



e4.2

Power control

Politecnico di Torino
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W-CDMA power control

Closed loop power control (UL and DL)

- It adjusts the mobile terminal (BS) transmitted power so as to maintain the UL (DL) Signal to Interference Ratio - SIR value equal to a given target.

Outer loop power control (UL and DL)

- On the basis of quality estimations, it evaluates the SIR target value to be used as a reference by the closed loop power control loop

Open loop power control (only UL)

- It adjusts the power transmitted during random access on the basis of the path loss estimations and interference on the UL

By means of the *Closed Loop Power Control* mechanism on the *up link*, the base stations belonging to the *Active Set* measure the power of the DPCCCH received on the *up link* after the *rake combining* phase, the total interference on the *up link*, hence the *up link* C/I. The base station generates the command *Transmit Power Control* (“up” or “down”) by comparing the C/I evaluated with the target C/I supplied through the *outer loop power control* mechanism described below.

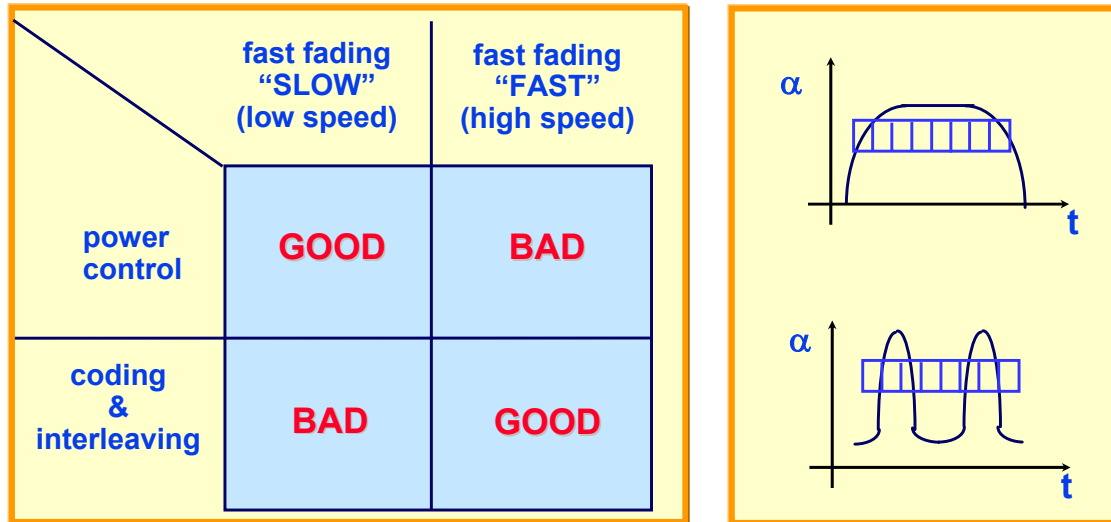
The *Transmit Power Control* is sent to the mobile through the DPCCCH. The mobile combines the TPC commands received in a single TPC *command*. MS increases or decreases the power according to an established granularity.

In the *down link* direction the terminal measures the received power on the DPCCCH after the *rake combining*, it also measures the total interference on the *down link*. It is hence able to estimate the actual C/I. The mobile terminal compares the measured C/I with the target one (supplied by the *outer loop* mechanism) and sends to the network the TPC *commands*. The base station transmitted power is tuned accordingly.

The *Outer Loop Power Control* configures the target powers in function of the BER requirements. This enables the monitoring of the communication quality and the tuning of the C/I as a consequence. The same mechanism regulates the power difference arising between DPDCH and DPCCCH. Among the reasons driving the C/I modifications there are: change of environment. Management actions, *active set* updating.

The *open loop* power control is used to regulate the power to be used on the PRACH during the access phase. The mobile measures the received power on the *down link Primary Channel* and evaluates the fading arisen on the base of the knowledge of the *Primary Channel* power (the latter is sent to all the cell mobiles by the BCCH).

