures that the slow loop never 'overrules' the fast power control loop, i.e. the sign of the TPC command, $SIGN_{TPC}$, is always the same as $sign(SIGN_{TPC} * \Delta_{TPC} + \Delta_{slow\_loop})$, the superposition of TPC power adjustment and slow loop power adjustment.

The figure below illustrates the transmit power change due to the slow loop. Note that the magnitude of the transmit power change due to this slow loop is always smaller than the transmit power change due to the TPC command ($\gamma < 1$).

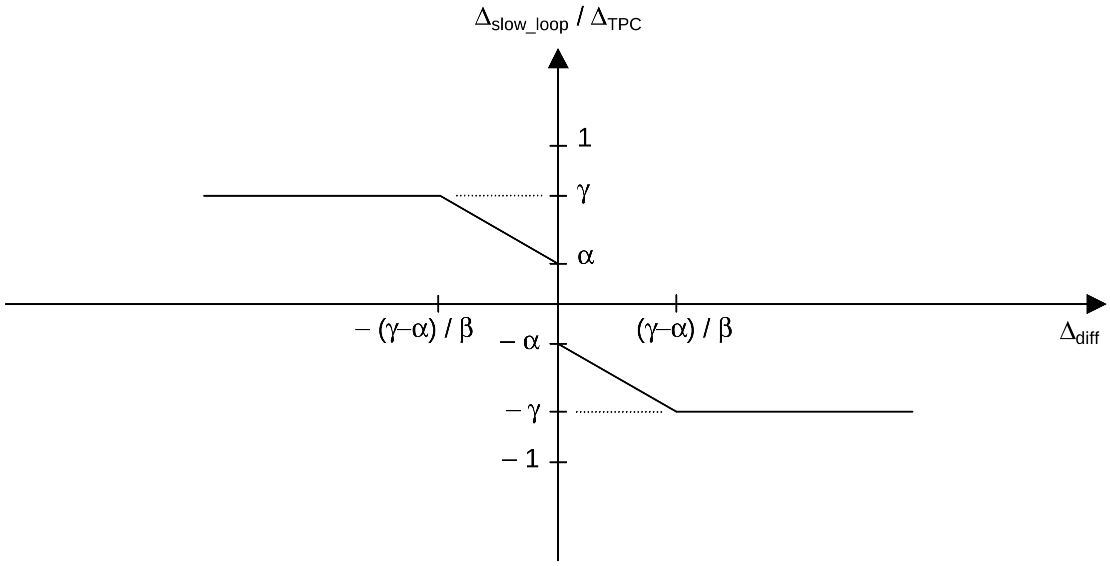

Fig. 3.1: Transmit power adjustment for slot "k+1" due to the slow loop as a function of $\boldsymbol{D}_{diff} = (P(k)_{dB} - P_{ref,dB})$

When limited resolution capabilities of the transmit power due to hardware limitations are considered, the algorithm described above changes as follows:

```
Δ_diff = (P_calc(k)_dB - P_ref,dB);
Δ_slow_loop = -sign(Δ_diff) * Δ_TPC * min{α + β*|Δ_diff|, γ};
P_temp = P_calc(k)_dB + SIGN_TPC*Δ_TPC + Δ_slow_loop;
// remark: SIGN_TPC*Δ_TPC due to TPC command; Δ_slow_loop due to P_ref.
IF P_temp > P_max THEN
   P_calc(k+1)_dB = P_max
ELSEIF P_temp < P_min THEN
   P_calc(k+1)_dB = P_min
ELSE P_calc(k+1)_dB = P_temp;
P(k+1)_dB = round(P_calc(k+1)_dB)
```

4 Conclusions & Proposal

Annex A shows the results of simulations that have been carried out for all options introduced in section 2, considering different scenarios.

After analysis of the results (see Annex A, § 5.3) , the table of section 2.5 can be completed with the evaluation of the radio performance:

	Without power balancing ↓	Option			
	w/o	**1**	**2**	**3**	**4**
Processing/Signalling:					
Signalling and processing effort UL	++	+	-	-	+
Signalling and processing effort DL	++	+	-	-	+
Radio Performance:					
Disruption of fast power control process ('+' = no, '-' = yes) Power balancing performance	++ --	-- +	- +	+ o	+ ++
Overall DL Interference minimisation	--	+	+	o	++

Legend: ← worse ---, --, -, o, +, ++, +++ better →

According to the conclusion of § 5.3, option 4 is the most favourable way to do power balancing.

4.1 Proposal

When we analyse the current description of the standard, it becomes clear that the message excange between Node Bs and SRNC for the purpose of power balancing needs to be further specified. But this is hardly possible without having in mind an algorithm that performs the power balancing. Up to now, only a message called “reference power” is specified, which is sent from SRNC to NodeBs. However, this is not sufficient information. For example, two NodeBs that work “according to option 1”, would need to reset their power synchronously in order to remove the power imbalance. Otherwise, the results would be much worse than those shown in the simulation results of this contribution. Another Node B that applies “option 4” with a manufacturer-dependent set of parameters {α, β, γ} is not going to perform optimum power balancing when in an active set together with an “option-1-NodeB”, and vice versa. Also, two “option-4-NodeBs” with different sets of parameters α, β, γ are expected to perform worse than in the case of using the same set of parameters, because a systematic power drift even in case of no TPC errors would occur.

