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Contents

Foreword

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1 Scope

This document captures the working assumptions and evaluation criteria of the different techniques being considered for Multiple-Input Multiple-Output (MIMO) in UTRA.

The purpose of this TR is to help TSG RAN WG1 to define and describe the potential enhancements under consideration and compare the benefits of each enhancement with earlier releases for improving the performance of the dedicated and shared transport channels in UTRA downlink, along with the complexity evaluation of each technique.

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] 3GPP TR 25.996 (V6.0.0): "Spatial channel model for Multiple Input Multiple Output (MIMO) simulations".

[2] 3GPP TR 25.848 (V4.0.0): “Physical layer aspects of UTRA High Speed Downlink Packet Access”

[3] 3GPP TR 25.869 (V1.2.0): “Tx diversity solutions for multiple antennas”

[4] 3GPP TR 25.896 (V6.0.0): “Feasibility Study for Enhanced Uplink for UTRA FDD.”

[5] 3GPP TR 25.892 (V6.0.0): “Feasibility Study for Orthogonal Frequency Division Multiplexing (OFDM) for UTRAN Enhancement.”

[6] Lucent Technologies, “Link Error Prediction for E-DCH”, R1-030777, New York, USA, Aug 25-29, 2003.

[7] Cingular Wireless, Orange, 3, Telecom Italia, T-Mobile, Vodafone Group, “Reference scenario for the selection of the UTRA MIMO scheme”, R1-051626, R1 reflector, December 2005.

[8] Motorola, “A comparison of ideal relative data throughput of MIMO and Release 5”, R1-030556, Marne la Vallee, France, May 19-22, 2003

[9] Qualcomm Europe, “Introduction of MIMO”, R1-071215, TS25.201 CR 032

[10] Ericsson, Qualcomm Europe, “Transmit diversity operation in MIMO mode”, R1-071167, TS25.211 CR 238.

[11] Philips, Ericsson, Qualcomm, Nokia, Siemens, Motorola, “Coding of HS-SCCH to support FDD MIMO”, R1-071165, TS25.212 CR 241r4.

[13] Qualcomm Europe, Philips, Ericsson, Nokia, “Definition of MIMO operation on HS-PDSCH, preferred precoding and CQI reporting procedures, modified CQI tables”, R1-071229, TS25.214 CR 430r10.

[14] Qualcomm Europe, “Introducing MIMO in UE Capability specification”, R2-071094, TS25.306 CR 0153

[15] Ericsson, Qualcomm Europe, Philips, “Introduction of MIMO in 25.308”, R2-071038, TS25.308 CR 0017.

[16] Qualcomm Europe, “Introducing MIMO in MAC specification”, R2-071091, TS25.321 CR 0316

[17] Qualcomm Europe, Philips, “Proposed CR to TS 25.331 [Rel-7] on Introducing MIMO in RRC specification”, R2-071092, TS25.331 CR 2985.[18] Qualcomm Europe, Nokia, “Introduction of MIMO in RNSAP”, R3-070363, TS25.423 CR 1267.

[19] Qualcomm Europe, Nokia, “Introduction of MIMO in NBAP”, R3-070362, TS25.433 CR 1342

[20] Alcatel-Lucent, “Introduction of MIMO in RANAP”, R3-070506, TS25.413 CR 0906.

[21] RAN WG1, “LS on 64QAM HSDPA and HSDPA MIMO UE categories”, R1-071238.

3 Background and introduction

In RAN#11 plenary the work item was approved for MIMO stating that MIMO shall be optional at the UE, in RAN#18 it was extended to cover TDD, and in RAN#19 it was further updated with the following description:

The purpose of this work item is to improve system capacity and spectral efficiency by increasing the data throughput in the downlink within the existing 5MHz carrier. This will be achieved by means of deploying multiple antennas at both UE and Node-B side.

The technical objective of this work item is the integration of MIMO functionality in UTRA, in line with recommendations from WG1, to improve capacity and spectral efficiency. The works tasks include the support for both FDD and TDD. In those cases where differences between FDD and TDD are identified, they should be considered as separate work tasks.

4 Requirements for the evaluation of techniques for Multiple-Input Multiple-Output in UTRA

The following considerations should be taken into account in the evaluation of the different techniques proposed for MIMO in UTRA.

1 The focus will be on UTRA using MIMO techniques and on the additional or modified uplink signalling required to support MIMO.

2 MIMO proposals shall be comprehensive to include techniques for 1, 2 or 4 antennas at the Node B and 1, 2, or 4 antennas at the UE. In this document, we will use the notation (x,y) to denote a system with x Node B antennas and y UE antennas. At least one of the cases (1,1), (2,1), (1,2), (2,2) or (1,4) shall be considered as reference. Any proposal shall cover one or more of the following antenna configurations and be restricted to only these: (2,2), (2,4), (4,1), (4,2), (4,4). If (2,2) is supported by the proposed MIMO technique, then these simulation results must be included.

3 For each proposal, the transmission techniques for the range of data rates from low to high UE geometry (SIR) shall be evaluated.

4 The antenna configurations (e.g. number of antennas, antenna spacing/polarization) at both the Node B and UE shall be described.

5 Operation of MIMO should be specified under a range of realistic conditions.

6 The semantic associated with the feedback bits from the UE to Node B and the use of these bits shall be provided.

7 The operation of a MIMO technique shall be described in sufficient detail to straightforwardly determine what changes to UTRA are needed to include the technique. Detailed descriptions of aspects that are specific to the technique shall be provided, including transmit and receive algorithms, physical layer signalling , and control.

8 Higher-level signalling on both uplink and downlink shall be described (see sections: Requirements for RAN WG2 & WG3).

9 The impact on non-MIMO UEs shall be evaluated The MIMO technique shall have no significant negative impact on features available in earlier releases

10 An analysis of its complexity shall be provided compared to existing solutions (both UE's and node B's), especially in terms of RF complexity, memory requirements, requirements on UE size, computational complexity, algorithm (hardware) reusability, signalling requirements. An analysis of migration from earlier releases to MIMO should also be provided in terms of, for example, antenna configurations and techniques.

11 The focus shall be on strengthening the UTRA system as a reliable and cost effective access technique in urban and sub-urban areas. This means the goal is to increase the number of users, and/or to increase their coverage compared to earlier releases. In other words, the improvement of the service availablility as compared to earlier releases shall be used as a primary evaluation criterion. The increase in maximum data rate per cell is also of interest.

12 For HSDPA, an example of the channel quality metric used for rate adaptation shall be described by the proponent.

13 Full mobility shall be supported, i.e., mobility should be supported for high-speed cases also, but optimisation should be for low-speed to medium-speed scenarios. For HS channels, the techniques considered shall be optimised at speeds typical of urban environments but techniques should apply at other speeds also.

14 MIMO techniques should demonstrate significant incremental gain over the best performing systems supported in the current release with reasonable complexity. The value added per feature and its complexity shall be considered in the evaluation.

15 The operation of MIMO techniques should be described in sufficient detail to enable realistic link calibration and system level performance studies. Such realistic simulations should include effects such as delay, channel estimation error, signalling error and pilots.

5 Layer 1 implications

5.1 FDD dedicated channels

5.1.1 Proposal 1

5.1.1.1 Basic physical layer structure of DCH for MIMO

{This section should describe the DCH physical layer structure which is distinct from the non-MIMO system.}

5.1.1.2 Associated Signalling

5.1.1.2.1 Downlink

{This section should describe the DCH-related downlink signalling which is distinct from the non-MIMO system.}

5.1.1.2.2 Uplink

{This section should describe the DCH-related uplink signalling which is distinct from the non-MIMO system.}

5.1.1.3 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.1.1.4 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.1.1.4.1 Analysis of User Equipment Complexity

5.1.1.4.2 Analysis of Node B impacts

5.1.1.5 Backward compatibility

5.1.1.6 Overview of changes required in the specification

5.2 FDD High Speed Channels

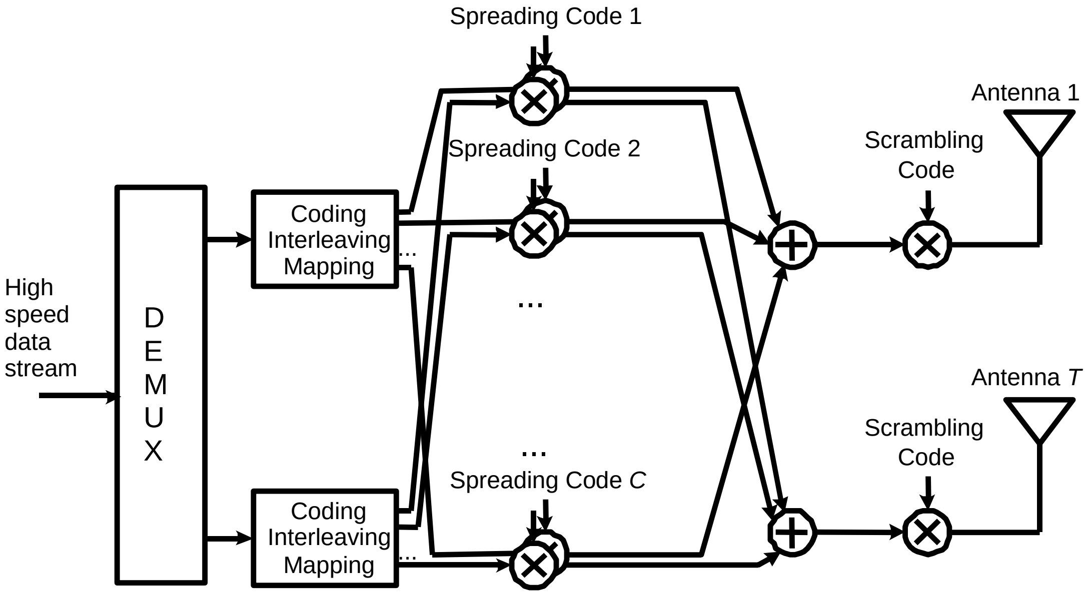
5.2.1 Proposal 1: Per-antenna rate control (PARC)

The PARC architecture is motivated by an information theoretic result stating that the Shannon capacity limit for an open loop MIMO link can be achieved if separately encoded data streams are transmitted from each antenna with equal power but possibly with different data rates, and if the receiver consists of a space-time MMSE linear filter followed by interference cancellation based on post-decoding symbols. The mobile receiver measures the signal to interference plus noise ratio (SINR) of each transmit antenna in the presence of interference from the other antennas and feeds back this information to the base. Then the base determines the data rate for each antenna. If the SINR for a particular antenna is too low to support even the lowest data rate, then that antenna is not used for transmission. Hence selection transmit diversity becomes a special case of PARC. Note that because PARC requires the SINR information to be fed back to the transmitter, it is not strictly an open loop technique. Therefore while the PARC concept itself is not actually an open loop technique, it achieves the theoretical open loop MIMO link capacity.

5.2.1.1 Basic physical layer structure of HS-DSCH for MIMO

The block diagram below shows the basic physical layer structure of the HS-DSCH for PARC. A block of data corresponding to a single high speed data stream is demultiplexed into a maximum of T low-rate streams, where T is the number of transmit antennas. Each of these low-rate streams is turbo encoded, interleaved, and mapped to either QPSK or 16QAM symbols. Because different coding rates and symbol mappings can be used on each low-rate stream, the number of information bits assigned to each stream can be different. The symbols for a given low-rate stream are associated with a particular transmit antenna. They are further demultiplexed into a maximum of C substreams, where C is the maximum number of HS-PDSCH defined by the UE capability. These substreams are spread using distinct OVSF channelization codes, summed, and then modulated by a scrambling code. The resulting CDMA modulated low-rate stream is transmitted from it associated antenna.

Note that because of the flexibility of PARC, various options are available for partitioning the physical layer resources of channelization codes, scrambling codes, and transmit antennas. These options are discussed in the following subsections.



5.2.1.2 Adaptive modulation and coding schemes

5.2.1.2.1 Modulation and channel coding

The modulation and channel coding for each low-rate stream depends on the received SINR of its associated transmit antenna. The SINR is the sum measured across all receive antennas at the UE for a given transmit antenna, and it accounts for intercode interference from the same antenna as well as spatial interference from other antennas. With T transmit antennas, up to 2^T-1 antenna combinations could be evaluated, and the subset of T antennas with the highest total data rate is chosen. Antenna powers are normalized so the total power is fixed.