Power control and interleaving in case of fast fading



3

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The figure explains the joint function played by power control and the interleaving.

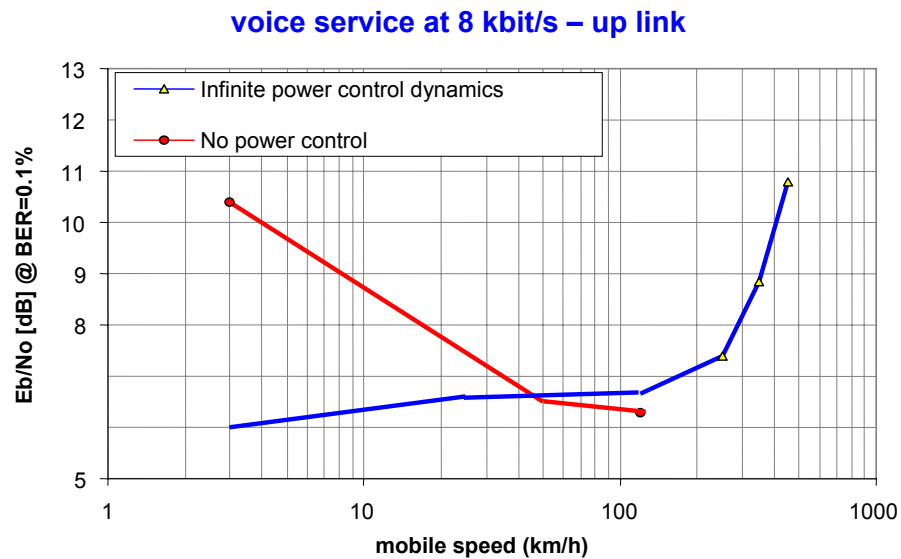
The system shows different behaviour in function of the MS speed (*fast fading*). Power control and interleaving mechanisms can be jointly used to manage these speed-tied effects.

With low speeds, the channel dynamic is not so significant and the power control mechanism is able to compensate the (variable) attenuation. As said, this technique relies on a feed-back scheme.

The same scheme becomes not effective when the channel variations become quite quick with the increase of the terminal speed. Above 100 km/h the fading dynamic is so high that there is no correlation between the power control actions and the effective channel status.

In this situation it is better to act through the *interleaving* which can spread in time the error bursts caused by the *fading*. With low speeds, conversely, the *interleaving* tends to be much less effective because the fading duration approaches the interleaving depth (in time).

Power control and interleaving



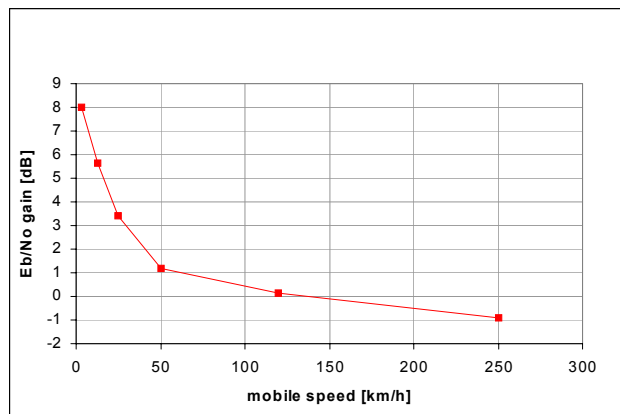
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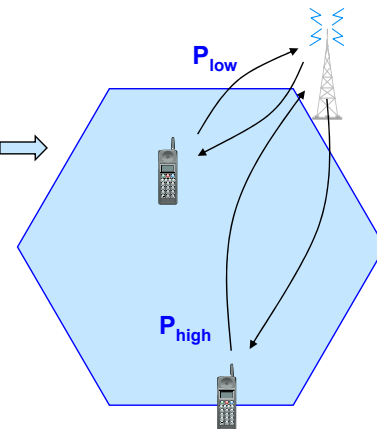
The complementary role played by the *power control* and the *interleaving* is confirmed in the figure. Without power control, the effectiveness of the *interleaving* increases with the increase of the mobile speed, while the power control keeps the required E_b/N_0 limited for lower speeds.

