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Abstract of document:

This technical report depicts the work on the Rel-5 work item “NodeB synchronisation for 1.28Mcps TDD”. It describes the NodeB synchronisation method via air interface in addition to the Rel-4 method via the synchronisation port.

Changes since last presentation to TSG-RAN Meeting:

The TR is revised to reflect the improved NodeB synchronisation algorithm proposed by Siemens and to include the modified synchronisation sequences proposed by Samsung and Mitsubishi for further investigation.

Outstanding Issues:

Contentious Issues:

TSG-RAN WG 1 meeting #22 **R1-01-1348**

Jeju, Korea, 19 –23 November, 2001

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Technical Report

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NodeB Synchronisation for 1.28 Mcps TDD
(Release 5)

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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

This TR describes the solution recommended to enable the synchronisation of NodeBs over the air in 1.28Mcps TDD for Rel 5.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] R1-01-0839 “Simulation results for NodeB synchronisation over the air for 1.28 Mcps TDD”.

3 Definitions, symbols and abbreviations

3.1 Definitions

3.2 Symbols

3.3 Abbreviations

4 Background and Introduction

NodeB synchronisation for 1.28Mcps TDD is a release 5 work item that was agreed in RAN#11 plenary meeting. This work item involves the introduction of functionality to enable nodeBs to be synchronised.

This report identifies the required modifications within the UTRA layers 1/2/3.The method described is in addition to the Rel. 4 feature of the synchronisation port contained in TS 25.402.

5 Motivation

Cell synchronisation is planned for 1.28Mcps TDD in order to fully exploit the system capacity. There are several factors that have an impact on the system capacity. The most important ones are:

- Inter-slot interference: without frame synchronisation there could be leakage from an UL timeslot into a DL timeslot, especially crucial for the UE due to the potentially close distance between UEs and the near-far effect.
- neighbouring cell monitoring: In TDD mode, certain measurements have to be performed in certain parts of certain timeslots of neighbouring cells. Without cell synchronisation, the UE would have to synchronise itself before being able to perform the measurements.

- Handover: The 1.28Mcps TDD mode may use timing advance and synchronisation in order to align receptions from all UEs at the cell's receiver. After a handover, the UE has to start transmission in the new cell with a timing advance value as good as possible. With the assumption, that the TDD cells are synchronised to each other, the handover performance can be optimised.

6 Accuracy Requirements

The minimum requirement for cell synchronisation accuracy determined by WG4 is 3us. Cell synchronization accuracy is defined as the maximum deviation in frame start times between any pair of cells on the same frequency that have overlapping coverage areas.

The minimum requirement for the synchronisation is set quite loose and in order not to impact the system capacity and the performance. However, the accuracy can be enhanced to allow the support of other purposes, such as LCS or improvement of handover procedure.

7 Concept of Node B Synchronisation

7.1 General

In addition to proprietary means there are two ways to achieve cell synchronisation in a TDD system:

- Synchronisation of nodes Bs to an external reference via the synchronisation port standardised for Rel-4
- Synchronisation of cells or Node Bs via the air interface described in this report for Rel-5

The solution described in this report allows a mixture of both schemes, i. e. some cells may be synchronised over the air, some via the synchronisation port. In general, at least one time reference (e. g. GPS) is needed for each island of cells having connectivity to each other.

The RNC shall be the master of the synchronisation process, since the measurements performed by a cell, shall be ordered, signalled to and processed by the RNC.

7.2 Node B on air synchronisation procedure by the DwPCH

The methods described in this section make use of the DwPCH to achieve Node B synchronisation over the air. Two options are investigated in the following sub-clauses:

- the centric option, which defers to the RNC all timing computations
- the distributed option, which leaves the maintenance of the synchronised status to the Node B by performing the timing adjustment

7.2.1 DwPCH centric solution

This section describes an example of how the RNC may implement a Node B and Cell synchronization procedure using over the air measurements including the measurement of one cell's DwPCH transmissions by other cells.

The synchronization procedure is based on making use of the transmissions of the DwPCH from neighboring NodeBs based on an RNC schedule. The timing offset measurements are reported back to the RNC for processing. The RNC generates cell timing updates that are transmitted to the Node Bs and cells for implementation. The synchronization procedure has three phases, the frequency acquisition phase, the initial phase and the steady-state phase. For Node Bs and cells with high accuracy frequency references, the frequency acquisition phase may be omitted. The procedure for late entrant cells is slightly different and is described separately.