We consider an example with $T = 2$ transmit antennas (denoted as antennas A and B), summarized by the table below. With $T = 2$, the 3 options for transmission correspond to only antenna A on, and only antenna B on, and both A and B on. These correspond respectively to options 1, 2 and 3. When both antennas are on, the transmit power from each is reduced by a half so the total power is the same as the cases with a single antenna on. For each option, the SINR is calculated based on the channel estimates and the detector architecture. The SINRs are mapped to achievable rates and their corresponding modulation and channel coding schemes, possibly based on conventional HSDPA rate mappings. In the example, option 1 achieves a rate of 2.332 Mbps by using 16QAM modulation with rate 0.486 coding over 5 spreading codes. Option 2 achieves a slightly higher rate because its SINR is higher. However, by transmitting simultaneously over both antennas, the total rate of 3.074 Mbps is the highest. Hence this transmission scheme would be signalled back to the Node B.

option	tx antenna power		SINR(dB)		modulation		coding rate		#codes		data rate (Mbps)		
	A	B	A	B	A	B	A	B	A	B	A	B	total
1	P	0	14	-inf	16QAM	N/A	0.486	N/A	5	N/A	2.332	0	2.332
2	0	P	-inf	15dB	N/A	16QAM	N/A	0.551	N/A	5	0	2.644	2.644
3	P/2	P/2	10.2	11.9	QPSK	16QAM	0.691	.371	4	5	1.292	1.782	3.074

Table 5.2.1.2.1-1: Example for determining rate request

5.2.1.2.2 Transmission algorithms

When spatial multiplexing is used (in other words, when multiple antennas are used to simultaneously transmit multiple low-rate streams), OVSF and scrambling codes can be assigned to the streams using several different options. The option chosen depends on the availability of codes and the potential interference that would be caused to other DCHs.

Option A: Common OVSF codes, common scrambling codes. If the number of OVSF codes for each stream is different, then the codes for the antenna with the most codes are first assigned, and then the codes for the other antennas are a subset of these assigned codes. For our example, the 5 OVSF codes for antenna B are first assigned, and then the 4 codes for antenna A are a subset of these 5. This option is known as "code reuse" since the spreading codes are reused among the antennas. This case incurs the most intercode interference among the spatially multiplexed channels, but creates the least interference to other DCHs. For MIMO transmission with more than T = 2 antennas, the subset of codes can be chosen judiciously to minimize the intercode interference, and the calculation of the SINR should account for this flexibility.

Option B: Common OVSF codes, distinct scrambling codes. In our example, the OVSF codes would be assigned in the same was as in option A, but different scrambling codes would be used for the antennas. This option reduces the intercode interference, and the calculation of the SINR should account for this factor.

5.2.1.2.3 Physical layer aspects for MCS Selection

The UE determines the CQI for all antennas and transmits this information to the Node B on the reverse link. The actual information transmitted on the reverse link can be considered more abstractly as an index into a table giving the modulation, coding, and number of codes used for each transmit antenna. If there are N CQI values with non-zero rate for a given UE configuration under conventional single antenna HSDPA, then there are up to $(N + 1)^T - 1$ combinations of CQIs with T antennas. A preferred subset of these combinations should be generated to reduce the amount of uplink signalling. The uplink information can also be multiplexed over multiple TTIs if necessary.

5.2.1.3 Associated Signalling

5.2.1.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.1.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.1.4 UE Capability

{This section should describe the parameters (e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.1.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.2.1.5.1 Analysis of User Equipment Complexity

5.2.1.5.2 Analysis of Node B impacts

5.2.1.6 Backward compatibility

5.2.1.7 Overview of changes required in the specification

5.2.2 Proposal 2: Rate-Control Multi-Paths diversity (RC MPD)

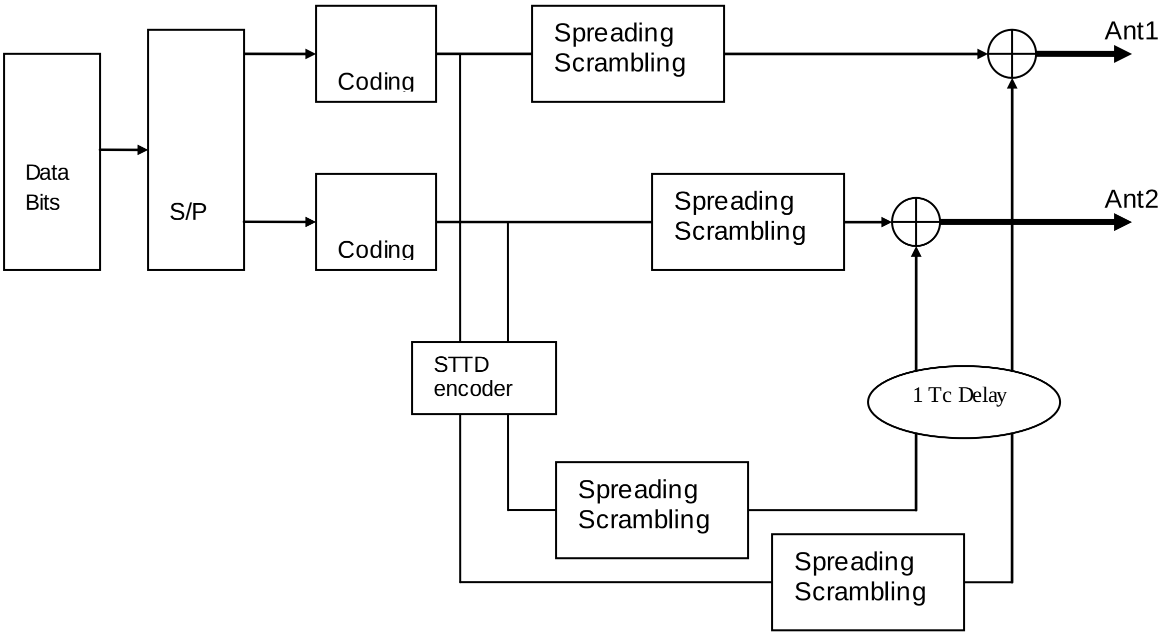
Multi-Paths diversity is MIMO technique with multi-streams transmission. The number of data streams is equal to the number of active transmitting antennas. Each data stream is sent from at least two antennas. Every pair of data streams that shares the same two antennas has the same data rate and modulation. The data rate for every pair is fixed by the Node-B according to the mobile measurements. The Node-B determines the most appropriate data rate and modulation to transmit for every stream.

5.2.2.1 Basic physical layer structure of HS-DSCH for MIMO

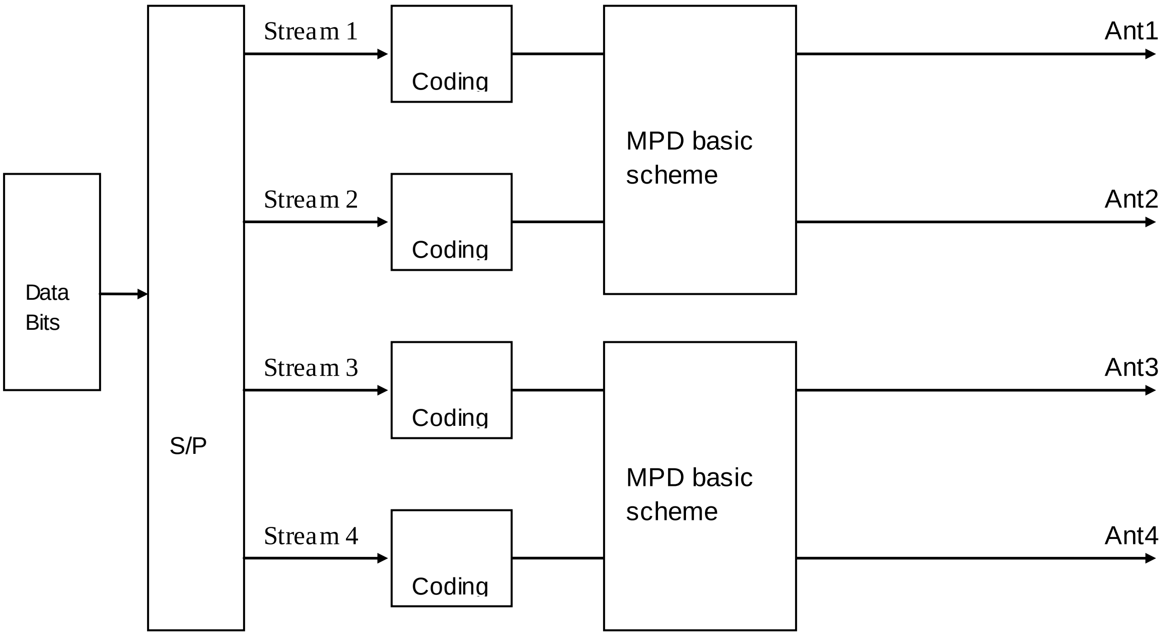
The MPD basic MIMO scheme is shown in the figure below for two transmitting antennas. The initial block of data bits is split into 2 independent streams of data bits; these two streams have the same rate. They are coded, interleaved and mapped to symbols. These two streams are spread and scrambled. Another copy of the same symbols is transmitted after one chip delay period and after encoding the symbols by the STTD code:

$$\begin{pmatrix} s_1 \\ s_2 \end{pmatrix} \Leftrightarrow \begin{pmatrix} -s_2^* \\ s_1^* \end{pmatrix}$$

Using the STTD code allows the symbols to be transmitted on one more antenna taking more advantage of the transmission diversity.



The extension to 4 antennas is shown in the figure below. The same MPD scheme is repeated for the antenna 3 and antenna 4. Note that the rates of stream 3 and stream 4 are equal but not necessarily equal to the rates of stream 1 and stream 2.



5.2.2.2 Adaptive modulation and coding schemes

5.2.2.2.1 Modulation and channel coding

The MCS used by each stream is decided by the Node-B according to the measurement made by the mobile while demodulating each stream. Note that these measurements are equal for every pair of streams that shares the same antennas allowing some reduction in the amount of feedback information to be sent by the mobile.

5.2.2.2.2 Transmission algorithms

The total number of assigned OVSF codes depends on the highest data rate used by a stream during one scheduling period. Other streams use necessarily the same set of OVSF codes. Optimal reusing should be performed so that each code is used as few as possible, example:

Supposing that 10 OVSF codes are used for stream 1 and stream 2 and 5 OVSF codes are used for stream 2 and 3. Then the allocation should be done as follows:

- Stream 1 shall use OVSF codes 1 to 10
- Stream 2 shall use OVSF codes 1 to 10
- Stream 3 shall use OVSF codes 1 to 5
- Stream 4 shall use OVSF codes 6 to 10

With such allocation, each OFSV code is used 2 times only.

The Node-B is responsible for choosing the appropriate antennas to pair and inform the mobile about it. The transmission power at all antennas is identical.

5.2.2.2.3 Physical layer aspects for MCS Selection

The mobile estimates the SINR of each stream, and transmits the according CQI. Since the CQI of two streams sharing the same pair of antennas are identical, this allows some reduction in the amount of feedback information. The Node-B decides itself what MCS to use for each stream. Note that one possible solution can be to let only 2 antennas among the 4 antennas to transmit.

5.2.3 Proposal 3: Double Space Time Transmit Diversity with Sub-Group Rate Control (DSTTD-SGRC) for 2 or more receive antennas

DSTTD-SGRC is a scheme for enhancing the achievable data rates and spectral efficiency of HS-DSCH channels using multiple transmit antennas at Node B and multiple (yet fewer) receive antennas at the UE. In DSTTD-SGRC, the four transmit antennas are divided into two sub-groups. Adaptive modulation and coding along with STTD-based transmission are used by each group to transmit data. The two transmit antennas belonging to each sub-group transmit using the same MCS, and therefore, the same rate. The data rate of each group is either independently or jointly adjusted by MCS selection.

By combining sub-group rate control with the STTD structure, which is mandatory in Rel'99 UEs, higher throughput, enhanced link diversity, as well as backward compatibility are achieved. The enhanced link diversity also makes the system more robust to feedback delay induced estimation errors. In addition, only half the feedback of schemes that control the MCS for every transmit antenna is required.