The example refers to a BER of 10^{-3} and shows the required E_b/N_0 for different values of the mobile speed.

Near-far effect and PC gain



near-far effect



gain of the fast power control

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5

The control of the power emitted on the *up link* acts against the so called *near-far* effect.

The attenuation perceived by a connected mobile terminal standing at border of the cell is much greater than the attenuation perceived by a terminal operating much closer the mobile station. In the absence of power control, the terminal close to the base station could *blind* the signal transmitted by the MS at the border. Power control reduces bit per bit the power transmitted by each mobile station to the minimum value needed such that all the mobile signals are received by the base station at the same level.

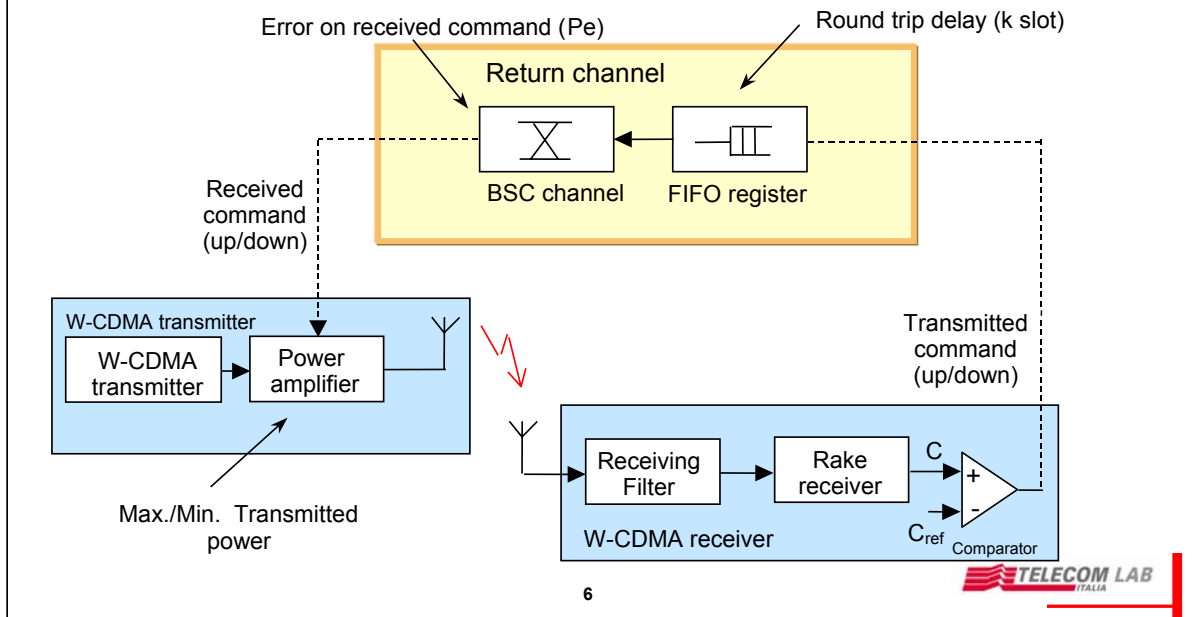
The gain introduced by the fast power control is represented in terms of the rate between the E_b/N_0 needed without and with the power control active. The gain decreases with the increase of the mobile speed: the limits of the power control mechanisms are confirmed.

The example refers to a connection at 8 kbit/s and assumes that the channel is the typical adopted for a vehicular context.

It can be shown that with a high mobile speed a slow power control mechanism shows even a better performance compared to that offered by a fast power control scheme. This is due to the errors arising in the C/I evaluation and to the delays accumulated on the return channel carrying the power control messages.