Frequency Acquisition Phase

The procedure for frequency acquisition is used to bring cells of an RNS area to within frequency limits prior to initial synchronisation. This phase would allow cells to use low cost reference oscillators with accuracies in the order of several ppm. No traffic is supported during this phase:

1 The cell(s) identified as master time reference (e.g. containing the GPS receiver or connected to an external time reference) shall transmit the SYNC_DL on DwPCH continuously

2 Initially all other cells shall be considered as unlocked (i.e. not in frequency lock).

3 While being in this state, a cell shall not transmit, but shall listen for transmissions from other cells. The cell shall perform frequency locking to any transmission received.

4 When a cell has detected that it has locked its frequency to within 50 ppb of the received signal it shall signal completion of frequency acquisition to the RNC and begin transmitting the own SYNC_DL.

5 When the RNC has received completion of frequency acquisition signals from all cells the frequency acquisition phase is completed.

Initial Synchronisation

For Initial Phase, where no traffic is supported, the following procedure for initial synchronisation may be used to bring cells of an RNS area into synchronisation at network start up.

1. The RNC sends a request over the relevant Iub to the cell(s) with a timing reference (e.g.GPS) for a timing signal. The RNC adjusts its clock appropriately, compensating for the known round trip Iub delay.
2. The RNC sends timing updates over the Iub to all the cells, apart from the one containing the GPS, instructing them to adjust their clocks towards its own timing. Each of the timing offsets is again adjusted.
3. At this point, none of the cells is supporting traffic. All cells are instructed to transmit their own SYNC_DL and listen to specific SYNC_DL from neighboring cells based on RNC schedule for initial synchronisation.
4. The cells those listen for transmissions and successfully detect other cells' DwPTSs shall report their timing and received S/(N+I) to the RNC over the relevant Iub. Knowing the schedule, the RNC is able to determine the cells which made the transmission and place a measurement entry in the relevant place in its measurement matrix. After all cells have made their transmissions, the RNC computes the set of updates, which will bring the cells nominally into synchronization.

5. Steps 3 and 4 are repeated several times (typically 10). This serves two purposes:
   - The rapid updates allow the correction of the clock frequencies as well as the clock timings to be adjusted in a short space of time. This rapidly brings the network into tight synchronization.
   - The S/(N+I) values are averaged over this period. This provides more accurate measurements (averaging over noise and fading), which can be used in the automatic generation of a measurement plan.
6. The S/(N+I) values are used, automatically, to plan a measurement pattern. This is performed as follows:
   - A matrix of minimal connectivity is computed on the basis of designating pairs of cells are minimal neighbours if either their estimated average S/(N+I) exceeds a threshold or if they have mutual neighbours.
   - The set of cells is divided into partitions of cells. Each partition must satisfy the requirement that no pairs of cells within that partition are minimally connected.

Steady-State Phase

The steady-state phase is used to maintain the required synchronisation accuracy. With the start of the steady-state phase, traffic is supported in a cell. A procedure that may be used for the steady-state phase make use of the DwPCH transmissions.

7. All of the cells are arranged to transmit its own predetermined SYNC_DL and receive specific other SYNC_DL from neighboring cells according to the above procedure. All cells report the reception timing for the specific SYNC_DLs back to the RNC.
8. At the end of each cycle, the RNC collates the information. In general there should always exist a path of bi-directional valid measurements that link every cell either directly or indirectly to the cell with UTC capability. However, the model is arranged such that only those cells which have such a path will be updated on any given occasion.
9. The process of transmissions/measurements and updating then continues indefinitely.

Late entrant Node Bs

A procedure that may be used for introducing new cells into an already synchronised RNS is as follows:

The scheme for introducing new node Bs into a synchronized RNS is as follows:

1. The late entrant Node B cells are instructed to listen to specific SYNC_DL from neighboring cells based on RNC schedule for its initial synchronisation..
2. After this time the late entrant Node B can measure the timings of DwPTS transmissions received from specific Node Bs from neighboring cells and report these to the RNC. In turn, the RNC specify a SYNC_DL and can give the late entrant Node B its own schedules for SYNC_DL measurements of neighboring NodeBs.