Hence, the main proposals:

1. We propose that a description of the DL power balancing method is included in TS25.214, see text proposal in Annex B. We further propose that all signalling messages between SRNC and cell via Iub or Iub/Iur that are needed for performing power balancing according to option “4” (“Additional Slow Loop”) in an optimum manner shall be included in the standard. A corresponding LS to WG3 would be needed.

2. We further propose that signalling messages for support of power balancing according to option 2/3 (in-band signalling dedicated to power balancing purposes) or option 1 shall not be specified by the standard.

<u>Regarding “main proposal 1.”</u>:

We propose that the following messages are introduced in the standard:

SRNC to cell:

- [SRNC signals a “reference power” to a cell. It can signal a new value for the reference power at any time during connection“. (already included in the standard)]

- Upon setup of a radio link, SRNC can signal to the cell a parameter “tav” indicating the averaging period for the TX power measurements (see below).
- Upon setup of a radio link, the parameters α, β, γ can be signalled from SRNC to the cell. If this was not done, each Node B would apply a different set of parameters, which would result in sub-optimum power balancing performance.

Cell to SRNC:

- During connection in SHO, each cell signals its averaged transmit power level (with respect to DPCCH of a certain UE) to the SRNC every “tav” seconds, whereas the averaging is done on the **dB-values** (rather than linear averaging) and the averaging time is “tav” (see above).

Regarding “Main Proposal 2.”:

- Assuming **option 1** would be applied for power balancing, the standard would need to specify when the power reset should occur (e.g.: “A power reset should occur in the 1^{st} slot of every n^{th} frame, starting with the 1^{st} frame of a super frame). Moreover, a signalling message for transfer of the parameter “n” would need to be defined, unless “n” was fixed by the standard. We propose to neither define the value “n”, nor to define when a “power reset” shall occur, nor to define a signalling message for “n”.
- Assuming **option 2 or 3** would be applied for power balancing, there would be a need for some in-band signalling. We propose that the standard does not define such messages.

If the “reference power” remains the only parameter defined for power balancing purposes, some NBs will apply “option 1”, others “option 4”, others maybe a third scheme. The result will always be sub-optimum performance, unless all Node Bs in a soft handover situation (and also the RNC, which supports manufacturer-dependent signalling) belong to the same manufacturer.

A Text Proposal for TS25.214 is given in Annex B.

5 Annex A: Simulations

System simulations have been carried out to judge the performance for the different power balancing options. Different scenarios have been considered in the simulations:

- Rayleigh channels, Vehicular A channels
- UE speeds of 5, 10, 50 km/h
- Relative path losses of 0 dB and 2 dB
- TPC detection error rates of 1%, 4%, 8%

5.1 Simulation Conditions

System level simulations have been carried out, considering a UE that is in a soft handover situation with two cells. The two downlink channels between cell and UE have been modelled as mutually uncorrelated channels – Rayleigh or Vehicular A (slow fading/shadowing has not been considered).

The following tables summarise the details of the simulation conditions.

Table 5.1-1: Simulation parameters ***common for all simulations****.*

Simulation Duration	10 seconds = 15000 slots
Number of UEs	1
Number of cells	2
Number of cells in the UEs active set	2
Carrier frequency	2 GHz
Power control cycle	666.67 µs
Dynamic range of DL TX power dedicated to the UE	18 dB
RAKE receiver	6 Fingers
Inner loop	Δ_{TPC} = 1 dB
Outer loop	Target Quality: Block error rate=1%, 20 ms interleaving, R=1/3 convolutional code, SF=128. Simulation of the steady state, i.e. SIR_target=const.
TPC detection error at cell site	1%, 4% or 8% for each cell, mutually uncorrelated for cell 1 and cell 2, and uncorrelated in time. Three BER sequences (for 1%, 4%, 8%) have been generated and stored. All simulation use the same BER sequences.
TPC generation error at UE	0%
DL channels	Mutually uncorrelated Rayleigh channels or Vehicular A channels for both cell 1 and cell 2. The channels have been generated and stored. All simulations used the same channels. Relative path loss: 0 dB or 2 dB.
UE velocity	5, 10, 50 km/h
DL interferences	Interference from both cells involved has been modelled, considering orthogonality factors (0 for rayleigh, 0.4 for Veh. A). Moreover, additional Interference due to noise and other surrounding cells has been added (modelled as AWGN).

*Table 5.1-2: **Constant** simulation settings for the different options.*

For option 1	The time intervall between two successive power resets is n=2 frames.
For option 1 and 2	Each "power reset" (once, synchronously, every 'n' frames) sets the TX powers of each of the cells to "0 dB" (see figures in 5.2).
For option 2 and 3	The delay between power report from the cells and adjustment of the TX-powers is 1 frame. The time intervall between two successive TX-power reports from the cells to the SRNC is n=2 frames.
For option 3	The power correction (removal of imbalance "Δ_{diff} [dB]") is realized by changing the TX power of the two cells by $+\Delta_{diff}/2$ and $-\Delta_{diff}/2$ respectively at the same time instant. An infinite resolution of the TX power is assumed.
For option 4	The reference power P_{ref} is the same for both cells, constant "0 dB" (see figures in 5.2). The **resolution** of the transmit power in Node B is assumed to be **1 dB**.