5.2.3.1 Basic physical layer structure of HS-DSCH for MIMO

5.2.3.1.1 Transmitter Structure

4 transmit antennas

The scheme is shown in the figure below for four transmitting antennas. The four antennas are divided into two sub-groups, with each sub-group consisting of two antennas.

The HS-DSCH data stream is split into two independent streams by the S/P demux module. Stream 1 is transmitted by sub-group 1 and stream 2 by sub-group 2. The number of information bits allocated to each stream depends on the MCS to be used for the respective sub-group and the number of OVSF spreading codes (OC), N, assigned to the given downlink user. Depending on the MCSs chosen for transmission for the two sub-groups, the two streams may be transmitted at different rates.

For each stream, the information bits output by the S/P demux are coded, interleaved, and modulated, as governed by the MCS scheme for the respective sub-group. The resultant symbol stream is then STTD encoded. Each STTD block yields two sub-streams, one for each antenna in a sub-group. The two data sub-streams are both further split into N parallel streams, one for each OVSF spreading code. These are then combined, scrambled, and transmitted. Use of the same scrambling code (SC) is envisaged for all the 4 antennas.

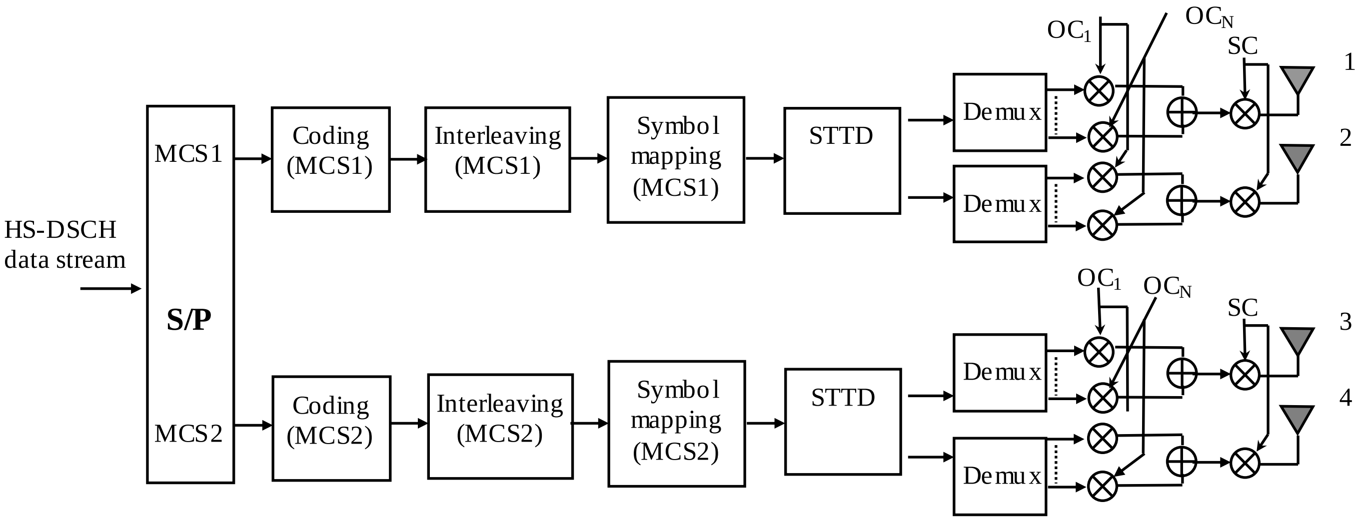


Figure 5.2.3.1.1 Transmitter Structure for DSTTD-SGRC

2 transmit antennas

For Node B's equipped with only two transmit antennas, only one of the above two sub-groups is to be used. This then reduces to a STTD transmission as defined in Rel'99 with the MCS adaptively chosen for only 1 sub-group.

5.2.3.1.2 Receiver Structure

The minimum number of receive antennas required is only half the number of transmit antennas.

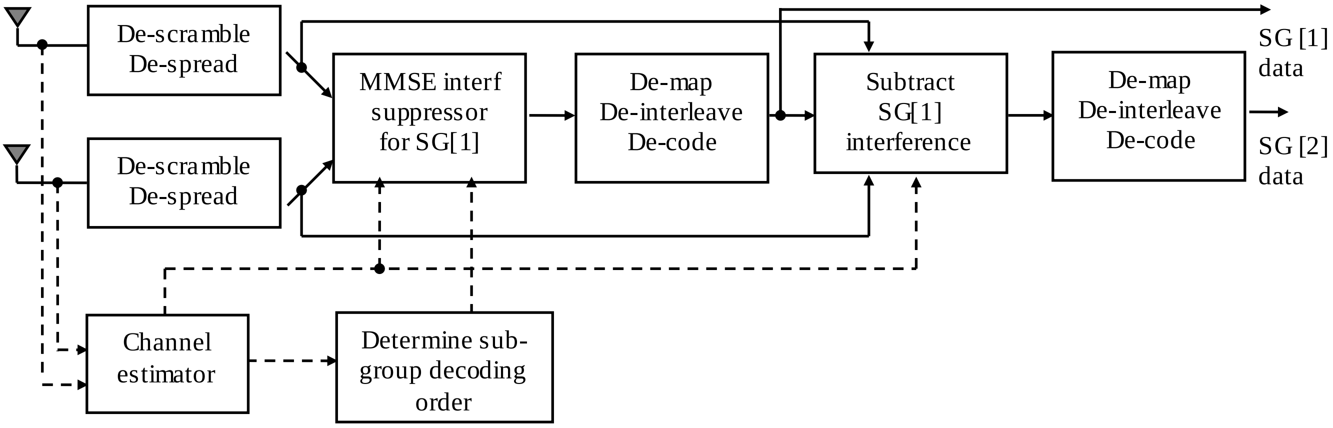


Figure 5.2.3.1.2 MMSE-SIC receiver for DSTTD-SGRC

A conventional MMSE interference suppressor with successive interference cancellation (SIC) receiver for 2 receive antennas is shown in Fig. 5.2.3.1.2. Based on the estimate of the spatial channel, the receiver determines the decoding order of the two sub-groups, with the sub-group having the higher SINR being decoded first. Let [1] denote the index of the sub-group decoded first and [2] denote the other sub-group.

The received signals from the two antennas are first de-scrambled and de-spread. The MMSE interference suppressor cancels the interference of sub-group [2] from sub-group [1]'s signal. Sub-group [1]'s data stream is then de-interleaved and decoded. The interference due to sub-group [1] is subtracted from the received signal before the data stream of sub-group [2] is de-interleaved and decoded.

For a 4 transmit antenna system, the channel matrix H can be written as $H = [h_1\ h_2\ h_3\ h_4]$, where h_i's are the constituent columns corresponding to different transmit antennas. The received signal for 2 receive antennas is then

$$\begin{bmatrix} y_1(0) & y_1(1) \\ y_2(0) & y_2(1) \end{bmatrix} = H \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \\ x_3 & x_4 \\ -x_4^* & x_3^* \end{bmatrix} + n,$$

where x_1 and x_2 are the transmitted symbols on sub-group 1, x_3 and x_4 are the transmitted symbols on sub-group 2, and n is the 2×4 noise matrix. Define the modified channel matrix G as

$$G = [g_1 \quad g_2 \quad g_3 \quad g_4] = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2^* & -h_1^* & h_4^* & -h_3^* \end{bmatrix}.$$

The modified received vector then becomes

$$\begin{bmatrix} y_1(0) \\ y_1^*(1) \\ y_2(0) \\ y_2^*(1) \end{bmatrix} = [g_1 \quad g_2 \quad g_3 \quad g_4] \begin{bmatrix} x_1 \\ x_2 * \\ x_3 \\ x_4 * \end{bmatrix} + n'.$$

Assuming that the UE decodes sub-group 1 first, the MMSE receiver with SIC performs MMSE detection to decode sub-group 1, subtracts the contribution of sub-group 1 from the received signal, and then decodes the sub-group 2 data stream assuming no interference. The post-detection SINRs for the two sub-groups for an MMSE-SIC receiver are given by:

$$SINR_1 = g_1' \left(g_3 g_3' + g_4 g_4' + \frac{1}{\rho} I \right)^{-1} g_1,$$

$$SINR_2 = \rho g_3' g_3,$$

where the received SINR at each receive antenna is $\rho = \frac{1}{4} \times \frac{E_c}{I_{or}} \times \frac{16}{10} \times \frac{I_{or}}{I_{oc}}$ (assuming that 10 OVSF codes are used) and I is the identity matrix.

5.2.3.2 Adaptive modulation and coding schemes

5.2.3.2.1 Modulation and channel coding

The modulation and channel coding scheme (MCS) for each sub-group depends on the CQI feedback by the UE. The five MCS schemes used in HSDPA are indexed in Table 5.2.3.2.1-2. An additional scheme (index 1) is also added to the table to allow for a sub-group, with a poor SINR, to be not used for transmission. This mechanism therefore incorporates transmit sub-group selection.

A joint MCS selection table for the two sub-groups, optimized to reduce the number of MCS combinations without loss in throughput, is given in Table 5.2.3.2.1-1. In addition to the higher peak rate of 14.4 Mbps that is achievable, HS-DSCH will support a finer granularity of data rates: 1.2, 2.4, 3.6, 4.8, 6.0, 7.2, 8.4, 12.0, and 14.4 Mbps.

A provision for a CQI value of 15 has also been made to indicate that the transmitter should stop data transmission on both sub-groups. This is for extreme channel conditions when transmission is expected to be unreliable. Not transmitting will reduce inter-cell interference.

CQI Value	**MCS**		**Info. Bits (per TTI)**		**Rate (Mbps) (10 OVSF codes)**		**Net Rate (Mbps) (10 OVSF codes)**
	SG1	**SG2**	**SG1**	**SG2**	**SG1**	**SG2**	
0	6	6	1440	1440	7.2	7.2	14.4
1	6	5	1440	960	7.2	4.8	12.0

2	5	6	960	1440	4.8	7.2	12.0
3	5	5	960	960	4.8	4.8	9.6
4	5	4	960	720	4.8	3.6	8.4
5	4	5	720	960	3.6	4.8	8.4
6	4	4	720	720	3.6	3.6	7.2
7	4	3	720	480	3.6	2.4	6.0
8	3	4	480	720	2.4	3.6	6.0
9	3	3	480	480	2.4	2.4	4.8
10	3	2	480	240	2.4	1.2	3.6
11	2	3	240	480	1.2	2.4	3.6
12	2	2	240	240	1.2	1.2	2.4
13	2	1 *(No tx)*	240	-	1.2	-	1.2
14	1 *(No tx)*	2	0	240	-	1.2	1.2
15	*1 (No tx)*	*1 (No tx)*	-	-	-	-	-

Table 5.2.3.2.1-1: CQI Mapping Table for DSTTD-SGRC

S. No.	**Mod Scheme**	**Coding Rate**
1 *(No Tx)*	-	-
2	4-QAM	1/4
3	4-QAM	1/2
4	4-QAM	3/4
5	16-QAM	1/2
6	16-QAM	3/4

Table 5.2.3.2.1-2: MCS Index

5.2.3.2.2 Transmission algorithms

Different number of OVSF codes may be assigned to the two sub-groups. One of sub-groups reuses a sub-set or all of the OVSF codes assigned to the other sub-group. Specification of this sub-set is FFS.

5.2.3.2.3 Physical layer aspects for MCS Selection

The post-detection SINR of each sub-group serves as the metric to calculate MCS used by each sub-group. The post-detection SINR is a function of the inter-sub-group interference as well as interference from other sources and noise. Due to the design of the STTD code, the signals transmitted from antennas belonging to the same sub-group do not interfere with each other. The MCSs for each sub-group are chosen based on the conventional HSDPA mapping table between SINR and MCS for a given frame error rate target.

The UE feeds back, through the CQI, the MCSs of the two sub-groups.

5.2.4 Proposal 4: Single Stream Closed loop MIMO with 4 Tx and L Rx antennas

This MIMO concept is a single-stream (4,2) closed loop MIMO scheme that is an extension of the (4,1) R2FNTM Tx diversity scheme discussed in [3]. The extension to more than one receive antenna is achieved by using Rx diversity in the receiver. A RAKE receiver with L Rx chains is assumed here, although alternative receivers are also possible.