7.2.2 DwPCH distributed solution

This section describes an example of how the RNC may implement a Node B and Cell synchronization procedure using over the air measurements including the measurement of one cell's DwPCH transmissions by other cells. This method intends to reduce the necessarily required high blanking rate of the method in 7.2.1.

The synchronization procedure is based on making use of the transmissions of the DwPCH from neighboring NodeBs based on an RNC schedule. The timing offset measurements are used in the NodeB, to adjust the timing to a neighbouring NodeB, depending on the configuration by the RNC. The RNC generates schedules, which define the blanking rate and time for the DwPCH of a Node B. The synchronization procedure has two phases, the initial phase and the steady-state phase. The procedure for late entrant cells is slightly different and is described separately.

Initial Synchronisation

For Initial Phase, where no traffic is supported, the following procedure for initial synchronisation may be used to bring cells of an RNS area into synchronisation at network start up.

1. The RNC sends a request over the relevant Iub to the cell(s) with a timing reference (e.g.GPS) for a timing signal. The RNC adjusts its clock appropriately, compensating for the known round trip Iub delay.
2. The RNC sends timing updates over the Iub to all the cells, apart from the one containing the GPS, instructing them to adjust their clocks towards its own timing. Each of the timing offsets is again adjusted
3. At this point, none of the cells is supporting traffic. All cells are instructed to transmit their own SYNC_DL and listen to specific SYNC_DL from neighbouring cells based on RNC schedule for initial synchronisation.
4. The cells those listen for transmissions and successfully detect other cells' DwPCHs shall report their timing and received SNIR to the RNC over the relevant Iub. .
5. Steps 3 and 4 are repeated several times (typically 10). This allows more accurate timing measurements to be performed. It also allows the SNIRs to be averaged over any fading to produce reasonably accurate entries for the path loss matrix.
6. The NodeBs adjust their timings according to adjustment commands received from the RNC based on the measurements above.The RNC forms a path gain matrix from the average of measurements reported to it from the various NodeBs. This is used for setting up the schedules for the steady state phase
7. The RNC also generates a table of path delays between NodeBs which can hear one another. The relevant entries of this table are communicated to the NodeBs so that they can compensate for path delays when adjusting their clocks during the steady state phase

Steady-State Phase

The steady-state phase is used to maintain the required synchronisation accuracy. With the start of the steady-state phase, traffic is supported in a cell. A procedure that may be used for the steady-state phase make use of the DwPCH transmissions.

1. All of the cells are arranged to transmit its own predetermined SYNC_DL and measure a specific other SYNC_DL sequence from a neighbouring cell according to the above procedure.
2. The NodeB compares the observed time difference, considering the known propagation delay and corrects its own timing.
3. The process of transmissions/measurements and updating then continues indefinitely.

Late entrant Node Bs

A procedure that may be used for introducing new cells into an already synchronised RNS is as follows:

The scheme for introducing new node Bs into a synchronized RNS is as follows:

1. The late entrant Node B cells are instructed to listen to SYNC_DL sequences from neighboring cells.
2. After this time the late entrant Node B can measure the timings of DwPCH transmissions received from specific Node Bs from neighboring cells and reports these to the RNC. In turn, the RNC specify a SYNC_DL and can signal the late entrant Node B its schedule for SYNC_DL measurements of a neighboring NodeB.

7.2.2.1 Some seen drawbacks by the opponents

1. Possible loss of control and supervision over network synchronisation operations. What happens if a Node B doesn't synchronise properly?
2. Steady state phase relies on a radio environment snapshot that has been captured during the initial phase and may quickly not be valid any more.
3. Iterative synchronisation of several slave Node B's in reference to a single master Node B.

7.3 Node B on air synchronisation procedure by extended synchronisation sequences

The method described in this section makes use of new synchronisation sequences, with respect to the ones currently defined by the standard. Actually, two alternative sequences are proposed of 128 or 192 chip length respectively; both sequences extend the DwPTS transmissions over the guard period and also the UpPTS (7.3.1).