*Table 5.1-3: **Varying** simulation settings for the different options.*

For option 4	Two sets of parameters α, β and γ (see §3). The first set ("4a") corresponds to NECs adjustment loop proposed in R3-99b46: β = 1-r = 0.04.

5.2 Simulation Results

The following tables show the results of various simulations. There are two simulation outputs for each simulation run:

- **DL Interference**: This parameter indicates by how many dB the overall transmitted power (linear sum of TX powers of both cells) of the two cells towards the UE is less compared to the same simulation without power balancing. Since more overall transmitted power towards the "dedicated" UE corresponds to more interference to other UEs, it entails a decrease of cell capacity. Hence, this is the most important parameter:
  DL Interference=$(PTX1_{linear}+PTX2_{linear})_{dB}$ - $(PTX1\_no\_bala_{linear}+PTX2\_no\_bala_{linear})_{dB}$.

- **STD of PTX1-PTX2**: This is the standard deviation (in dB) of the differences of the powers levels (dB) tranmitted to the UE by the two cells: **$STD(PTX1_{dB}-PTX2_{dB})$**. The smaller the value, the better is the TX power balanced between the two cells.

The column labelled "**settings**" refers to the settings of some parameters that are specific to the respective balancing scheme.

Different tables correspond to different channel environments (Rayleigh or Veh. A, relative path loss) and UE speeds.

Each table shows three simulation categories (TPC-BERs of 1%, 4%, 8%). Within each category, the three best results have been highlighted with yellow background colour to make reading easier.

5.2.1 Two Rayleigh Channels, same Path Loss

Table 5.2-1: Simulation results for two rayleigh channels with the same path loss, 5 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
1210	w/o		0.00	3.76
1211a	1	n=2	-0.47	1.05
1212a	2	n=2	-0.40	1.07
1213a	3	n=2	-0.34	1.55
1214a 1214b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.42 -0.44	1.00 1.06
		TPC-BER=4%:		
1220	w/o		0.00	5.44
1221a	1	n=2	-0.89	2.15
1222a	2	n=2	-0.88	2.06
1223a	3	n=2	-0.84	2.90
1224a 1224b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.87 -0.93	1.92 1.77
		TPC-BER=8%:		
1230	w/o		0.00	6.89
1231a	1	n=2	-0.99	2.92
1232a	2	n=2	-1.02	2.78
1233a	3	n=2	-0.77	4.00
1234a 1234b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.97 -1.05	2.62 2.22

Table 5.2-2: Simulation results for two rayleigh channels with the same path loss, 50 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
1210	w/o		0.00	5.30
1211a	1	n=2	-0.32	1.13
1212a	2	n=2	-0.33	1.07
1213a	3	n=2	-0.27	1.54
1214a 1214b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.36 -0.43	1.03 0.59
		TPC-BER=4%:		
1220	w/o		0.00	5.17
1221a	1	n=2	-0.36	2.14
1222a	2	n=2	-0.35	2.13
1223a	3	n=2	-0.32	3.05
1224a 1224b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.41 -0.51	1.98 1.14
		TPC-BER=8%:		
1230	w/o		0.00	5.86
1231a	1	n=2	-0.71	2.79
1232a	2	n=2	-0.52	2.62
1233a	3	n=2	-0.33	4.17
1234a 1234b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.61 -0.72	2.58 2.01

5.2.2 Two Rayleigh Channels, 2 dB different Path Loss

Table 5.2-3: Simulation results for two rayleigh channels with 2 dB different path loss, 5 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
1510	w/o		0.00	3.73
1511a	1	n=2	-0.25	1.05
1512a	2	n=2	-0.20	1.08
1513a	3	n=2	-0.12	1.52
1514a 1514b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.22 -0.27	1.01 1.05
		TPC-BER=4%:		
1520	w/o		0.00	5.84
1521a	1	n=2	-0.81	2.11
1522a	2	n=2	-0.72	2.16
1523a	3	n=2	-0.66	2.95
1524a 1524b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.84 -0.90	1.92 1.73
		TPC-BER=8%:		
1530	w/o		0.00	6.46
1531a	1	n=2	-0.79	2.87
1532a	2	n=2	-0.76	2.85
1533a	3	n=2	-0.58	3.97
1534a 1534b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.78 -0.88	2.65 2.19

Table 5.2-4: Simulation results for two rayleigh channels with 2 dB different path loss, 10 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
1510	w/o		0.00	4.07
1511a	1	n=2	-0.44	1.13
1512a	2	n=2	-0.31	1.08
1513a	3	n=2	-0.27	1.57
1514a 1514b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.36 -0.40	1.01 0.88
		TPC-BER=4%:		
1520	w/o		0.00	5.04
1521a	1	n=2	-0.46	2.12
1522a	2	n=2	-0.26	2.10
1523a	3	n=2	-0.25	2.89
1524a 1524b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.38 -0.47	1.97 1.56
		TPC-BER=8%:		
1530	w/o		0.00	5.48
1531a	1	n=2	-0.58	2.81
1532a	2	n=2	-0.38	2.86
1533a	3	n=2	-0.25	3.98
1534a 1534b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.43 -0.56	2.60 2.05

