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Agenda item:

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Title: Performance loss in uplink due to compressed mode

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1 Introduction

The use of compressed mode for measurements on other frequencies, modes and systems is necessary to avoid expensive and power consuming receiver structures. The major drawback when using compressed mode in the uplink is the performance loss due to the limited output power of the UE. Schemes, such as modifying the spreading factor or the channel coding, compress the information in time but require a higher transmit power in order to maintain the target bit-error rate (BER) or frame-error rate (FER).

2 Cell border

The problem of limited output power at the UE is most severe at the cell border. Here, the transmission power of the UE is already at its maximum, which corresponds to a case without power control. If the UE was not operating at maximum power at all time, it would be possible to move further away from the BS by increasing the transmit power. Consequently, when compressed mode is entered, the power can not be increased in order to keep the target BER or FER.

Note that this is a somewhat simplified picture of what the cell border actually means. However, it is a useful approximation to show the effects of uplink compressed mode on coverage.

3 Performance at the cell border

The service investigated in this paper is the 8 kbps speech service. The simulation parameters are presented in Table 1. To evaluate the performance at the cell border, fast power control was not used. The environment used in the evaluation was the *Outdoor to indoor and pedestrian A* channel. The terminal velocity was set to 3 km/h.

Table 1. Service parameters

Physical channel rate	32 kbps
Info/CRC/tail bit per frame	160/16/8 (20ms)
Convolutional coding rate	1/3
Repetition	88 bits per 20ms (552->640)
Interleaver	20 ms, 20*32
Pilot/TPC/TFI bits per slot	7/3/0
Power control	No
Antenna receiver diversity	Yes
Channel estimation	Two successive estimates are averaged.

In the compressed mode simulations, two successive frames are operating in compressed mode, creating a transmission gap length of 10 ms (see Figure 1).

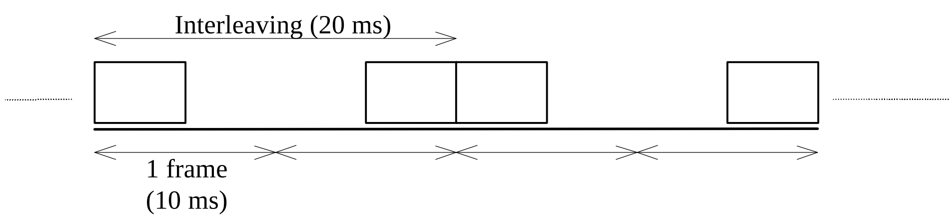

Figure 1. Compressed mode transmission.

The DPDCH is transmitted by using a reduced spreading factor. To maintain the required BER or FER, the transmit power is increased for the DPDCH. For the DPCCH however, the pilot symbols and power control bits are associated with each transmitted slot. There is therefore no need to increase the power of these[1]. Assuming the DPDCH/DPCCH ratio to be 3 dB in normal transmission, this would lead to a DPDCH/DPCCH ratio of 6 dB in compressed mode. If the ratio between the DPDCH and DPCCH is maintained at 3dB, i.e. also the DPCCH power is increased by 3 dB, the quality of the channel estimates and the PC commands will be improved.

The overhead of the DPCCH can be calculated as:

$OH = (P_{DPCCH} + P_{DPDCH}) / P_{DPDCH}$.

The possible gain when reducing the relative power of the DPCCH in compressed mode can be calculated as:

$G = OH_{3dB} / OH_{6dB} = ((2 + 4) / 4) / ((1 + 4) / 4) = 1.5 / 1.25 = 1.2 = 0.79\ dB.$

The loss, in terms of link-level performance, when using compressed mode has been shown in for example [1]. Here, the loss when using compressed mode was up to 1 dB depending on the environment and on the power control scheme. The largest contributing part of this loss is the limited operation of the fast power control. On the cell border however, the UE is always operating at the maximum output power so the fast power control is not working.

The performance at the cell border for an 8 kbps speech service is shown in Figure 2. In the figure, the dashed line shows the performance for normal operation. The two solid lines show the performance for a DPDCH/DPCCH power ratio of 3 and 6 dB. As seen in the figure, the gain of using a stronger DPCCH is slightly smaller than the loss due to the increased overhead of the DPCCH, although the curves very much coincide.