As in closed-loop Tx diversity systems, the weights of transmit antennas are determined at a mobile station and fed back to the base station. These weights are chosen to maximize the SNR at the UE.

5.2.4.1 Basic physical layer structure of HS-DSCH for MIMO

The figure below shows the general structure of single-stream closed-loop MIMO transmitter at the base station. The transport and physical channel processing are identical as in Release 5 HS-DSCH. The spread and scrambled chip sequence is finally multiplied by the antenna specific complex weight before transmission. The transmission of the pilot symbols from each antenna is for further study.

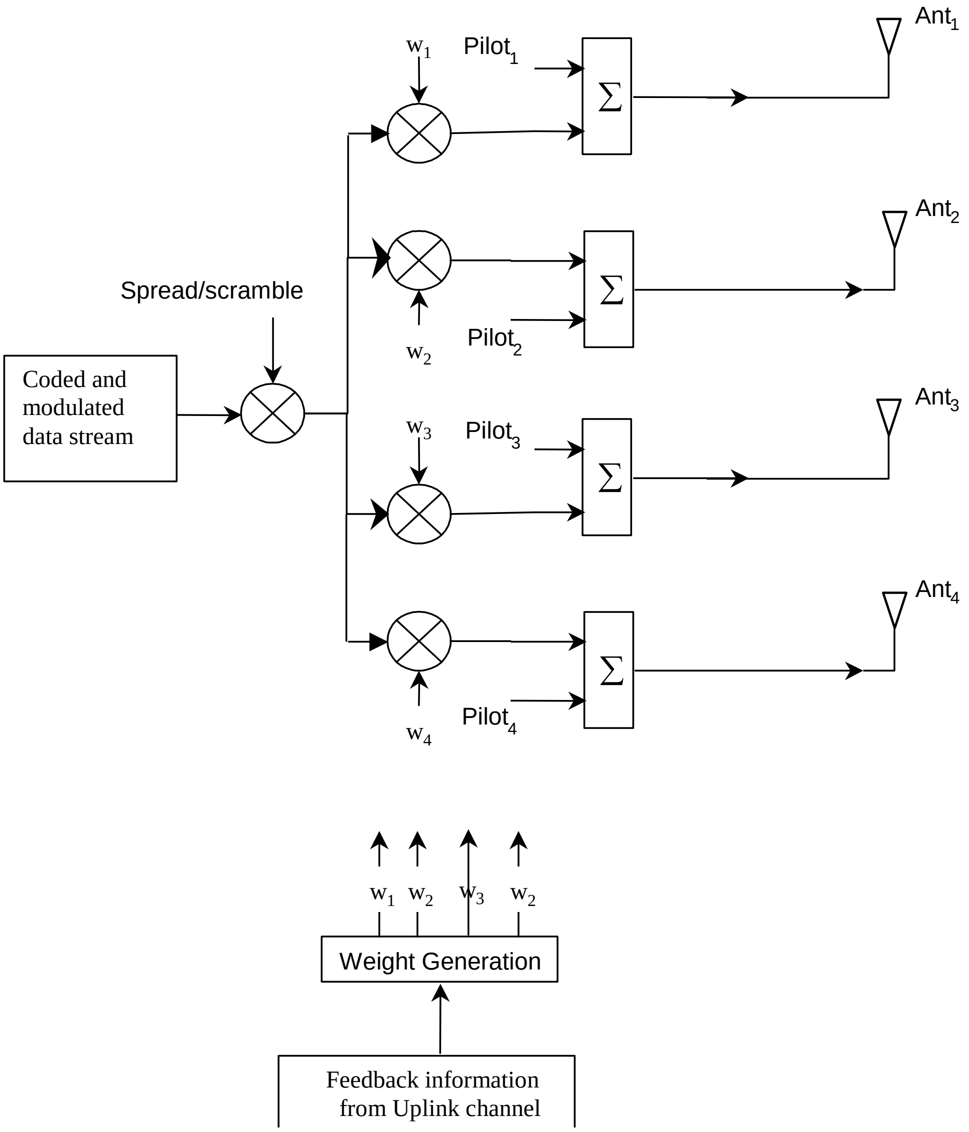


Figure 5.2.4.1-1: Single stream closed loop MIMO transmitter

5.2.4.2 Adaptive modulation and coding schemes

5.2.4.2.1 Modulation and channel coding

The full set of HSDPA allowable modulation and coding combinations is permitted. The MCS utilised based on CQI feedback is identical for each transmit antenna.

5.2.4.2.2 Transmission algorithms

The number of channelisation codes is identical for each antenna.

5.2.4.2.3 Physical layer aspects for MCS Selection

The Channel Quality Indicator (CQI) is calculated based on the quantized feedback weights. Assuming that the feedback bits are interpreted in the transmitter as antenna weight vector $\underline{w_q}$ the conditional channel power used in calculating CQI is

$$P_q = \underline{w}_q^H H^H H \underline{w}_q$$

where H is the estimated channel matrix of size PL X 4 where P is the number of paths in the channel impulse response.

5.2.4.3 Associated Signalling

5.2.4.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.4.3.2 Uplink

The filtered R2FNTM uplink signalling method proposed in [3] is considered here where the rotation constellation set per antenna remains the same as in Rel.-99, length of the phase adjustment filter is N, and there are M Tx antennas. In order to maintain the same rate of feedback as in the Rel.-99 mode 1, the weight of only one antenna is fed back in one slot. Hence, the actual memory of the filter is (M-1)(N-1) slots. In case of 4 Tx antennas (M=4), let Z1, Z2, Z3 be the feedback for antennas 2,3,4 respectively, with antenna 1 being the reference antenna. Assuming N = 4 (R2F4T4), it is clear that in this example the current antenna weight relies on feedback weights sent 9 slots in the past as illustrated in 5.2.4.3.2-1.

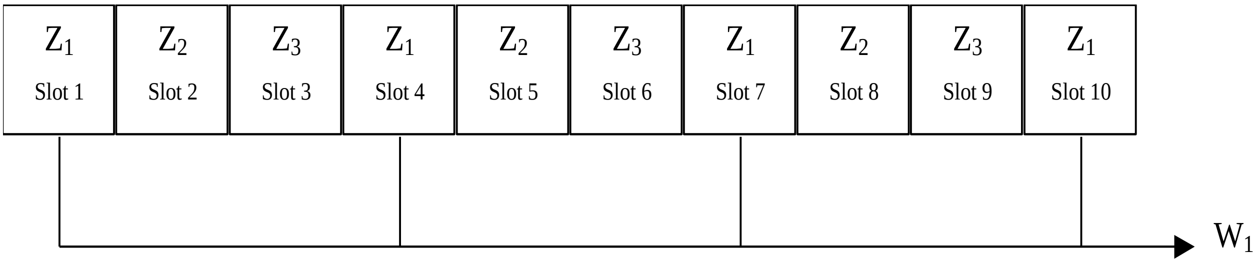


Figure 5.2.4.3.2-1 Filtering of the feedback commands

5.2.4.4 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.4.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc)

5.2.4.5.1 Analysis of User Equipment Complexity

5.2.4.5.2 Analysis of Node B impacts

5.2.4.5.3 Backward compatibility

5.2.5 Proposal 5: Per-User Unitary Rate Control (PU^{2}RC)

The PU^{2}RC is a MIMO scheme which is designed to accommodate multi-user communications with multiple antenna arrays. It uses spatial division multiplexing (SDM) and spatial division multiple access (SDMA) to transmit multiple users, where using the feedback information the transmit weights are calculated based on the preferred unitary matrix corresponding to MIMO channels.

5.2.5.1 Basic physical layer structure of HS-DSCH for MIMO

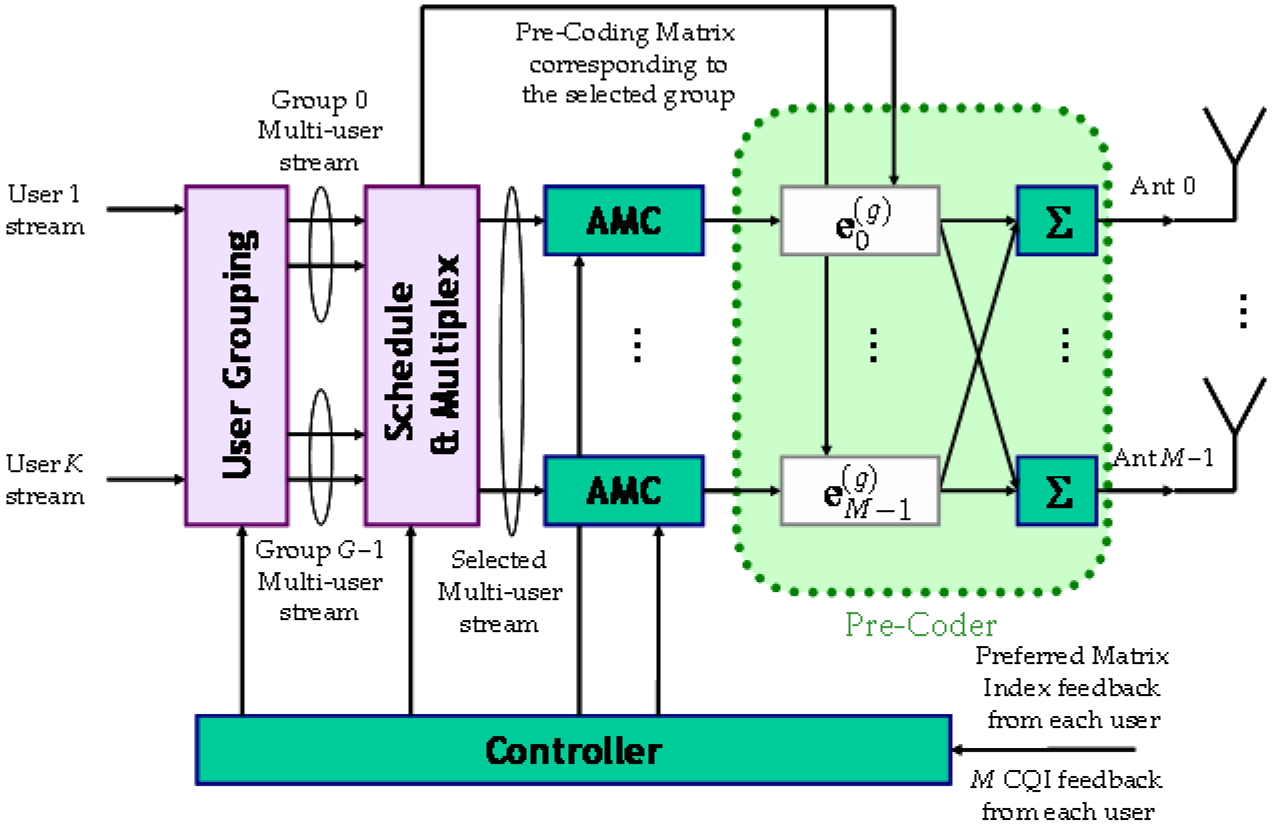


Figure 5.2.5.1-1: Schematic of transmitter for PU^{2}RC with SDM/SDMA (*M* CQI feedback)