Table 5.2-5: Simulation results for two rayleigh channels with 2 dB different path loss, 50 km/h:

Sim.#	**Opt.**	**Settings**	**DL Interference (dB)**	**STD of PTX1-PTX2 (dB)**
		TPC-BER=1%:		
1610	w/o		0.00	4.38
1611a	1	n=2	-0.30	1.13
1612a	2	n=2	-0.29	1.10
1613a	3	n=2	-0.24	1.59
1614a 1614b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.34 -0.42	1.08 0.63
		TPC-BER=4%:		
1620	w/o		0.00	5.71
1621a	1	n=2	-0.48	2.04
1622a	2	n=2	-0.48	2.12
1623a	3	n=2	-0.37	2.94
1624a 1624b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.55 -0.64	1.87 1.16
		TPC-BER=8%:		
1630	w/o		0.00	6.61
1631a	1	n=2	-0.42	3.00
1632a	2	n=2	-0.38	2.94
1633a	3	n=2	-0.30	4.31
1634a 1634b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.46 -0.63	2.79 1.64

5.2.3 Two Vehicular A Channels, same Path Loss

Table 5.2-6: Simulation results for two Vehicular A channels with the same path loss, 5 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
2110	w/o		0.00	5.28
2111a	1	n=2	-0.41	1.07
2112a	2	n=2	-0.40	1.08
2113a	3	n=2	-0.39	1.58
2114a 2114b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.42 -0.41	1.01 0.58
		TPC-BER=4%:		
2120	w/o		0.00	6.82
2121a	1	n=2	-0.65	2.12
2122a	2	n=2	-0.67	2.27
2123a	3	n=2	-0.54	3.05
2124a 2124b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.65 -0.73	2.02 1.17
		TPC-BER=8%:		
2130	w/o		0.00	7.23
2131a	1	n=2	-0.58	2.77
2132a	2	n=2	-0.59	2.90
2133a	3	n=2	-0.40	4.06
2134a 2134b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.60 -0.69	2.63 1.50

Table 5.2-7: Simulation results for two Vehicular A channels with the same path loss, 10 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
2210	w/o		0.00	4.51
2211a	1	n=2	-0.33	1.00
2212a	2	n=2	-0.35	1.07
2213a	3	n=2	-0.31	1.49
2214a 2214b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.35 -0.36	1.04 0.55
		TPC-BER=4%:		
2220	w/o		0.00	6.05
2221a	1	n=2	-0.44	2.17
2222a	2	n=2	-0.46	2.14
2223a	3	n=2	-0.41	3.07
2224a 2224b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.46 -0.51	2.05 1.10
		TPC-BER=8%:		
2230	w/o		0.00	6.60
2231a	1	n=2	-0.40	2.91
2232a	2	n=2	-0.37	2.86
2233a	3	n=2	-0.22	4.08
2234a 2234b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.41 -0.47	2.64 1.47

Table 5.2-8: Simulation results for two Vehicular A channels with the same path loss, 50 km/h:

Sim.#	**Opt.**	**Settings**	**DL Interference (dB)**	**STD of PTX1-PTX2 (dB)**
		TPC-BER=1%:		
2310	w/o		0.00	4.90
2311a	1	n=2	-0.21	1.10
2312a	2	n=2	-0.21	1.11
2313a	3	n=2	-0.18	1.57
2314a 2314b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.21 -0.25	1.10 0.51
		TPC-BER=4%:		
2320	w/o		0.00	6.27
2321a	1	n=2	-0.23	2.11
2322a	2	n=2	-0.22	2.09
2323a	3	n=2	-0.20	3.06
2324a 2324b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.24 -0.29	2.00 1.04
		TPC-BER=8%:		
2330	w/o		0.00	7.10
2331a	1	n=2	-0.34	2.88
2332a	2	n=2	-0.32	2.89
2333a	3	n=2	-0.25	4.14
2334a 2334b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.34 -0.43	2.84 1.41

5.2.4 Two Vehicular A Channels, 2 dB different Path Loss

Table 5.2-9: Simulation results for two Vehicular A channels with 2 dB different path loss, 5 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
2410	w/o		0.00	6.61
2411a	1	n=2	-1.00	1.13
2412a	2	n=2	-0.99	1.04
2413a	3	n=2	-0.95	1.53
2414a 2414b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-1.02 -1.00	0.96 0.67
		TPC-BER=4%:		
2420	w/o		0.00	6.50
2421a	1	n=2	-0.55	2.04
2422a	2	n=2	-0.55	2.13
2423a	3	n=2	-0.46	3.09
2424a 2424b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.54 -0.57	2.06 1.19
		TPC-BER=8%:		
2430	w/o		0.00	6.59
2431a	1	n=2	-0.29	2.98
2432a	2	n=2	-0.28	2.92
2433a	3	n=2	-0.26	4.00
2434a 2434b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.31 -0.39	2.70 1.64