Due to the longer duration, both sequences increase the processing gain with respect to what can be achieved with the DwPCH; therefore a reduction of the blanking rate with respect to the method described in section 7.2.1 is expected, though how much blanking rate can be reduced is still to be investigated.

Furthermore, the extension over the guard interval and the UpPTS (7.3.1), requires detailed investigations about possible impacts to the system performance.

In particular, some seen drawbacks by the opponents are:

- make use of GP by transmissions (frame structure)
- blanking of UpPCH accesses (lost RACH capacity),
- claimed gain is seen questionable, because UEs would try to access the system (no signalling on “forbidden” timeslots is possible)
- possible problems in HO, because UpPCH can not be received
- unclear, what this means to UE – positioning, because with DwPCH it was possible to reuse the blanking for IPDLs for UE Positioning (method in 7.3.1)

7.3.1 CEC sequences

This method is based on using both DwPTS and UpPTS time slots to transmit dedicated sequences for Node B synchronisation. The transmitted sequences are 192 chips long CEC (Concatenated Extended Complementary) sequences. In addition to the 3 dB extra processing gain brought by their higher length, they present a 32 chips wide perfect correlation window around the main peak and allow 2 Node B's to transmit their sequences simultaneously in steady state phase without interfering to each other in the tracking phase .

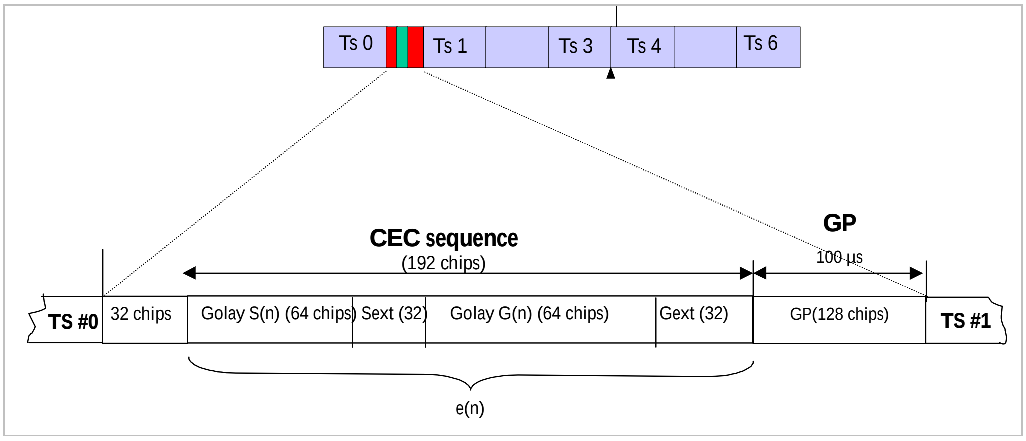

Figure: Structure of the combination of the CEC implementation for Node B synchronisation

At first, the sequence detecting performance for the Node B synchronization can be improved due to the 3dB extra processing gain brought by the CEC sequences in regards of SYNC_DL sequences. Then a second gain comes from the possibility for dual Node B transmission. By properly selecting the Node B for the transmission of the second sequence, the need for first interferer blanking is avoided and even replaced by a second measurement. It then appears that the number of blanked sub-frames due to Node B synchronization can be reduced. In addition, signalling amount over Iub is expected to be reduced since there is no need for signalling to the Node B which sequence to correlate with.

The DL / UL separation is shifted at the end of the CEC sequence but not reduced. The impacts to the system performance due to the blocking of RACH procedure should be investigated further by simulation. The expected extra performance gain due to the perfect correlation window must be investigated as well.

7.3.2 Extended SYNC_DL sequence using Gold sequence

This method is based on using an extended SYNC_DL sequences with the length of 128 chips which consists of first 64 chips, being the original SYNC_DL sequences and the second 64 chips is the modified Gold sequence.

The procedure based on extended SYNC_DL sequence is similar to the procedure based on DwPCH centric solution described in 7.2.1.. The extended sequence will be transmitted in DwPTS and the first 64 chips of the GP after the DwPTS during Node B synchronization.