Closed loop power control

limits in C/I estimate, return channel, delay



The transmission power is controlled and regulated with a pace of about 1500 Hz.

However the closed loop power control is undergoing some delay along the control chain. For this reason it cannot be suitable for fast fading situations.

The *up-down* commands refer to the power amplifier and are carried by the return control channel.

The closed loop power control is active in both directions.

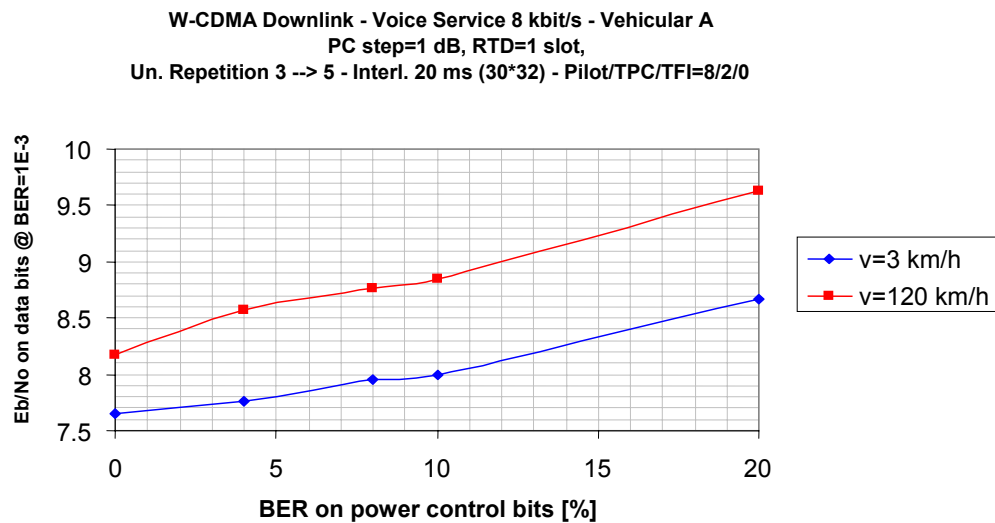
But on the *down link*, the power control has a different meaning with respect to the up link. On the *down link* the station is a single source of signals which are received by all the mobile stations. The power control is mostly driven by the cell-border mobiles, subject to a greater attenuation. The power control on the down link aims mostly at preserving the down link in terms of interference (hence in terms of down link capacity).

On the *up link*, the power control preserves the link capacity by reducing the overall level of interference. The *down link* capacity is instead not influenced by the power received by any single mobile station.

The need of having a closed loop scheme comes from the fact that the system is using different frequencies for the two transmission sides: it would be arduous to control the power through an open loop scheme because the two transmission directions show a rather different *fast fading* statistics, substantially independent from each other.

The open loop power control remains necessary for the MS access phase.

Effect of errors on the return channel



7

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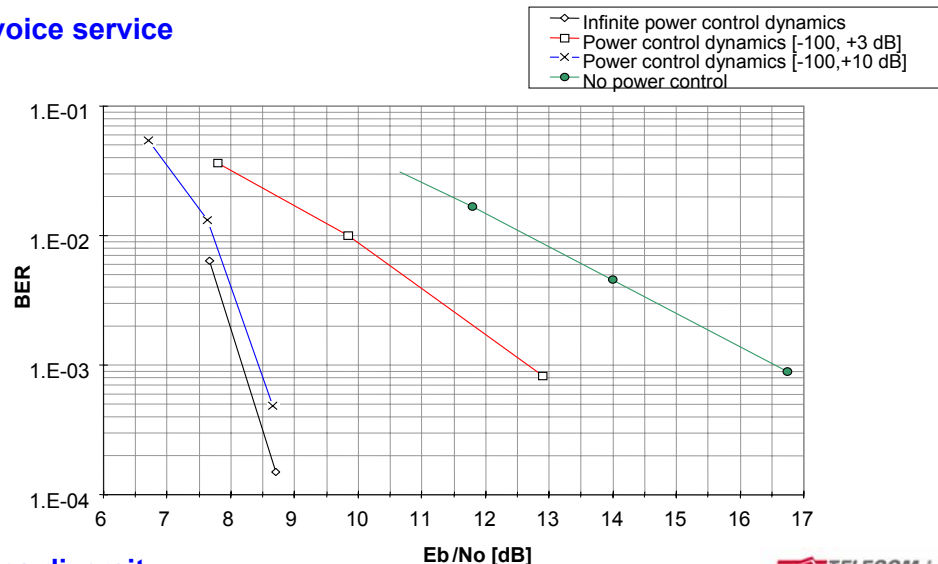
The effect of the transmission errors on the power control messages is apparent in terms of levels of E_b/N_0 which become necessary on the receiving side.