Table 5.2-10: Simulation results for two Vehicular A channels with 2 dB different path loss, 10 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
2510	w/o		0.00	4.48
2511a	1	n=2	-0.15	1.03
2512a	2	n=2	-0.15	1.12
2513a	3	n=2	-0.11	1.54
2514a 2514b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.15 -0.17	1.05 0.61
		TPC-BER=4%:		
2520	w/o		0.00	7.04
2521a	1	n=2	-0.42	2.16
2522a	2	n=2	-0.45	2.09
2523a	3	n=2	-0.33	3.13
2524a 2524b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.42 -0.48	2.05 1.15
		TPC-BER=8%:		
2530	w/o		0.00	7.02
2531a	1	n=2	-0.46	2.89
2532a	2	n=2	-0.46	2.93
2533a	3	n=2	-0.37	4.11
2534a 2534b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.52 -0.56	2.72 1.59

Table 5.2-11: Simulation results for two Vehicular A channels with 2 dB different path loss, 50 km/h:

Sim.#	Opt.	Settings	DL Interference (dB)	STD of PTX1-PTX2 (dB)
		TPC-BER=1%:		
2610	w/o		0.00	5.58
2611a	1	n=2	-0.29	1.14
2612a	2	n=2	-0.29	1.14
2613a	3	n=2	-0.26	1.58
2614a 2614b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.29 -0.33	1.07 0.56
		TPC-BER=4%:		
2620	w/o		0.00	6.25
2621a	1	n=2	-0.35	2.11
2622a	2	n=2	-0.35	2.10
2623a	3	n=2	-0.29	3.10
2624a 2624b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.38 -0.43	1.92 1.07
		TPC-BER=8%:		
2630	w/o		0.00	6.68
2631a	1	n=2	-0.29	2.91
2632a	2	n=2	-0.29	2.89
2633a	3	n=2	-0.22	3.93
2634a 2634b	4	α=0.0, β=0.04 dB^{-1}, γ=inf (NEC) α=0.1, β=0.1 dB^{-1}, γ=0.3	-0.33 -0.40	2.86 1.48