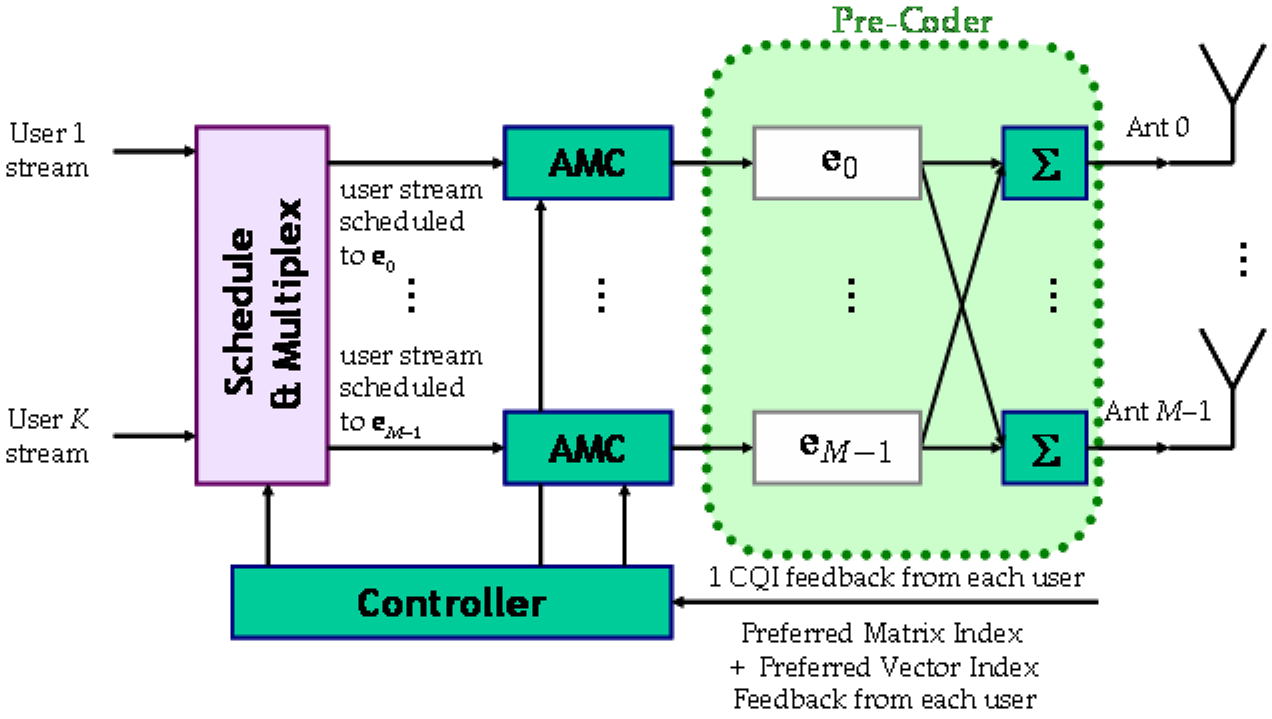


Figure 5.2.5.1-2: Schematic of transmitter for PU^{2}RC with SDMA (1 CQI feedback)

As shown in Figures 5.2.5.1.1 and 5.2.5.1.2, the PU^{2}RC system has two main features. The first one is multi-user based transmission through multiple transmit antennas. The other one is that more than one unitary precoding matrix at the transmitter (i.e.,, {$\mathbf{E}_1$, $\mathbf{E}_2$, …, $\mathbf{E}_G$}), and G is the possible number of the precoding matrices, are considered in the PU^{2}RC.

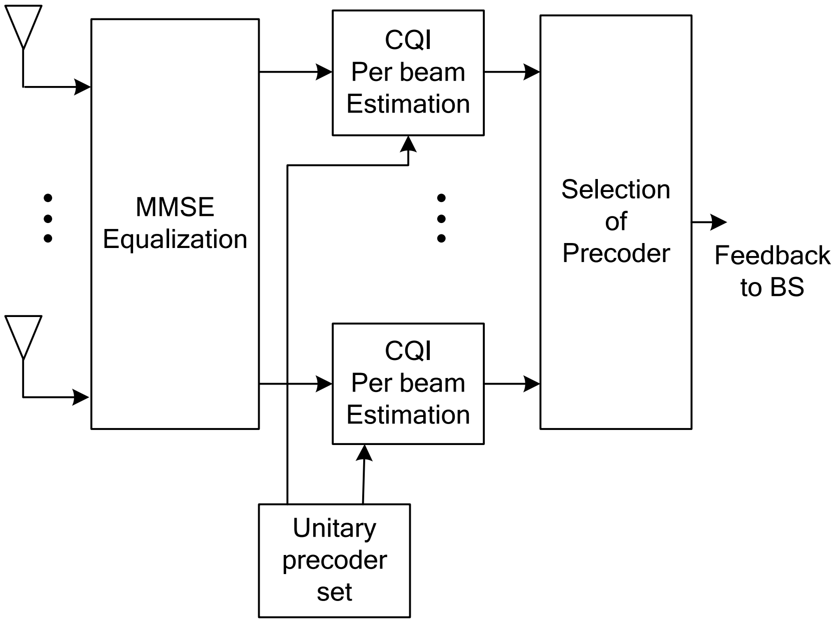


Figure 5.2.5.1-3: Schematic of an example of receiver for PU^{2}RC

In Figures 5.2.5.1.1, 5.2.5.1.2, and 5.2.5.1.3, g is the index of the selected unitary matrix and $SINR_i$ ($i = 1,\ldots,M$) is the estimated CQI information according to the selected unitary matrix. The unitary basis matrix **E** at the transmitter is the combination of the selected unitary basis vectors from all UEs as in equation (1). If PU^{2}RC is operated for SDM/SDMA mode as in Figures 5.2.5.1.1, the selected unitary basis vectors are only taken from a UE or partly from several UEs. Node B then receives feedback information of CQI, the selected unitary matrix and basis vectors from each UE. Once the selected UEs are scheduled for transmission, rate adaptation and precoding process are taken by multiplexing multiple user data streams. If PU^{2}RC is operated for SDMA mode as in Figures 5.2.5.1.2, each selected unitary basis vector is taken from a different UE (i.e., not more than one vector from the same UE) so as to reduce the feedback amount at the expanse of small performance degradation at the regime of a low number of UEs. For the procedure of Node B multiplexing transmission, it follows the case of SDM in Figures 5.2.5.1.1. Note that in both modes, total number of the vectors is fixed as M. Furthermore, such selections are taken based on the space-time multiuser diversity theory for maximum capacity achievement subject to the given scheduling policy.

$$\mathbf{E} = [\mathbf{e}_0^{(gk)} \ldots \mathbf{e}_m^{(gk)} \ldots \mathbf{e}_{M-1}^{(gk)}], \qquad (1)$$

where $\mathbf{e}^{(gk)}$ is the g_kth unitary basis matrix, g_k is the index of the unitary basis matrix which is fed back from kth UE and $\mathbf{e}_m^{(gk)}$ is the mth unitary basis vector of of the g_kth UE's. Note that each UE's preferred unitary basis matrix can be different from each other. In Figures 5.2.5.1.3, each UE computes the given performance metric to select the preferred unitary matrix and/or unitary basis vector when the predetermined set of unitary precoding matrix is known to both Node B and UEs. Depending on the feedback signalling policy, each UE sends the index of the preferred unitary matrix and/or the index of unitary basis vector together with CQI information back to Node B.

5.2.5.2 Adaptive modulation and coding schemes

5.2.5.2.1 Modulation and channel coding

Adaptive modulation and coding scheme is required for MIMO systems to improve the system capacity with high spectral efficiency. In PU^{2}RC systems, modulation and coding are adaptively performed corresponding to the feedback information. As for feedback signalling, the main burden comes from the set of the unitary basis matrix, because SINR depends on the unitary basis matrix. The quantized form of the unitary basis matrix is used. In SDM/SDMA mode of PU^{2}RC (shown in Figure 5.2.5.1.1), the first two-step approach for feedback signalling as in Table 5.2.5.2.1 is executed as. As an example, consider the following scenario for information feedback, assuming the system with 2 (4) Tx antennas for Node-B and 2 (4) Rx antennas for each UE. One bit is allocated for indexing the precoding matrix, denoted as g in Figure 5.2.5.1.1 so as to maximize the system capacity subject to the given scheduling policy. Table 5.2.5.2.1 shows the configuration of the feedback channel format (for uncoded feedback information bit):

CQI for each UE	
Precoding Matrix Selection	AMC
1 bit	5M bits, M = 2 or 4 (M CQI)
Additional part	Revised conventional part (E.g., TDM)

Table 5.2.5.2.1: One example of CQI format for PU^{2}RC with SDM/SDMA (M CQI)

In SDMA mode of PU^{2}RC (shown in Figure 5.2.5.1.2), the second two-step approach for feedback signalling as in Table 5.2.5.2.2 is executed. As an example, consider the following scenario for information feedback, assuming the system with 2(4) Tx antennas for Node-B and 2(4) Rx antennas for each UE. Totally two (three) bits are allocated for representing unitary precoding matrix, denoted as g in Figure 5.2.5.1.2, where one bit is used to specify the unitary precoding matrix and other one (two) bits are used to indicating one appropriate precoding vector among elements of the specified precoding matrix so as to maximize the system capacity subject to the given scheduling policy. Table 5.2.5.2.2 shows the configuration of the feedback channel format (for uncoded feedback information bit):

CQI for each UE		
Basis Set Selection	Basis Selection	AMC
1 bit	1 bit for 2x2 MIMO 2 bits for 4x4 MIMO	5 bits (1 CQI)
Additional part		Conventional part

Table 5.2.5.2.2: One example of CQI format for PU^{2}RC with SDMA mode (1 CQI)

Note that this is an example of CQI for each UE when there are many UEs to receive HS-DSCH, and hence the burden of AMC feedback follows the conventional way according to the quantization of the estimated SINR. The selections of modulation level, code rate, and the number of OVSF codes for each UE are based on HSDPA metric.

5.2.5.2.2 Transmission algorithms

The assignment of OVSF codes depends on the selected UEs and its number of data streams. The Node B determines the number of OVSF codes.

5.2.5.2.3 Physical layer aspects for MCS Selection

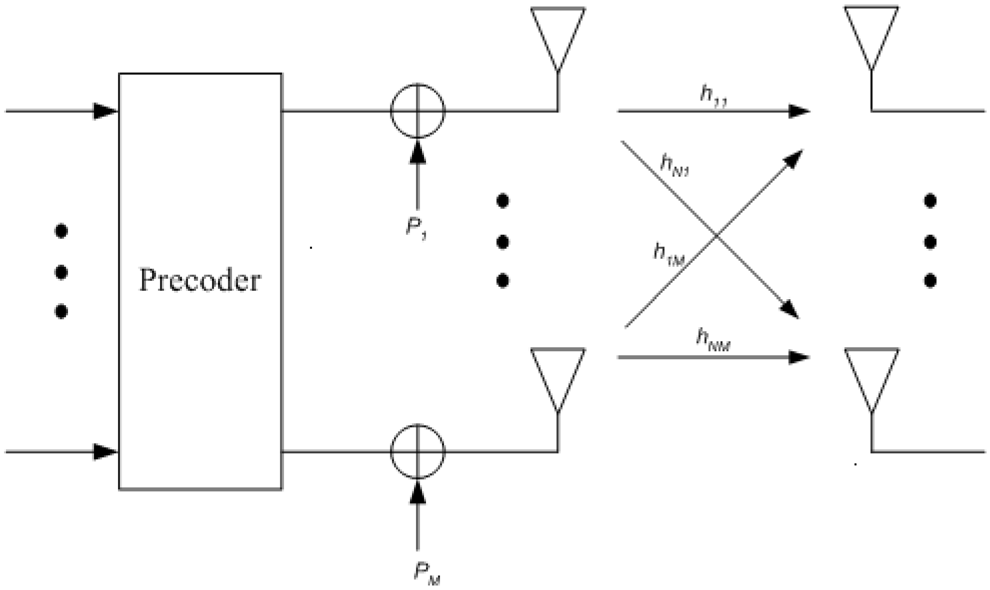


Figure 5.2.5.1.3: Schematic of pilot transmission for CQI estimation at UEs

All the UEs are required to transmit CQI information back to the Node B on the uplink through feedback signaling. The CQI information is based on the received SINR measured for each transmit precoding vector based on the common pilot $\{p_1, \ldots, p_M\}$ as shown in Figure 5.25.1.3. Then, the Node B determines the MCS level for each UE according to the CQI.

5.2.5.3 Associated Signalling

5.2.5.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.5.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.5.4 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.5.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.2.5.5.1 Analysis of User Equipment Complexity

5.2.5.5.2 Analysis of Node B impacts

5.2.5.6 Backward compatibility

5.2.5.7 Overview of changes required in the specification

5.2.6 Proposal 6: TPRC for CD-SIC MIMO

The MIMO channel metric considering the frequency selective channel has been used for the antenna domain link adaptation in the extended MIMO systems. In the receiver part of the systems, which are considering such dispersive channel, the interference signals from the multiple antennas in space-domain are cancelled by the interference canceller; however, the interference signals from the multiple paths in time-domain are not cancelled by one but suppressed by linear space-time equalizer in front of other signal processing.