With the increase of the BER on the return channel, the requested E_b/N_0 increases at an increasing rate with the speed of the mobile.

W-CDMA performance

in function of the Power control dynamic (up link)

8 kbit/s voice service



no antenna diversity

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The power control dynamics is a key factor for the error protection. Without power control performances are worsening while the best performance is reached with an infinite dynamic of the power control scheme.

The standard fixes at least 71 dB the dynamic for power classes of 21dBm. In particular it must range between 21dBm e -50 dBm being -50 dBm the minimum power level that can be controlled.

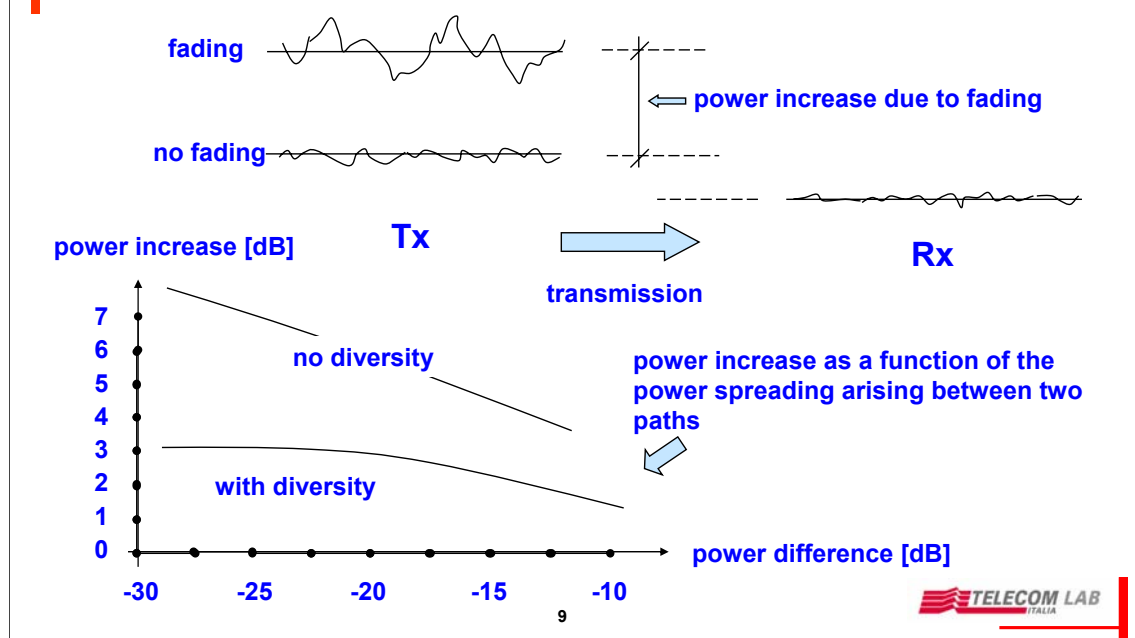
A *fast power control* gain is introduced. It can be shown that the lower the diversity level of the connection, the higher the fast power control gain.

The *fast power control* gain is measured with:

- the value of E_b/N_0 necessary on the receiving side with and without *power control*
- the value of the transmitted power needed for receiving in a correct way the signal with and without *power control*.