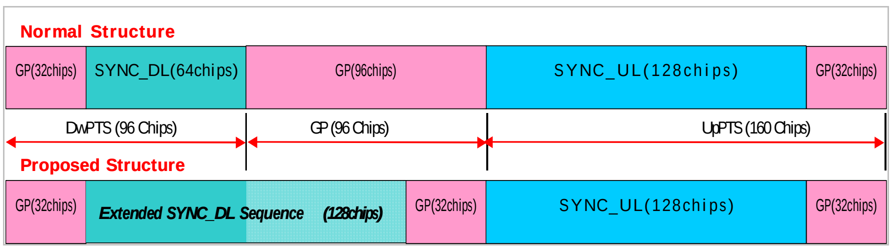

Figure: Structures of DwPTS and GP and UpPTS

Since the extended SYNC_DL sequences have the double length of the original SYNC_DL sequences, their processing gain is increased by 3dB, compared with the method based on DwPCH. The detecting performance of sequence for the Node B synchronization can be improved due to the increase of the processing gain. This will appear that the required transmission power of sequence for Node B synchronization can be decreased, which results in the number of the blanked sub-frames due to Node B Synchronization can also be reduced. In addition, no more signaling for extended sequences is needed since it gives the one-to-one mapping between SYNC-DL sequence and extended sequence.

Due to the longer sequence, the length of GP is changed from 96 chips to 32 chips, the impacts to the system performance due to the blocking of RACH procedure should be investigated further by simulation.

7.4 Potential Improvements for Handover

For handover the UE may be provided with information about the synchronization accuracy of the new cell so that it can apply the proper handover procedure to new cell and proper timing advance value in the new cell:

1. In cells with low sync accuracy (e.g. > 0.5us), HO will be done similar to random access procedure by sending UpPCH to the target cell to reach accurate uplink synchronization (the UpPCH may be sent with the calculated TA to the target cell to assure not to interfere with other time slots). The new value of TA is calculated by the UE after receiving the FPACH acknowledging the respective UEs UpPCH.
2. In cells with high sync accuracy (e.g. +- 0.1us) autonomous calculated TA in the UE will be used to synchronize to the target cell during HO. The maximum timing inaccuracy will be 0.4us.

The necessity to transmit the UpPCH for handover or not is indicated by higher layers signaling.

7.5 DwPCH for UE positioning

7.5.1 UE positioning enhancement with IPDL

To support time difference measurements for location services, idle period can be created in the downlink (hence the name IPDL) during which time the transmission of a NodeB is temporarily switched off. During the idle periods, the visibility of neighbour cells from the UE is improved. The idle periods are arranged in a determined pattern according to high layer signalling.

As discussed in NodeB synchronisation procedure, the NodeB switches off its DwPCH transmission and listens to the neighbour cells according to the schedule of RNC. Since timing difference measurement can be performed on any channel, so the blanking of the DwPCH (IPDL) can also be used for the UE.

7.5.2 UE positioning without IPDL

If the UE has the capability of an advanced technique such as interference cancellation, UE positioning without IPDL can be considered as an alternative solution. In case of UE positioning without IPDL, the UE complexity increase needs to be considered. Further study needs to be done to investigate the performance and the complexity issue.

8 Impact on Interfaces

8.1 Uu Interface

There is an impact on the receiving cell.

The receiving cell has to blank its own transmission of DwPCH on certain times and listen to the neighbouring cell. The UE may be informed about the blank of DwPCH, e.g., it can use such blanking period as IPDL for the measurements supporting LCS.

The cell sync codes to be used are SYNC-DL sequence, which have been described in detail in TS 25.223.

For handover the UE may be provided with information about the synchronisation accuracy so that it can apply the proper timing advance value and procedure in the new cell as described in section 7.3.

8.2 Iub Interface

The messages between a NodeB and the RNC are described in detail in RAN3.

Procedures necessary are:

to instruct the transmitting Node B to transmit its normal SYNC_DL sequence in the DwPTS and

to blank the DwPCH of the neighbouring Node Bs and

to request measurements from the individual cells.

8.3 Iur Interface

Each RNC area is synchronised individually to at least one reference clock (e. g. GPS). This automatically ensures synchronisation between RNC areas. Therefore, no communication over Iur is necessary for cell synchronisation between RNC areas.

9 Impact on network elements

9.1 UE

The UE shall have the capability to take into account the blanking of DwPCH and shall support the synchronisation accuracy signalling mechanism and have the capability to correct its TA value for handover.