5.2.6.1 Basic physical layer structure of TPRC for CD-SIC MIMO

On the other hand, to cancel out the effect of time-domain interference signal, the code-domain interference canceller may be good choice rather than the time-domain one because of its good performance and simplicity. However, we should carefully study the properties of a canceller, especially those of the successive interference canceller like one in the receiver of MIMO with SIC (successive interference cancellation) systems, to make use of its best advantages. In practice, the successive interference canceller may cause unbalance of the post-detection SINRs among the outputs of the detection stages, e.g., the output SINRs of the different code channels.

To compromise such features, we apply to MIMO systems

- First, the Code-Domain SIC (CD-SIC), which is named ***CD-SIC MIMO***, and

- Second, the Code-Domain Tx Power Ratio Control (CD-TPRC), to take full advantage of CD-SIC, which is named ***TPRC for CD-SIC MIMO***.

The block diagram below shows the basic physical layer structure of the TPRC for CD-SIC MIMO in the HS-DSCH, which is considering proposed both CD-SIC and CD-TPRC in MIMO systems.

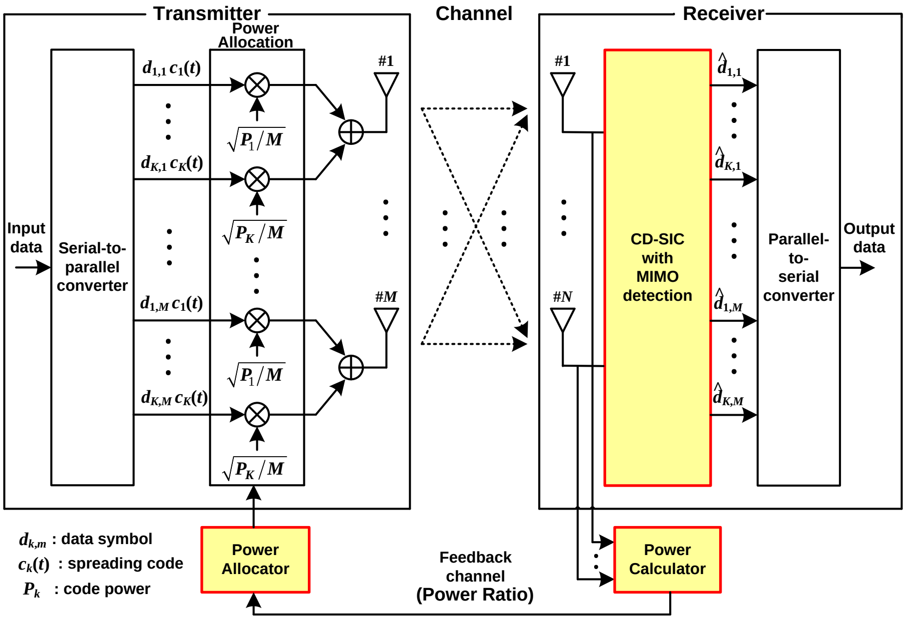


Figure 5.2.6.1-1: Basic physical layer structure of the TPRC for CD-SIC MIMO in the HS-DSCH

5.2.6.2 Adaptive modulation and coding schemes

5.2.6.2.1 Modulation and channel coding

The modulation and channel coding for each stream relies on the received SINR of its associated transmit antenna.

5.2.6.2.2 Code-Domain Successive Interference Cancellation

The conventional MIMO receiver does not have code-domain successive interference canceller, but has only space-domain interference suppression technique such as successive interference canceller, which subtracts the contributions of pre-detected transmit antenna signals from the received signal. Unlike the interference canceller only in the space-domain, we propose to apply the code-domain successive interference cancellation (CD-SIC) to MIMO receiver additionally, as shown in Figure 5.2.6.1-1. In this scheme, in addition to the space-domain signal processing appropriate for given MIMO transmission technique, the contributions of pre-detected code channel signals are subtracted from the received signal. In such a way, the impacts from not only space-domain interference but also code-domain interference are suppressed and higher performance reliability can be achieved. Moreover, applying code-domain Tx Power Ratio Control (CD-TPRC) to this system attains the significant performance improvement with a little overhead of feedback signalling, which will be described in the next section.

5.2.6.2.3 Code-Domain Tx Power Ratio Control with CD-SIC

Based on the CD-SIC MIMO, we now propose a new "**single**" scalar feedback scheme to allocate Tx power to the code channels so that its performance could be improved far more, and show that the feedback rate for this scalar can be sufficiently reduced by utilizing the long-term properties of fading channels.

In the conventional MIMO transmitter, Tx power is not controlled per code-domain in each channel. In contrast, we suggest using a scalar feedback for Tx power ratio control (TPRC) between code channels. Here, only single scalar power ratio between all adjacent code channels is signaled through uplink channel, and then this ratio is geometrically applied to from the first code channel to the last code channel in the transmitter as

$$P_k = \left(\frac{1-\gamma}{1-\gamma^K} P_T \right) \gamma^{k-1}, \qquad k = 1, 2, \cdots, K$$

where P_T is the total transmit power of all code channels and γ is the power ratio determined by the channel amplitudes and the expected code cross-correlations. By doing so, the code-domain post-detection SINRs between the different code channels are well balanced, and the significant performance improvement can be accomplished. It should be noted that this power control can be applied regardless of the specific MIMO transmission technique. Moreover, further investigation on the TPRC for CD-SIC MIMO shows that the feedback rate of uplink signaling can be reduced significantly. That is, feedback information based on only "**long-term**" properties of fading channel amplitudes is sufficient for this TPRC information to achieve almost the same performance improvement.

5.2.7 Proposal 7: Selective Per Antenna Rate Control (S-PARC)

It is well known that MIMO techniques that rely on spatial multiplexing such as CR-BLAST are able to exploit a large portion of the capacity of the MIMO channel. CR-BLAST works well when the number of receive antennas is equal or greater than the number of transmit antennas. However, performance is severely degraded when there are fewer receive than transmit antennas. Another promising technique that has been developed recently is per-antenna-rate-control (PARC) which can operate with fewer receive than transmit antennas.
Recent results have shown that PARC, coupled with successive interference cancellation/decoding at the receiver, achieves the full open-loop capacity of the flat fading MIMO channel. However, at low SNRs and/or when the number of receive antennas is less than the number of transmit antennas, there is a significant gap between the open-loop (OL) capacity and the closed-loop (CL) capacity. The performance gap indicates that, depending on the antenna configuration and operating regime, there is significant room for improvement over conventional PARC. One way of overcoming this performance gap is by the S-PARC scheme.

5.2.7.1 Basic physical layer structure of HS-DSCH for MIMO

The essence of the approach presented here is to adaptively select the number of antennas from which to transmit, i.e., mode, as well as select the best subset of antennas for the selected mode.

5.2.7.2 Adaptive modulation and coding schemes

5.2.7.2.1 Modulation and channel coding

5.2.7.2.2 Transmission algorithms

5.2.7.2.3 Physical layer aspects for MCS Selection

For the scheme presented in Section 5.2.1, the link adaptation process is configured such that the UE makes a decision about how many data sub-streams to transmit (i.e., the "mode") and which antennas to use for the selected mode. Furthermore, the UE decides which coding rate to use on each active antenna. Implicitly, these decisions must take into account the available power and code resources at the base station. However, without explicit signaling of this resource availability, the UE is not equipped to make such decisions.

In this section, we describe a method whereby the most of the decision process is transferred to the base station and the UE formats its feedback accordingly to enable the decision at the base to take place. This is preferable since the base station is aware not only of the power and code resource availability, but also the amount of data in queue for each user. The resulting method is line with the philosophy of today's HSDPA where the CQI feedback from the UE is treated as a suggestion only. The base station ultimately handles the scheduling and MCS selection.

A brute-force approach would require the UE to feed back several CQI metrics for each possible mode and antenna selection, as well as the antenna selections themselves, resulting in excessive feedback load. In the proposed approach, this is avoided by restricting the antenna selections to obey a special property, thus drastically reducing the required feedback. With M transmit antennas, the feedback load is reduced to only M or fewer CQI metrics and one antenna processing order – a reasonable increase compared to conventional single antenna HSDPA. The CQI metrics are determined at the UE assuming some predetermined reference value for code and power allocations. The base station may then modify the CQI feedback metrics to account for the actual resource availability as well as the amount of data in queue for each user. It then makes a decision about what mode to transmit and what coding rate to use on each active antenna.

5.2.7.2.3.1 Measurements Performed at UE

As described in section 5.2.1, the brute-force approach is for the UE to consider all possible antenna selections and determine that selection with the maximum supportable sum data rate. In contrast, the approach presented here considers only those antenna selections that obey a "subset property" in order to reduce the amount of feedback to the base station.

Consider the example of $M = 4$ transmit antennas. Use the term "mode" to refer to the number of transmitted data streams, which is equivalent to the number of *active* antennas. To search the possible antenna selections using the subset property, we first consider the transmission of only one data sub-stream (mode-1) from a single antenna in a similar fashion as in section 5.2.1.2.1. There are 4 possible antennas, and the UE must make a measurement of SINR on each one using the corresponding pilot signal. This measurement assumes a reference (nominal) value for the power allocation which must be later adjusted for the actual power allocation at the base station. The SINRs are then mapped to transmission rates using an MCS look-up table that assumes a nominal code allocation. Again, this allocation will be adjusted for the actual allocation at the base station. After measuring all 4 SINRs, the UE determines which antenna supports the largest data rate, e.g., antenna-3.

For mode-2, the UE needs to determine the best subset of 2 antennas; however, by use of the subset property, only those selections that contain the antenna selection for the prior mode are considered, i.e., {1,3}, {2,3}, and {4,3}. See Table 5.2.7.2.3.1 where these selections are listed, as well as the ones that are excluded from the search (lower half of the table). The actual selections for this example are shown in bold. Within each selection, the UE needs to measure the SINR corresponding to each antenna. For example, for selection {1,3}, it needs to first measure the SINR for antenna 1 taking into account the spatial interference from antenna 3. The UE must then measure the SINR for antenna 3; however, since successive interference cancellation (SIC) is inherently used for S-PARC, the measurement must neglect the spatial interference from antenna 1 to model the effect of SIC.

MODE			
1	2	3	4
1 2 **3** 4	1,3 **2,3** 4,3	1,2,3 **4,2,3**	**1,4,2,3**
	1,2 1,4 2,4	1,2,4 1,3,4	

Table 5.2.7.2.3.1 Possible antenna selections for all modes for the case of M = 4 transmit antennas

The two SINRs are then mapped to a rate using the same MCS table as before, and the UE computes the sum rate over the two antennas. This process is repeated for the other two antenna selections ({2,3} and {4,3}) and the UE determines which antenna selection supports the largest sum rate, e.g., selection {2,3}.

The ordering of the antennas within each selection is an important consideration. Notice that in the three searched selections for mode-2, the ordering is such that the signal from antenna-3 is decoded last, i.e., antenna-3 corresponds to the final stage of successive interference cancellation. The reason for this is that after the spatial interference from the other antenna is removed in the second stage of SIC, the interference scenario is virtually identical to that for the prior mode (mode-1), which also uses antenna-3 due to the subset property. Consequently, the second stage SINR for mode-2 is identical, within a scale factor, to the SINR for mode-1. This would not be true in general without imposing the subset property.

The scale factor accounts for the equal division of power across transmit antennas. For mode-1, all of the HS-DSCH power is allocated to antenna 3, whereas in mode-2, only half of the power is allocated to antenna-3. Consequently, the second stage SINR for mode-2 is approximately one half that for mode-1. Since the scale factor is pre-determined, the only new piece of information in mode-2 is the first stage SINR corresponding to antenna-2 in this example. The second stage SINR may be derived from the SINR for mode-1 through scaling by the factor 1/2. Consequently, it is only necessary to feed back the first stage SINRs for modes-1 and 2 to the base station.

For modes-3 and 4, the UE performs a similar selection process always ensuring that the antenna selection for each mode contains the selection for the prior mode as a subset. For example, say that the best selections for modes-3 and 4 end up being {4,2,3} and {1,4,2,3}, respectively (see Table 5.2.7.2.3.1). Again the ordering is important. For example, the ordering for mode-3 is such that antennas 2 and 3 are decoded last. This means that the SINRs for the final two stages of SIC are identical, within scale factors, to the first stage SINRs for modes-2 and 1, respectively. In this case, the scale factors are approximately 2/3 and 1/3, respectively.