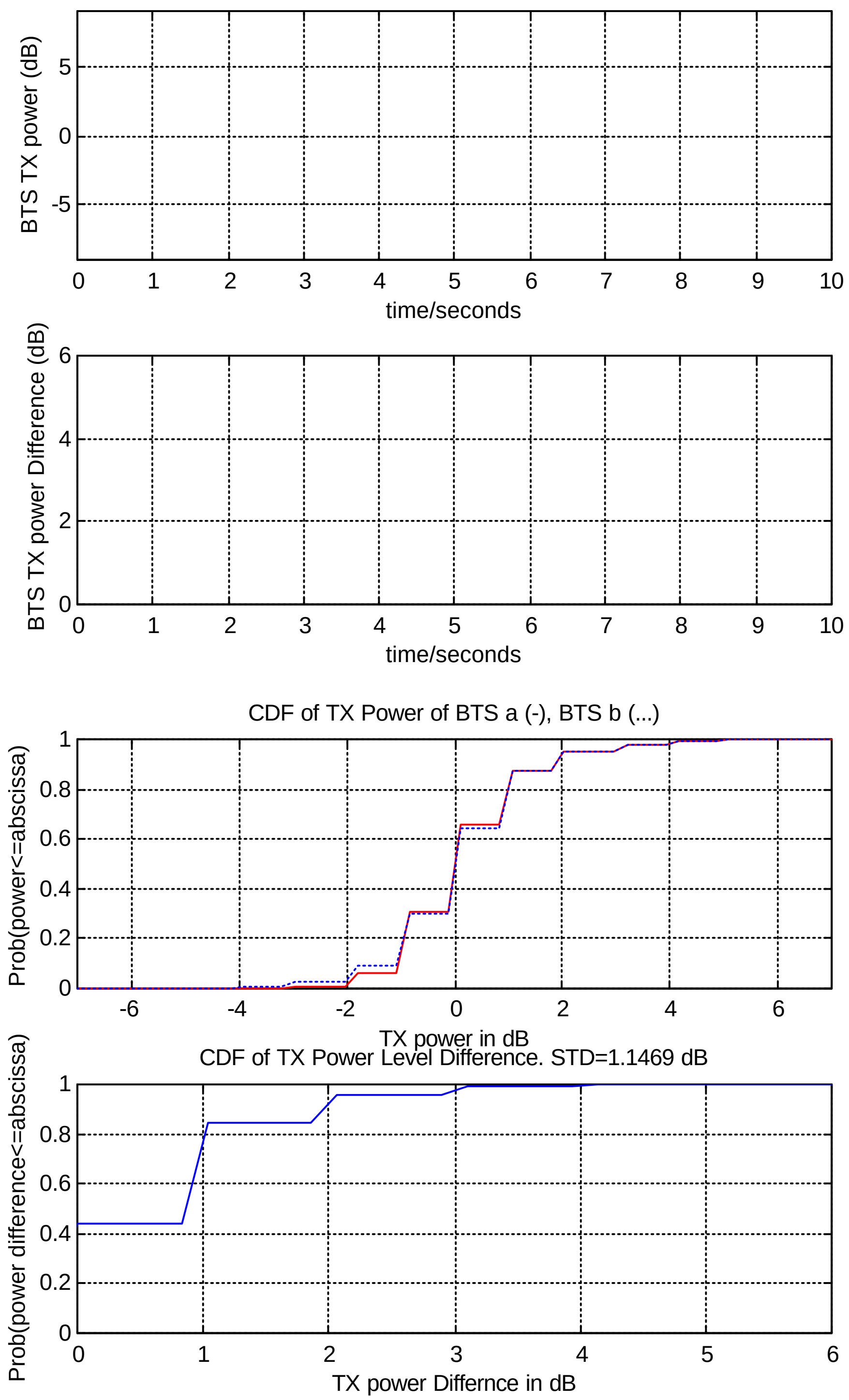

Figure 5.2-1: Illustration of Simulation No. 2524b: Power Balancing according to "option 4". See Table 5.2-10.

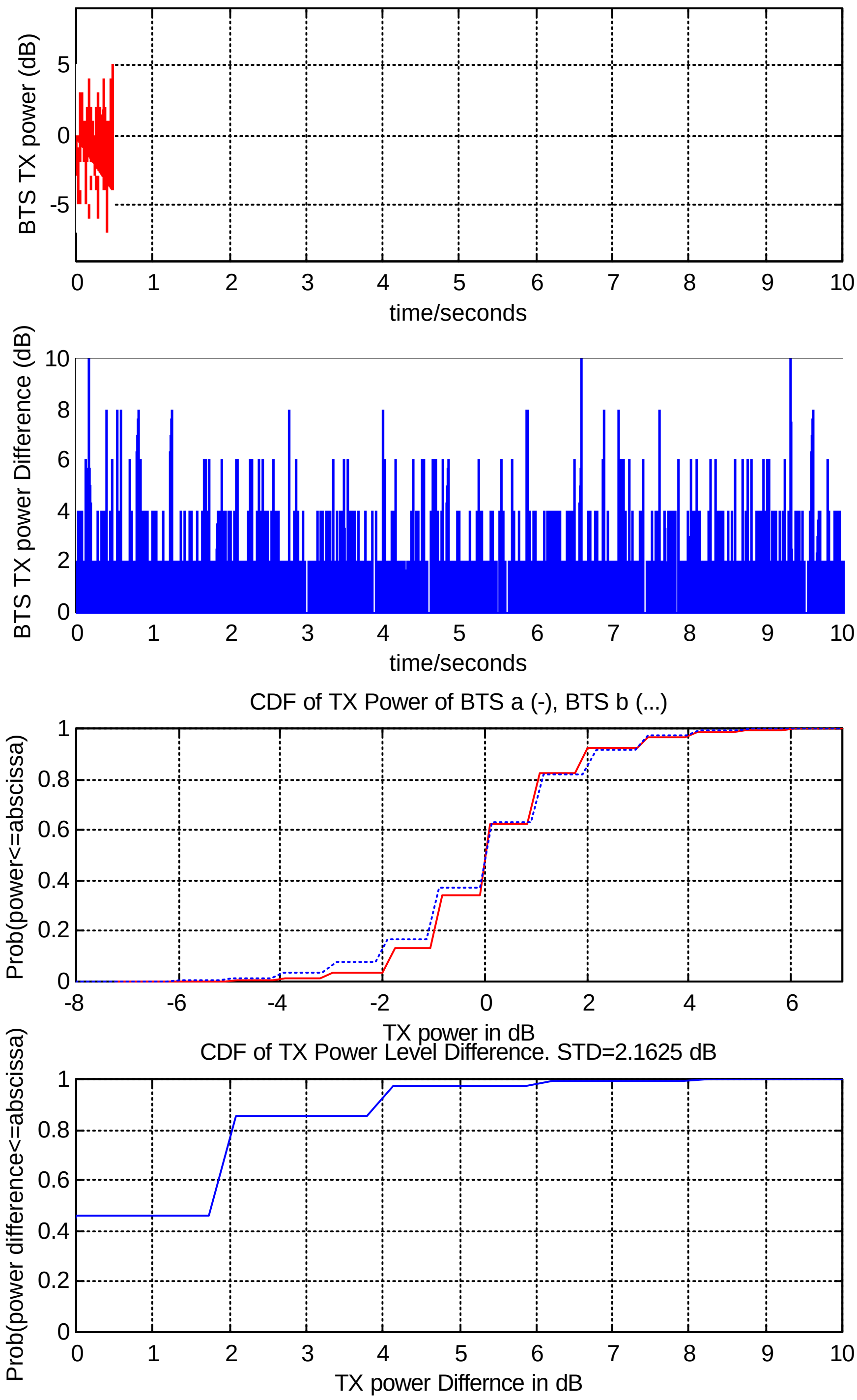

Figure 5.2-2: Illustration of Simulation No. 2521a: Power Balancing according to "option 1". See Table 5.2-10.