The blanking interval of the DwPCH has to be chosen in such way, that this blanking is transparent for the initial cell search procedure also to the Rel-4 UEs.

9.2 Node B

The transmitting Node B would send its normal SYNC_DL sequence in the DwPTS. The neighbouring Node Bs measure this sequence in their DwPTS, therefore the DwPTS has to be blanked in the neighbouring cells for certain sub-frames to allow the measurements of the transmitting Node B.

The cells shall support the reception of the DwPCH from the neighbouring cells as well as measure the reception time. At least one external reference clock (e.g. GPS receiver) has to be added per connectivity area.

Furthermore, the cells shall have to provide means for adjusting their timing and optionally the clock rate on command. The changes in the NBAP protocol have to be supported.

9.3 RNC

The RNC has the control of the whole algorithm. It shall initialise, establish and maintain a connectivity plan. It shall order and collect measurements and compute adjustment commands as well as support the necessary NBAP signalling. It may estimate the synchronisation accuracy between cells and signal the relevant information to the UEs for handover.

10 Performance Analysis

10.1 Blanking of the DwPCH

Simulation assumptions:

- 6 immediate neighbours
- all of the NodeBs at the same range
- frequency reuse = 1

→ the only variable is the lognormally distributed shadowing effect (assuming that the NodeBs are on a regular grid).

Description:

For each deployment, the signal to interference ratio was computed for the signal from every neighbour. Then, the strongest N interferers to that signal were blanked, where N ranged from 1 to 4. Cumulative density functions were plotted for these cases. In the simulation, shadowing is considered, using a typical figure of 8 dB.

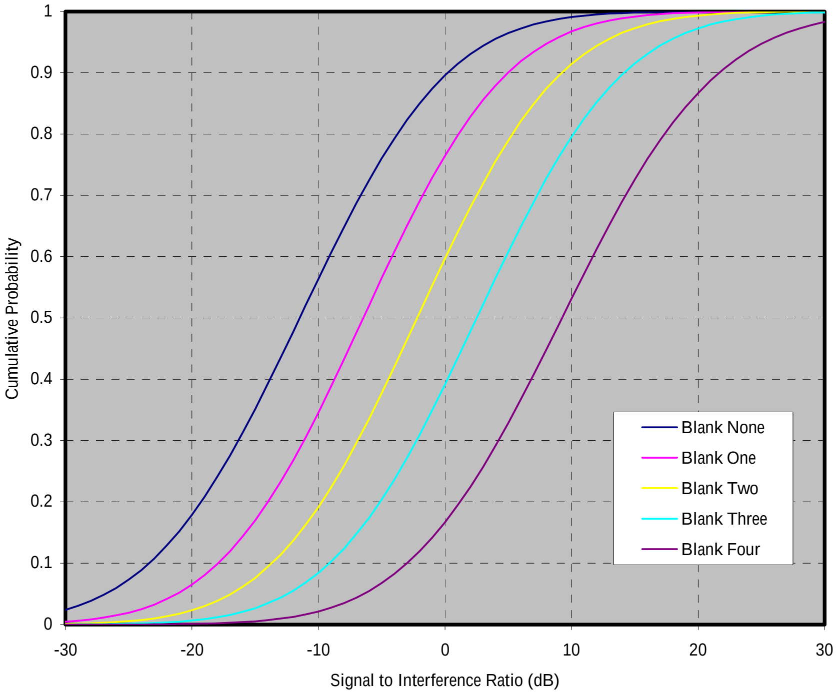

Figure 1: Signal to Interference Ratio Distribution with 8 dB Lognormal Shadowing

The simulation shows:

- the median performance with blanking improves
- there are gains from selecting the strongest interferers to blank
- choice of the sequences for blanking and the number of blanked sequences must carefully be chosen by the RNC
- The more neighbours are blanked, the higher the SIR (in median performance) for a given SYNC-DL sequence
- These simulations show, that blanking is essential for the operation of the Node B synchronisation method, using the DwPCH for a single frequency re-use deployment.