Clearly, only the first stage SINR for each mode is important, and thus need be fed back to the base station. With this information, along with an "antenna processing order" described below, it is possible for the base station to derive the per-stage SINRs for all modes through simple scaling. In general, the scale factors for mode-m can be simply $\{(m-1)/m, (m-2)/m, \ldots, 1/m\}$ which are applied to the first stage SINRs for modes-$\{m-1, m-2, \ldots, 1\}$, respectively. The scale factor for the first stage SINR of mode-m is simply unity, i.e., no scaling is necessary.

The antenna processing order, which also needs to be fed back to the base station, is simply the ordered antenna selection for the highest order mode. In the above example, mode-4 is the highest order mode, and the processing order is 1-4-2-3. This ordering serves the dual purpose of specifying the antenna selections for all modes as well as the encoding/decoding order to be followed by the base station and UE. The antenna selection for mode-m is simply the last *m* integers in the processing order. For example, mode-3 would use antennas 4, 2, and 3, and the agreed-upon encoding/decoding order would be 4-2-3.

By following the above selection process, the UE is responsible for determining the best antenna selection for each mode. However, no decision is made at the UE about which mode to use. This decision is left to the base station. This decision process is discussed in more detail in section 5.2.7.2.3.3.

5.2.7.2.3.2 Uplink Feedback Format

The purpose of employing the subset property for antenna selections is to minimize the amount of feedback while enabling the base station to make a decision on which mode to use. Without the subset property, it would be necessary to feedback several CQI metrics for each mode. Specifically, mode-m requires m CQI metrics, and with M = 4 antennas, modes-1, 2, 3, and 4 are all possible, and thus the UE would need to feedback 1 + 2 + 3 + 4 = 10 metrics plus 4 antenna selection indicators, one for each mode.

The CQI metrics could be quantized versions of the SINRs for each stage of SIC assuming a nominal code and power allocation. Alternatively, they could be indices into a reference MCS table, or they could be a quantized transmission rate that uniquely determines the modulation and coding scheme.

For today’s HSDPA, the CQI metric is simply an index into an MCS table, and the number of feedback bits for the single CQI metric is 5, which covers all 30 entries in the table. If this same number were used for S-PARC, then the total number of feedback bits without using the subset property would be

$$N_b = \sum_{m=1}^{M} \left(5m + \left\lceil \log_2 \binom{M}{m} \right\rceil \right), \qquad (1)$$

in general. The first term in the summation is the number of bits required for m CQI metrics. The second term is the number of bits required to feedback the antenna selection for mode-m. For example, for mode-2 there are 6 possible selections of 2 antennas out of 4, thus requiring 3 bits. For the example of M = 4 antennas, the total feedback load without using the subset property would be N_b = 57 bits. This is compared to only 5 in today’s HSDPA – clearly a very large increase.

In contrast, with the subset property, it is only necessary to feed back M CQI metrics and one antenna processing order. If 5 bits are used for each CQI metric, then in general the feedback load reduces to

$$N_b = 5M + \left\lceil \log_2 (M!) \right\rceil . \qquad (2)$$

The second term is the number of bits required to feedback the antenna processing order which is simply a permutation of M integers. For the example of M = 4 antennas, the total feedback load using the subset property is reduced to N_b = 25 bits – a very significant reduction compared to the brute-force approach.

This feedback load should be compared to the amount required by the approach that is described in section 5.2.1. For that approach, the UE makes a decision on both the mode and the antenna selection, so it needs only feedback m CQI metrics when mode-m is selected plus an antenna selection (permutation of m integers). Consequently, the feedback load varies as the mode changes. However, the maximum load (selection of mode-M) is identical to that in (2).

Clearly, the advantage of our proposed feedback approach based on the subset property is that the base station can make the decision on mode as well as properly adjust for the instantaneous power and code resources. It can also take into account the available data in queue for each user.

5.2.7.2.3.3 MCS Selection Performed at Base Station

The MCS selection process at the base station proceeds as follows:

- Obtain the first-stage SINRs from the feedback signal either directly or indirectly. For example, if the CQI feedback is in terms of an index into an MCS table, then the reverse mapping of SINR to MCS index must be employed to obtain the SINRs in an indirect fashion.
- Derive the per-stage SINRs for each mode using the first stage SINRs along with the antenna processing order. The derivation for mode-m is simply to apply the scale factors $\{(m-1)/m, (m-2)/m, \ldots, 1/m\}$ to the first stage SINRs for modes-$\{m-1, m-2, \ldots, 1\}$, respectively. The scale factor for the first stage SINR of mode-m is simply unity, i.e., no scaling is necessary.
- Adjust the derived SINRs according to the actual power and code allocations used at the base station. This adjustment is necessary since the UE used the agreed-upon nominal values during measurement. With linear receivers, the SINR typically scales linearly with the power and code allocations. Often the scaling slope is unity, or close to it, thus the scaling is a simple matter as long as the nominal values used for measurement are known.
- Map the SINRs for each antenna to a transmission rate using the appropriate MCS table based on the actual code allocation.
- Compute the sum rate across antennas and choose the mode that maximizes the sum rate. If not enough data is available in queue, then the base station may reduce the mode, code allocation, coding rate, or power accordingly to conserve system resources.

5.2.7.3 Associated Signalling

5.2.7.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.7.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.7.4 UE Capability

{This section should describe the parameters (e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.7.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.2.7.5.1 Analysis of User Equipment Complexity

5.2.7.5.2 Analysis of Node B impacts

5.2.7.6 Backward compatibility

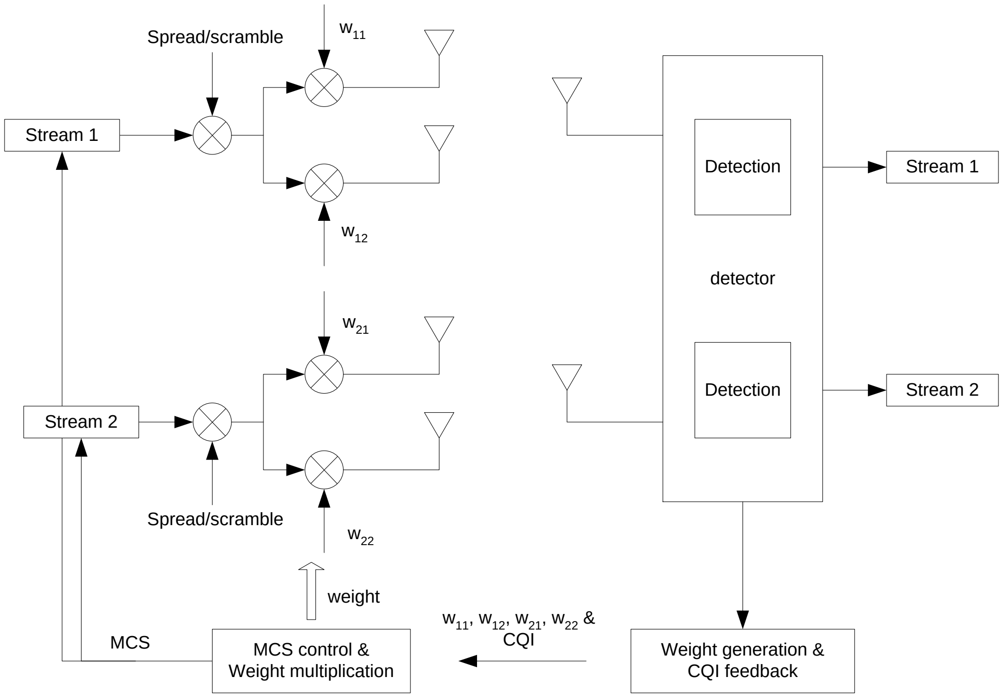
5.2.7.7 Overview of changes required in the specification

5.2.8 Proposal 8: Double Transmit antenna array (D-TxAA)

D-TxAA is a MIMO scheme for sending multiple data streams with spatial multiplexing. In D-TxAA, if four transmit antennas are employed in Node B, transmit antennas are divided into two sub-groups and each sub-group transmits independent data stream with TxAA operation of a pair of transmit antennas. The data rate of each sub-group can be controlled independently. If two transmit antennas are employed in Node B, the current TxAA in Release 5 can be used.

5.2.8.1 Basic physical layer structure of HS-DSCH for MIMO

The block diagram for D-TxAA is shown below for four transmit antennas and two receive antennas. Two independent data streams are spread and scrambled, and then allocated to two sub-groups. The data stream in each sub-group is multiplied by a weight vector and transmitted by a pair of transmit antennas in that sub-group. If $\mathbf{h_j} = \begin{bmatrix} h_{1j} \\ h_{2j} \end{bmatrix}$ is a channel vector from the j-th transmit antenna to two receive antennas, the weight vector for each sub-group can be obtained by eigen-analysis of covariance matrices, $\mathbf{H}^{\mathbf{H}}_{subgroup1}\mathbf{H}_{subgroup1}$ and $\mathbf{H}^{\mathbf{H}}_{subgroup2}\mathbf{H}_{subgroup2}$ where $\mathbf{H}_{subgroup1} = [\mathbf{h_1} \quad \mathbf{h_2}]$ and $\mathbf{H}_{subgroup2} = [\mathbf{h_3} \quad \mathbf{h_4}]$. That is, the weight vectors of subgroup 1 and 2 are the eigenvectors corresponding to maximum eigenvalues of $\mathbf{H}^{\mathbf{H}}_{subgroup1}\mathbf{H}_{subgroup1}$ and $\mathbf{H}^{\mathbf{H}}_{subgroup2}\mathbf{H}_{subgroup2}$, respectively. An example of the weight implementation for each sub-group is to employ that of the transmit diversity of Mode 1. The extension to 4 receive antennas is straightforward.



5.2.8.2 Adaptive modulation and coding schemes

5.2.8.2.1 Modulation and channel coding

The MCS for data stream in each sub-group is determined by the Node-B based on the CQI feedback from the UE. The MCS for each data stream can be selected differently.

5.2.8.2.2 Transmission algorithms

The number of OVSF codes assigned for each sub-group depends on the MCS determined in Node B. The optimal OVSF code assignment including code re-use technique is FFS.

5.2.8.2.3 Physical layer aspects for MCS Selection

UE transmits the CQI based on the SINR estimation for each data stream. When the CQI in Release 5 is applied for each data stream, the number of possible combinations of CQI increases exponentially as the number of data streams increases. The reduction of the possible combinations of CQI without significant throughput loss is FFS.

5.2.8.3 Associated Signalling

5.2.8.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.8.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.8.4 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.8.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.2.8.5.1 Analysis of User Equipment Complexity

5.2.8.5.2 Analysis of Node B impacts

5.2.8.6 Backward compatibility

5.2.8.7 Overview of changes required in the specification

5.2.9 Proposal 9: Spatial Temporal Turbo Channel Coding (STTCC)

In many downlink application cases, the number of receive antennas is limited by the weight, size and battery consumption requirements of the terminal. Therefore techniques which can operate efficiently with a single antenna are of interest. Spatial Temporal Turbo Channel Coding (STTCC) is a technique combining channel coding, modulation and spatial multiplexing together to achieve high data rate and performance. The advantage of this approach is that STTCC can make use of a single receive antenna to achieve high throughput for 3GPP HSDPA. Moreover, Rate Control (RC) can be adopted for STTCC, which results in more flexible data transmission and higher average throughput.

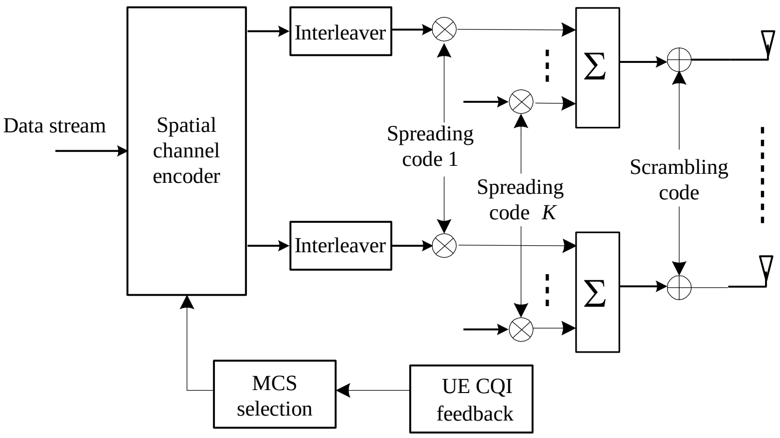
5.2.9.1 Basic physical layer structure of HS-DSCH for MIMO

The basic physical layer structure of the HS-DSCH for STTCC is shown in Figure 5.2.9.1.1(a). A data stream is encoded to form multiple substreams by a STTCC encoder, interleaved and spread by distinct OVSF codes. Multi-code operation is achieved by summing up all multiple spread data streams. The summed results are scrambled by a single scrambling code and finally transmitted independently from multiple antennas.