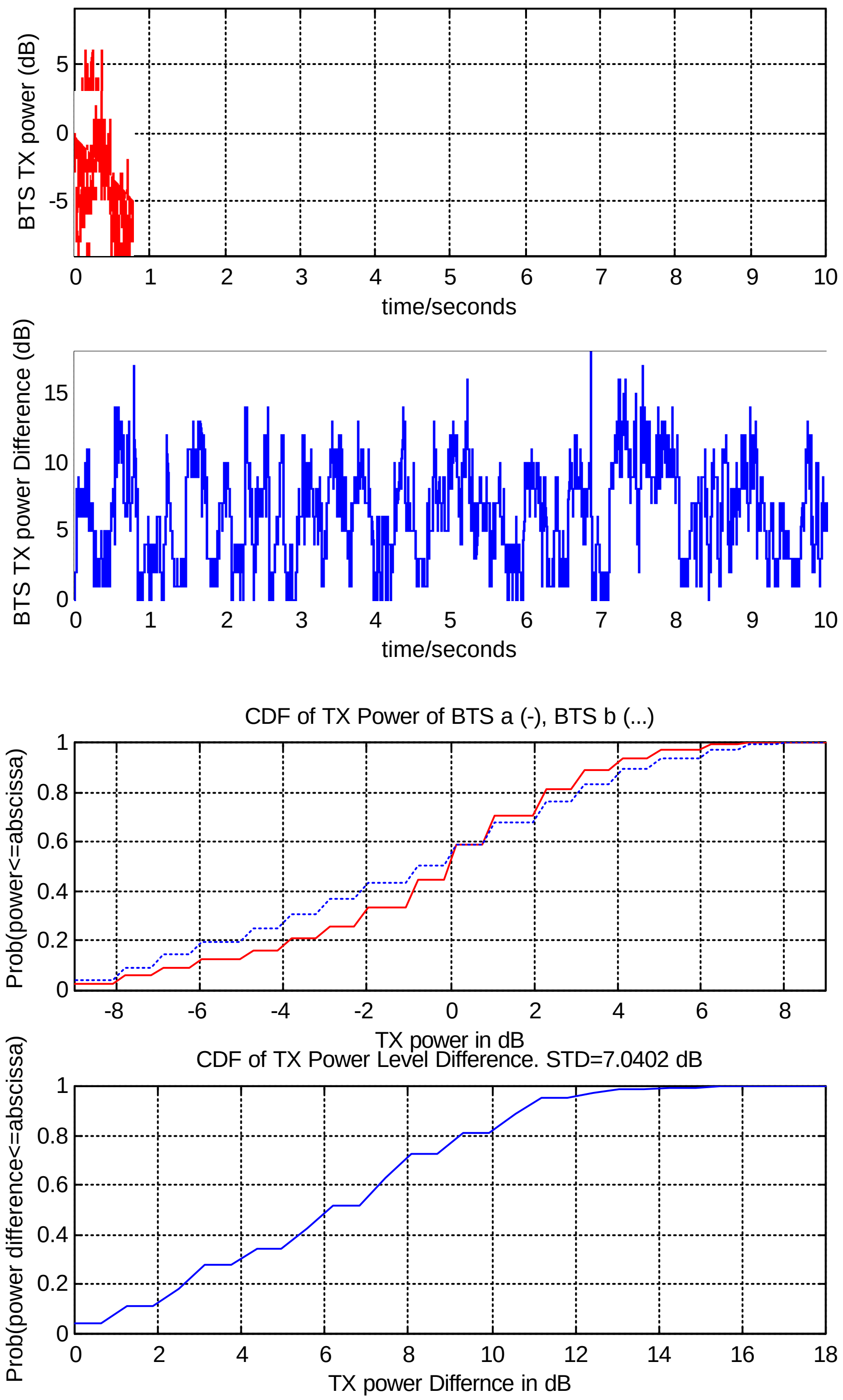

Figure 5.2-3: Illustration of Simulation No. 2520: No Power Balancing". See Table 5.2-10.

5.3 Analysis of the Simulation Results

The simulation results given in the tables of section 5.2 show that all options achieve a significant improvement of the radio performance ("DL Interference" and "STD") compared to the case without power balancing (up to 1dB power balancing gain w.r.t. DL Interference). Options 1, 2 and 4 outperform option 3 for all simulation scenarios, as far as overall transmitted power is concerned. Concerning the STD of the power difference, the method according to option 4 performs clearly best. Moreover, the results suggest that the advantages of option 4 are bigger for realistic channels (Veh.A) than for the more theoretical pure rayleigh channels.

Moreover, options 1 and 4 require less signalling and processing overhead (no frequent in-band signalling on Iub/Iur), see section 2. Hence, the decision needs to be made between option 1 and option 4.

It must be noted that negative effects caused by the disruptions of the fast power control process imposed by option 1might not be fully accounted for in the simulations. The reason for this statement is the fact that all simulations used the same sequence of TPC detection errors. However, whenever the algorithm according to option 1 resets the TX powers, the fast power control process is disrupted. As a result, extra TPC errors can occur in the DL direction, which in turn affects overall performance in both directions.