Conclusion:

Blanking of the DwPCH is necessary in order to reduce the interference in the DwPTS and allow for node B synchronisation over the air. Blanking of strong neighbours allows for monitoring more distant and therefore weaker other neighbours. The performance can further be improved by Network planning and averaging of different measurements.

10.2 Usage of receive beamforming

Simulation assumptions:

- 6 immediate neighbours
- all of the NodeBs at the same range
- frequency reuse = 1
- receive beamforming

Description:

Figure 2 present the results for the cumulative density function of signal to interference ratio for blanking up to 4 interferers for the case, that receive beamforming is applied.

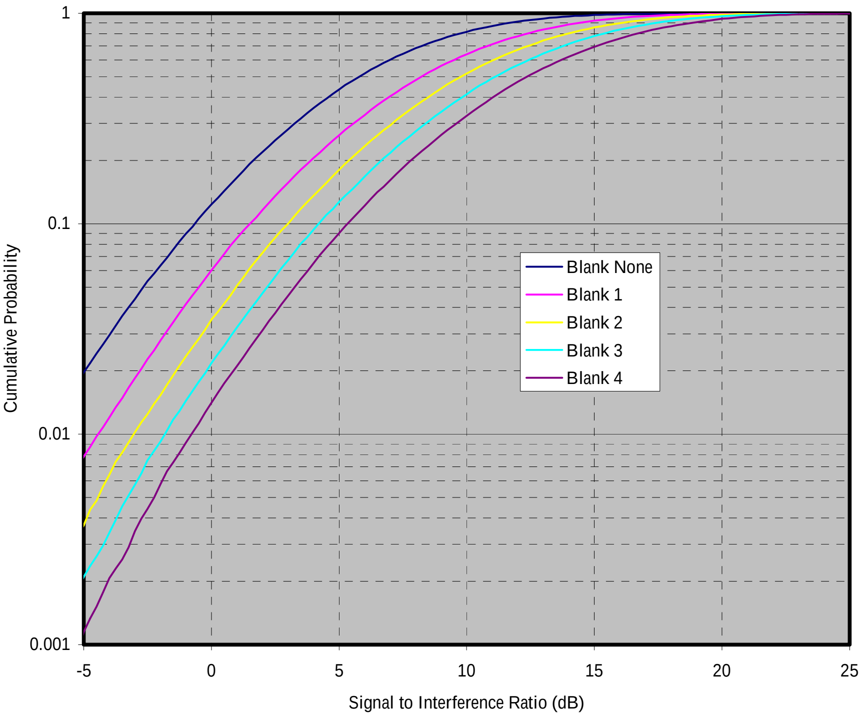

Figure 2: Cumulative Probability of SIR for Antenna Diameter 1.25 Times Wavelength - Partially Correlated Shadowing

The simulation shows:

- receive beamforming increases the signal to interference ratios of the SYNC-DL sequences
- the number of blanked neighbours is no longer the dominant criterion for the achieved performance of the synchronisation method
- fewer neighbouring interferers cause interference to a specific node B
- with receive beamforming the number of interferers (SYNC-DL sequences), that have to be blanked to achieve the required performance, can be reduced

Conclusion:

The use of smart antennas further increases the performance of this node B synchronisation method which could reduce the number of neighbours, which have to be blanked (only DwPCH).

11 Backward Compatibility

UTRAN: The synchronization over the air in Rel-5 can be used in addition to and in combination with the synchronization via the sync port in Rel-4. Therefore backward compatibility is ensured for the UTRAN.

UE: The Rel-4 UEs cannot receive the DwPCH when it is blanked based on the RNC schedule. However, the UE algorithms involved in detecting and processing the DwPCH for initial cell search have to cope with failed detection of one or more DwPCH(s), e.g. due to fading. Therefore, backward compatibility is satisfied for the Rel-4 UE if the DwPCH of Rel-5 or later BS is blanked at an acceptably low rate. The determination of the required blanking rate in order to meet the required Node B synchronization accuracy remains to be done, and then the impact of this rate on initial cell search must be verified to be minor.

Annex A:
Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
22/05/01					TR structure agreed on WG1#20		
28/06/01					revised based on the text proposals on WG1#adhoc		
02/09/01					Version 1.0.0 revised based on the text proposals on WG1#21		
27/11/01					Version 1.1.0 revised based on the text proposals on WG1#22		