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1 Introduction

It has been questioned if the possibility to use short uplink scrambling codes in UTRA/FDD should be retained in the specification. Especially the handling of a mixed scenario of some cells using short scrambling codes and some cells using long scrambling codes has been identified as requiring further elaboration.
It is Ericsson's belief that supporting short uplink scrambling codes is important and should be kept in the specification. In this paper some further elaboration and motivation for this is given.

2 Motivation for using short uplink scrambling codes

To boost capacity, coverage and link quality, interference cancelling (IC) algorithms and multi-user detectors (MUD) are promising techniques. The algorithms for doing interference cancellation and multi-user detection can be divided into three categories.

1) Algorithms that require short scrambling codes.
   This category contains algorithms that e.g. use sample covariance matrices [1]. If the sample covariance matrix is obtained by averaging the received signal for several symbol periods, the scrambling code has to be short.
2) Algorithms that do not require short scrambling codes, but will be possible to implement with lower complexity if short codes are used.
   An example of an algorithm that belongs to this category is the well known decorrelator or zero forcing receiver [2]. In this case a covariance matrix is calculated using time delay estimates and knowledge about the used scrambling codes in the system. If short scrambling codes are used, the covariance matrix needs only be updated when a major change occur in the received signals (e.g. a large change of a time delay, or the appearance of a new user). This can be utilised to lower the complexity of the receiver.
3) Algorithms that will not benefit from short scrambling codes.
   The serial IC algorithm is an example of an algorithm that belongs to this category [3].

Since there exist algorithms in category 3, one could be tempted to not allow short scrambling codes. However, this is connected to the risk of effectively prohibiting the use of category 1 or category 2 algorithms in the future. Those algorithms, relying on the cyclostationary nature of short spreading codes, might have better properties than category 3 algorithms, e.g. regarding complexity, performance or robustness. A random pick of an IC/MUD algorithm from any IEEE transaction magazine will with high probability require the use of short codes.
Hence, by keeping the possibility to have short scrambling codes the available "menu" of algorithms to use for more advanced receiver implementation is larger, increasing the probability that some of the algorithms will be implemented in hardware.

3 Supporting short uplink scrambling codes

To ensure that the operator and manufacturer of a base station requiring short scrambling codes for its advanced receiver algorithms benefit from this advanced receiver it is essential that all terminals support the short scrambling codes.
For the network side, questions have been raised on how to handle scenarios when cells with advanced receivers requiring short codes are located close to cells using long codes, and a user is in soft handover between these different cells. The answer given is that the cell where normally long codes are used should switch to use short codes for all users that are in soft handover with the cell requiring short codes. This would mean that a user using long code scrambling would need to change to short code scrambling when entering soft handover. The change of scrambling code for the call is done by higher layer procedures. In RAN WG2 they have specified a procedure called "Physical Channel Reconfiguration" that could be used for doing this reallocation. Moreover, this strategy means that support of both long and short scrambling codes would be mandatory for base stations in a cell neighbourhood of a network where the operator selects to use short code scrambling and advanced receivers in some cells.

4 Cost of supporting / not supporting short uplink scrambling codes

4.1 Complexity

Support of the short scrambling codes in the terminal is seen as having negligible impact on complexity. Codes of length 256 may be computed once using software, and then stored into a 256 bit memory, or computed on-line using shift registers. At least for the first of these two options it is clear that the cost is very small of supporting short codes in addition to the long codes.

By letting the long code base station switch to short codes for users in soft handoff with and advanced receiver requiring short codes, the advanced receiver base station does not have to be equipped with further hardware that is able to decode long code scrambled signals in addition to its normal short code receiver. The cost of forcing the advanced receiver to also handle long code scrambled data could be very high, since it would need to add some normal RAKE receivers or similar. However, letting all base stations support both short and long codes would have only a very minor implication on complexity, depending on actual implementation. Similar to the terminal, the short codes can always be computed once per connection in software and stored in a memory. This memory may even be the same memory used to store the channelization codes.

If short scrambling code support is not mandated in the terminals from the beginning this will probably mean that no base station manufacturer would ever choose to implement an advanced receiver depending on short codes, since it must in addition support demodulation of long code scrambled signals, which could mean a totally different receiver structure and hardware. In the extreme case (the very extreme case, not really realistic but still indicating the effects), if there is one single terminal in the world that supports only long scrambling codes, all base stations in the entire world would need to have capability to detect this long code scrambled signal, even if they are all using advanced receivers expecting short codes. That would mean one extra parallel receiver in each base station in the world to be able to detect this single user, not a very cost effective solution… Hence, support of short scrambling codes should be specified in Release 99, if ever.

4.2 Performance

It has also been asked what happens with performance when some signals using short code scrambling and other signals using long code scrambling is detected in the same base station. Will the short code scrambling degrade performance? Before answering this, we need to keep in mind that there is a very substantial gain by using the advanced receiver in the first place, and any drawbacks with using short codes in the normal cells should be weighted against that.

It is clear that the short code scrambled signals will not affect the performance of the long code scrambled signals. The correlation properties is changing all the time, so interference averaging is as effective as when long codes are used. Similarly, it can also be argued that the short code users will experience good interference averaging from the long code users. That leaves the case of short code user to short code user interference, which is not averaged and the same correlation properties reappears every symbol interval. For this case there should not be any significant performance impact of using short codes compared to long codes. There are papers in the literature showing that short codes can give slightly better performance than long codes [4]. For average code performance it would be very difficult to show any significant difference in performance. What is avoided with long codes is performance variation depending on user combinations [4], since some combinations of codes may have worse correlation properties than other combinations. However, these combinations are not common and should not lead to catastrophic system performance, since the connection is in soft handoff. At worst, one of the cells in the active set could experience somewhat worse performance due to badly matched short codes. For the unlucky cases where the codes are so badly matched that it affects performance, which should be fairly uncommon, the gain of introducing the advanced receiver in the first place more than compensates for this bad effect.

5 Conclusion

In conclusion, supporting short scrambling codes gives extra receiver algorithm and design choices that could lead to earlier introduction of advanced receivers to boost capacity, coverage and link quality. Support must be mandated from the beginning in the terminals to be able to benefit from the short codes. The cost of keeping the short scrambling code support in the specification is negligible.

Hence, it is proposed to maintain the short scrambling code description in the S1.13 documents and include this support in Release 99.

References

[1] S. Parkvall and E. Strom, "Near-Far Resistant Receivers without A Priori Synchronization for Asynchronous DS-CDMA Systems," *Proceedings of ISSSTA '96*, May 1996.

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[3] K. Jamal and E. Dahlman, "Multi-Stage Serial Interference Cancellation for DS-CDMA," *Proceedings of VTC'96*, USA, pp. 671-675, April 1996.

[4] S. Parkvall, "User performance variability in DS-CDMA systems – long vs short spreading sequences," *Proceedings of Globecom'98*, 1998.