When comparing the two simulations of option 4, the results indicate that the parameter setting for option “4a” according to NECs tdoc R3-99b46 is not able to remove the power imbalances as efficiently as the parameter setting according to “4b”. Much smaller values for the STD of the TX power difference for “4b” are the result. Also the overall DL Interference is smaller for “4b”. This can be explained by a possibly too small choice of β (β=0.04, corresponding to NECs ‘r=0.96’) and by the fact that small differences “P_{TX}-P_{ref}” only yield small corrective adjustments. A larger choice of β could however result in situations where the additional adjustment loop overrules the fast power control procedure, which is not desireable. Therefore, the introduction of the parameter “γ” is useful, which limits the adjustment due to “P_{TX}-P_{ref}” to a maximum value. Moreover, the introduction of the parameter “α” enables the adjustment loop to perform efficient adjustments already for small values “P_{TX}-P_{ref}”.

5.4 Conclusion

The consequence of the above analysis is that the most favourable power balancing scheme is clearly the one according to option 4.

Moreover, introduction of parameters α and γ in addition to the “NEC parameter“ β enables to improve/optimise the performance of the adjustment loop according to option 4.

6 Annex B: Text Proposal for TS25.214

[...]

5.2.3.6 DL Power Balancing

The DL power balancing procedure counteracts the relative drifting of DL transmit powers in a soft handover situation when several Node Bs are in the active set of a UE. It consists of the following parts:

1. Transfer of parameters at link setup
2. Performing an additional slow loop.
3. Transfer of averaged transmit power level from cell to SRNC
4. Update and transfer of reference power from SRNC to a cell

5.2.3.6.1 Transfer of Parameters at Link Setup

At link setup, SRNC signals the following power balancing specific parameters to the target cell:

- tav: Averaging time
- α: Parameter for slow loop
- β: Parameter for slow loop
- γ: Parameter for slow loop
- P_{ref}: Reference power

5.2.3.6.2 Additional Slow Loop

Additionally to the usual fast power control, the DL transmit power is changed by Δ_{slow_loop} dB every slot. The value Δ_{slow_loop} is determined by the additional slow loop procedure, as described in the following:

Let P(k) be the transmit power of a cell (w.r.t. a certain UE) at slot k. Moreover, let P_{min} and P_{max} denote the minimum and maximum tolerable transmit powers, and let $SIGN_{TPC} \in \{-1, 1\}$ denote the direction of the transmit power change due to the received TPC command. All powers are expressed in logarithmic scale (dB). Then the transmit power P(k+1) in slot k+1 calculates as follows:

```
Δ_diff = (P(k) - P_ref);
Δ_slow_loop = -sign(Δ_diff) * Δ_TPC * min{α + β*|Δ_diff|, γ};
P_temp = P(k) + SIGN_TPC*Δ_TPC + Δ_slow_loop;
IF P_temp > P_max THEN
   P(k+1) = P_max
ELSEIF P_temp < P_min THEN
   P(k+1) = P_min
ELSE P(k+1) = P_temp;
```

In case of Node B hardware limitations, the actual transmit power can be a rounded version of the calculated power “P(k)”.

In case of SSDT mode, P(k) corresponds to the power “P1”, hence the algorithm does not distinguish between primary and non-primary cells.

Notes:

- *The parameters **a**, **b** and **g** should be chosen such that **a £ g** < 1 and **b** > 0 dB^{-1}, otherwise they do not make sense.*
- *For **b** = 0 dB^{-1}, the value of **g** has no relevance (as long as **a £ g**). In this case, the slow loop will always steer the transmit power towards the reference power with the fixed stepsize **a*D**$_{TPC}$.*

- *For $\boldsymbol{b} > 0\ dB^{-1}$, the slow loop will steer the transmit power towards the reference power with a stepsize which is larger, the larger the difference between current transmit power and reference power. Hower, the stepsize is limited by $\boldsymbol{g}*\boldsymbol{D}_{TPC}$ in order not to overrule the fast power control.*
- *For $\boldsymbol{a} = \boldsymbol{g}$, the value of $\boldsymbol{b}$ has no meaning.*
- *The condition $\boldsymbol{g} < 1$ ensures that the slow loop never 'overrules' the fast power control loop.*
- *If the digital resolution of the Node B hardware is limited and cannot resolve small stepsizes "$\boldsymbol{D}_{slow\_loop}$", then the manufacturer can implement the algorithm in Node B in a sub-optimum way. For example, instead of performing the slow loop with "$\boldsymbol{D}_{slow\_loop}$" every slot,NodeB could perform the slow loop with "2 $\boldsymbol{D}_{slow\_loop}$" every 2^{nd} slot.*

5.2.3.6.3 Transfer of Averaged Transmit Power Level from Cell to SRNC

Every tav seconds, each cell transfers the averaged power level (w.r.t. DL DPCCH transmitted to respective UE) to the SRNC. This averaged power level is an average of the dB values of the power. The averaging window is tav.

5.2.3.6.4 Update and Transfer of Reference Power from SRNC to a Cell

The SRNC runs a process to update the reference powers. It can set the reference power of each cell to a new value at any time.

Note: The averaged power levels are an important input to the process for updating the reference powers. The exact algorithm for updating the reference powers does not need to be standardised.