The gain on the former metric is typically greater than the one induced on the latter.

Power control and diversity



Power control and diversity are strictly tied together.

To evaluate the effect of diversity on power control normally the following parameter is addressed: the increase of power necessary in transmission to guarantee to the receiving side the same power when the channel passes from a situation without fading to a situation with fading.

In both cases it is assumed that a fast power control is active. It can be shown that the necessary power increase depends on the diversity degree (number of alternative paths) characterising the connection. Also the power dispersion arising between the paths is key.

The diversity advantage becomes negligible with the increase of the mobile speed: a confirmation of the weakness of the power control against the Rayleigh fast fading. However, even at high speeds, the diversity tends to maintain constant the received power, hence the communication quality.

Power increase due to the non ideal power control

Mobile speed	Average power increase
3 km/h	2.1 dB
10 km/h	2.0 dB
20 km/h	1.6 dB
50 km/h	0.8 dB
140 km/h	0.2 dB

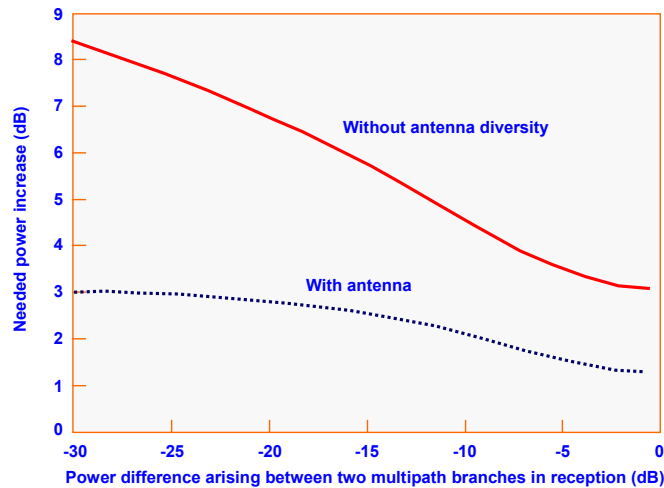
10



Some examples of the power increase needed to keep into account the fact that power control is non-ideal.

The assumptions are: *multipath* channel ITU Pedestrian A. space diversity reception.

Theoretical power increase vs. the power difference of two multipath components

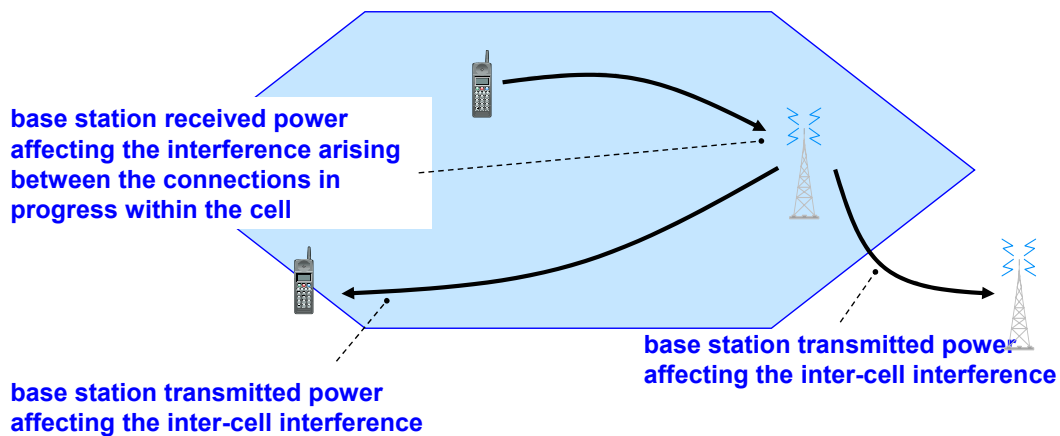


- Rayleigh fading
- two paths

Also the variance of the transmitted power depends on the diversity degree as well as on the dispersion of the power levels characterising the various paths at the receiving side.