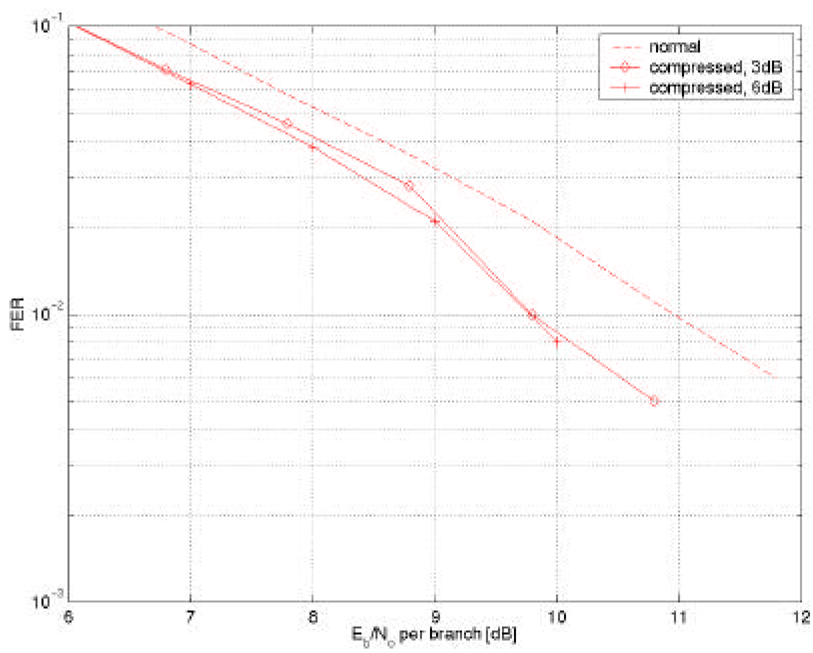

Figure 2. Performance for the speech service at the cell border.

[1] The performance of the TFCI will be degraded. For these simulations, blind rate detection was assumed.

The reason why compressed mode performs slightly better (!) than normal mode is that there is no power control. Hence, there is no loss in performance due to degraded power-control performance. Moreover, with 6 dB DPDCH/DPCCH power ratio, there is less overhead (only half the DPCCH energy compared to normal mode), while with 3 dB power ratio, the overhead is the same as in normal mode, but it is used more efficiently to improve the channel-estimation somewhat.

4 Impact of compressed mode

Despite the improved link-level performance with compressed mode, as illustrated in Figure 2, there will be an overall degradation, due to the limited transmit power at the cell edge. The degradation for each frame operating in the compressed mode can be found from Figure 2 by comparing the required E_b/N_0 of the service (11.0 dB @ 1% FER) with the E_b/N_0 that can be accomplished by the UE.

When the UE is operating at its peak power in normal mode, the E_b/N_0 that can be accomplished by the UE will be reduced by 3 dB. Looking at Figure 2, this would increase the FER from 1% around 4%, for the case of DPDCH/DPCCH power ratio of 3 dB. A relative DPDCH/DPCCH power ratio of 6 dB gives a similar FER.

However, the important thing is the “average” FER, which depends on how often compressed mode is used, i.e. the transmission gap period. By assuming a transmission gap period of 12 frames, which means that 2 out of 12 frames are operating in compressed mode, the overall FER will be approximately 5/6*1% + 1/6*4% ≈ 1.5%, i.e. an increase of 0.5%, compared to the case of no compressed mode.

As an alternative view, one can find from Figure 2 that the E_b/N_0 needs to be increased by approximately 0.6 dB, (11 dB →11.6 dB and 8 dB →8.6 dB) in order to keep the average FER at 1%. Assuming a path loss exponent $\alpha=4$, this implies that the use of compressed mode would reduce the cell radius by approximately 3%, a relatively small figure.

5 Conclusion

The performance loss in the uplink due to compressed mode at the cell edge has been considered as a large problem. This paper shows that the loss is relatively small. For the studied example, the FER for a UE in compressed mode operating at the cell edge will be increased from 1% to around 1.5%. Alternatively the cell radius will be reduced by approximately 3%.

It should be noted that these figures have been derived for a case of relatively high compressed-mode intensity (2 out of 12 frames operating in compressed mode). With a lower intensity of compressed mode, the loss will obviously be lower.

Furthermore, a more optimised DPDCH/DPCCH power ratio in compressed mode may further reduce the loss.

References

[1] Improved closed loop power control algorithm in slotted mode, TSGR1#4(99)342