The figure shows a case related to a speed of 3 km/h with and without antenna diversity.

The effect of transmitted and received power



12

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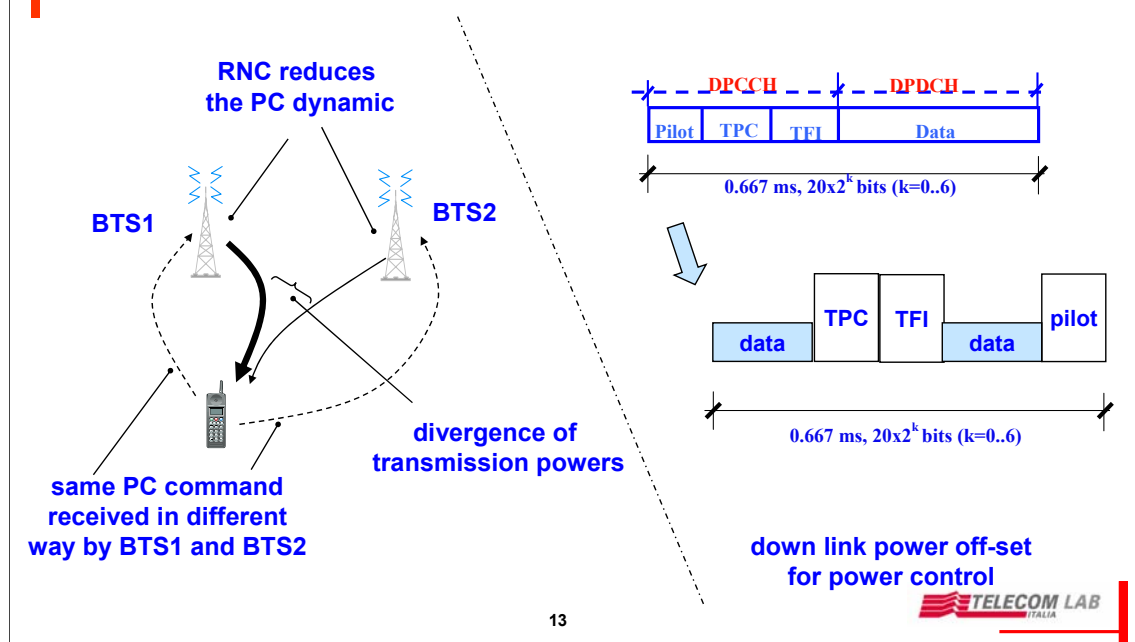
The effect of the powers on the system interference is sketched in the figure.

The power transmitted by the mobile station and by the base station affect the interference level generated towards the other cells.

On the *down link*, in order to maximise the available capacity it is needed to minimise the Base station transmitted power while the power received by the mobile station does not affect the cell capacity.

On the *up link*, the power generated by the mobile terminal increases the interference with the other cells. But the *up link* capacity is affected by the power requested on the receiving side which must be kept at the minimum level. The *up link* capacity is then not conditioned by the increase of the transmission power previously introduced.

Soft handover and power control



13

In *soft handover* conditions the power control may be difficult to control on both the *down* and the *up link*.

The figure shows how errors can affect the power control commands sent by the mobile to the stations (*active set*). The combining function cannot be applied to these commands since the decision (to be taken by the RNC) would require too much time.

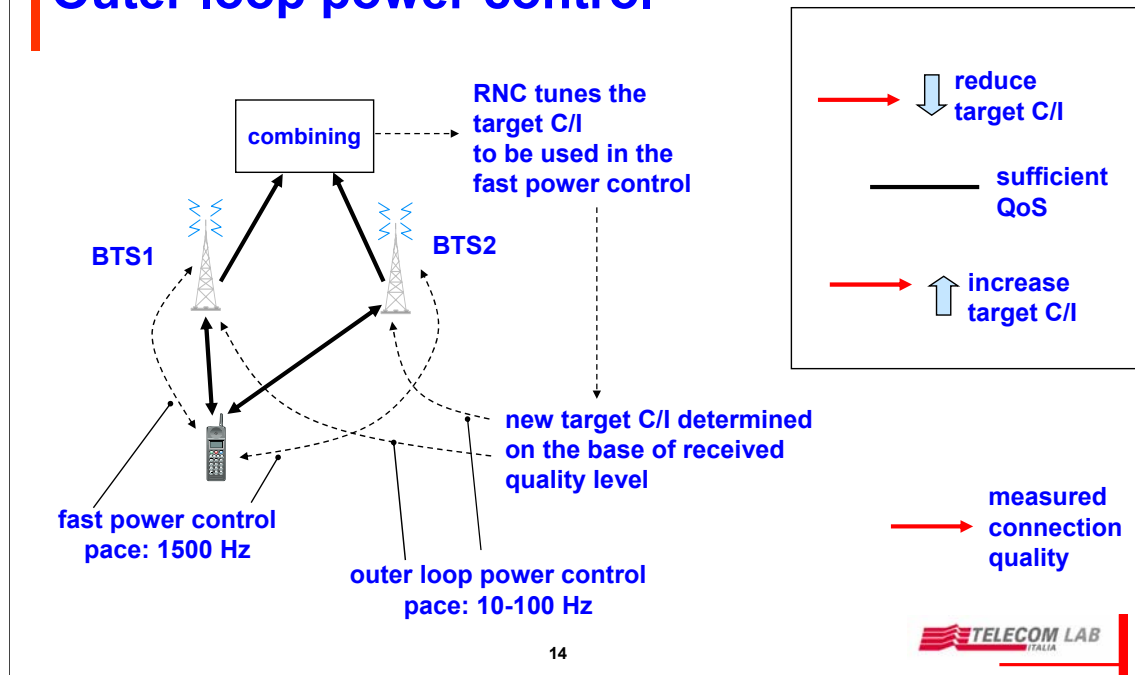
A phenomenon of divergence between the active set transmitted power can then take place. The divergent attitude can be controlled by the RNC which is in the position of reducing the dynamic of the power control on the *down link*. However, as seen, reducing the power control dynamic, implies a worsening of the communication efficiency.

A dilemma is then emerging: two factors are worsening the fast power control gain. Reducing the power control dynamic and accepting the increasing divergence of the macro diversity paths power are contradicting choices.

The inconvenience on the *up link* resides in the fact that the commands tuning the MS emitted power are different from each other (they are generated independently from the *active set* base stations). They cannot be combined and are subject to different errors over the different paths.

To improve the quality of the signal received by the mobile, the station(s) can transmit the range containing the power control at a greater power in the down link (*power off-set*). The mechanism is realised along any single transmission slot. The power can be controlled in a differentiated way for the different control channels multiplexed in the *down link*: *Transport Format Control Indicator*; *Pilot*; *Power control*.

Outer loop power control



The scheme adopted for the target C/I level used in the *outer loop* power control is based on the quality measured by the RNC on the connection in progress.

The decision of increasing or decreasing the reference value is taken in way that the connection quality is maintained at a sufficient level. The RNC role is necessary because the quality of a connection can just be measured after the *combining* in the soft handover status on the *up-link* has been performed.

The true problem to be solved to guarantee an effective power control in *outer loop* is the estimate of the connection quality, to be performed by the RNC. The value of E_b/N_0 of the received signal can help in this sense. Similarly, the *side info* supplied by the Viterbi decoder or the error rate revealed by the error detection code can be used by the RNC.

The most appropriate choice of the parameters depends on the type of service the connection refers to. For example, for a service requiring a low error rate, it is better to use the *side info* rather than the revealed error rate: the latter parameter would give too slow elements for a C/I tuning choice, perhaps too slow with respect to the modified context conditions.