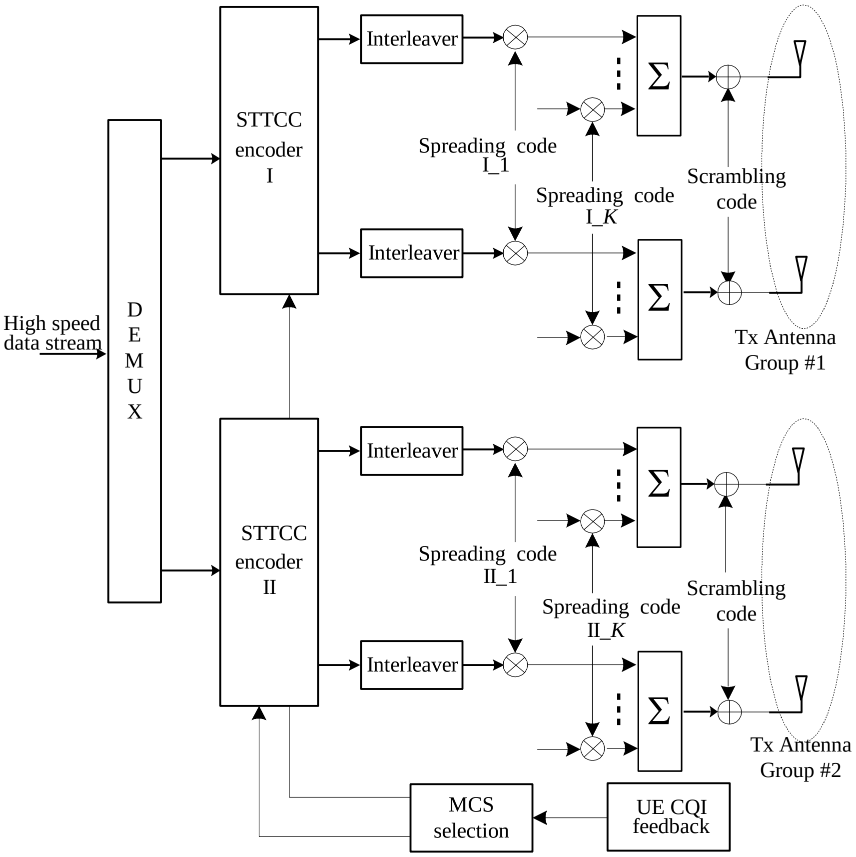
If more flexibility of rate control is needed, the scheme with two STTCC encoders is proposed in Figure 5.2.9.1.1(b).

In the case of a single receive antenna, every pair of transmit antennas are used as one group, with each group using an STTCC encoder and different spreading codes being used for different groups.

In the case of multiple receive antennas, the same spreading codes and scrambling codes can be used for different groups. Multiple receive antennas are used to distinguish different groups based on the MIMO spatial channel characteristic.



(a) One STTCC encoder scheme



(b) Two STTCC encoder schemes for per antenna group rate control

Figure 5.2.9.1.1: Spatial Channel Coding for 3GPP HSDPA

The general construction of STTCC is shown in Fig.2x. We assume that the required data rate is L bit/symbol period. The information bit vector $\mathbf{B} = [b_1, ..., b_L]$ goes through three paths respectively as follows:

- In the path used for systematic bits, $\mathbf{B}$ is sent directly into modulation mapping, and not encoded. Through modulation mapping, the symbols can be obtained by $\Phi[B] = [s_1, ..., s_U]$, where $\Phi(\cdot)$ is the function of mapping binary integer values into the transmitted symbols and $U = L/2$ when QPSK is used. The systematic bits will be used in the decoder for better decoding performance.

- In one path used for parity bits, $\mathbf{B}$ is firstly sent into recursive encoder 1 (RE1) for encoding. The output bits of the encoder are $\mathbf{D} = [d_1,...,d_M]$. Then, if rate matching is carried out, $\mathbf{D}$ becomes $\mathbf{C} = [c_1,...,c_P]$. Rate matching can be either puncturing to give a higher code rate, or repetition for a lower code rate. Through modulation mapping, the encoded symbols can be obtained by $\Phi[C] = [s^1_{U+1},...,s^1_N]$, where N is the number of transmit antennas.
- In a second path used for parity bits, $\mathbf{B}$ firstly pass through an interleaver, and then into RE2, rate-matching, and modulation mapping, which have the same function as the first path used for parity bits. Through modulation mapping, the encoded symbols are $[s^2_{U+1},...,s^2_N]$. In the STTCC encoding, RE1 and RE2 have the same generation matrix. The interleaving is an odd-even symbol interleaving, which maps even symbols to even symbol positions, and odd symbols to odd positions. Here, one symbol means L bits in $\mathbf{B}$.

The output of the two paths used for parity bits are multiplexed according to different times, for example, in Fig.5.2.9.1.2, at time t_1, $[s^1_{U+1},...,s^1_N]$ is sent out from the multiplexer and at the next time t_2, $[s^2_{U+1},...,s^2_N]$ is sent out from the multiplexer. Finally, a circular shifted switcher is used to get the benefit of time diversity in each propagation path, i.e. symbols $[s_1,...,s_N]$ are sent to the different channel interleavers in Figure 1x (a) alternately.

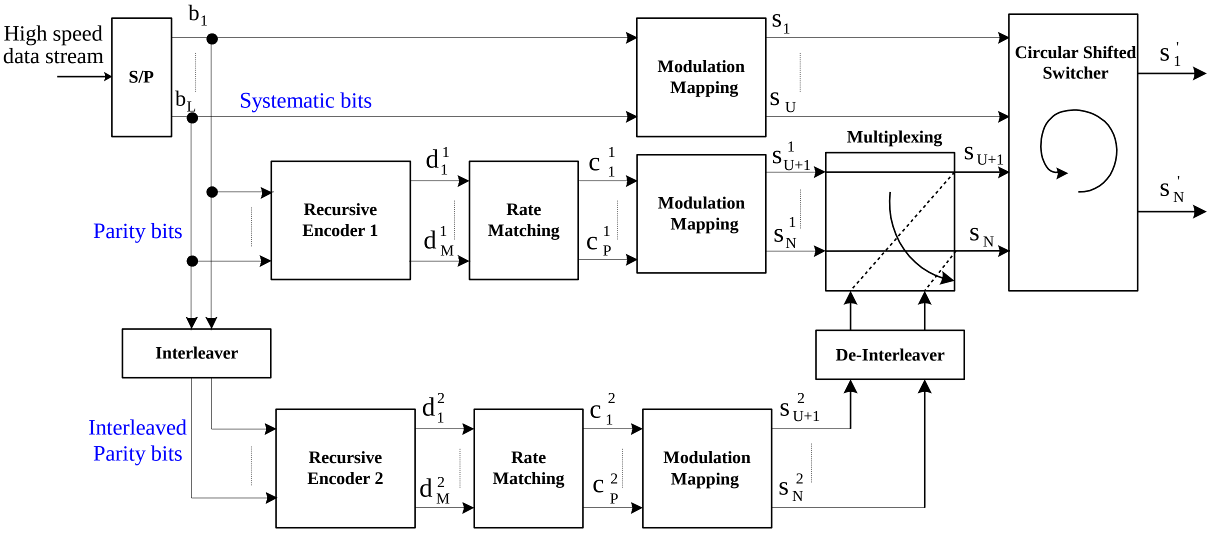


Figure 5.2.9.1.2: Spatial Temporal Turbo Channel Encoder

5.2.9.2 Adaptive modulation and coding schemes

5.2.9.2.1 Modulation and channel coding

The Node B selects a Modulation and Coding Scheme (MCS) based on channel quality measurements reported by the UE. Although STTCC is a relatively specific spatial-temporal code design using the spatial and time correlation between modulated symbols transmitted from different antennas to enable single antenna detection in UE, more receiver antennas can be utilized to further increase the diversity order and make it feasible to enhance the data rate by increasing the spatial code rate under the same modulation set. Some examples of different allocations of MCS can be found in Table 5.2.9.2.1.1, where different cases can be selected according to the practical channel conditions.

Table 5.2.9.2.1.1 Application comparison of STTCC with different antenna configuration

(N, M)	Spatial code rate	Modulation	Spectral efficiency (bit/symbol period)	Diversity order
(2,1)	1/2	QPSK	2	2
(2,2)	1/2	QPSK	2	4
(2,1)	1/2	16QAM	4	2
(2,2)	1/2	16QAM	4	4
(4,1)	1/2	QPSK	4	4
(4,2)	1/2	QPSK	4	8
(4,1)	1/2	16QAM	8	4
(4,2)	1/2	16QAM	8	8
(4,4)	1/2	16QAM	8	16

5.2.9.2.2 Transmission Algorithms

5.2.9.2.3 Physical layer aspects for MCS Selection

5.2.9.3 Associated Signalling

5.2.9.3.1 Downlink

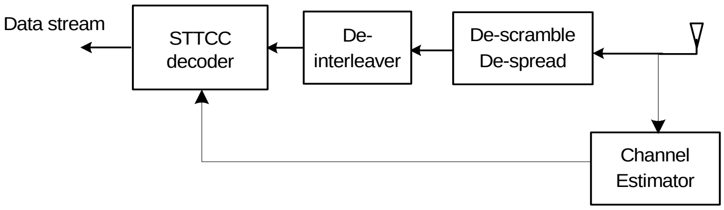
{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.9.3.2 Uplink

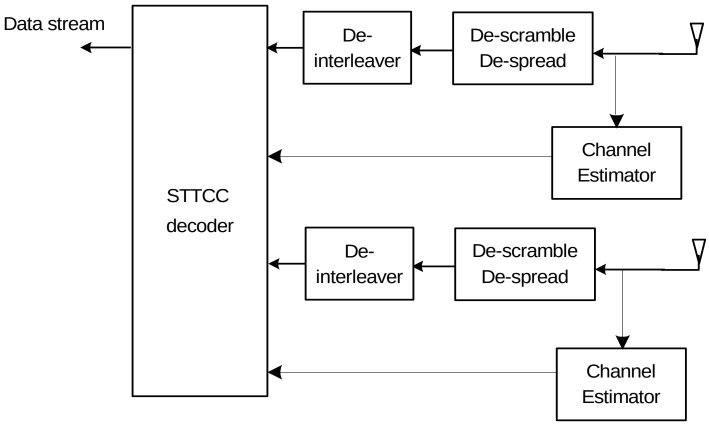
{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.9.4 UE capability

In Figure 5.2.9.4.1(a), when the UE has one receive antenna, the signals are firstly de-spread and de-interleaved, and fed to the STTCC decoder for final data decision with the help of channel estimation results. The SCC decoder is a symbol MAP decoder. STTCC can be extended to multiple receive antennas as in Figure 5.2.9.4.1(b).



(a) Receiver with one antenna



(b) Receiver with multiple antennas

Figure 5.2.9.4.1: Spatial Temporal Turbo Channel Decoder

5.2.10 Proposal 10: Double Adaptive Space Time Transmit Diversity with Sub-Group Rate Control (D-ASTTD-SGRC)

Assuming at most 4 transmit antennas, the transmitter structure of the D-ASTTD with SGRC is shown in Fig.5.2.10.1. The adaptive weights w_{s1} and w_{s2} are real valued, such that $w_{s1}^2+w_{s2}^2=1$, where $s=1,2$ is the index of antenna sub-group. The weights are calculated separately for each antenna subgroup, on the basis of the respective feedback information (FBI) bits received in each slot from the UE on the dedicated uplink channel (DPCCH). As the user-specific uplink DPCCH channels exist also in HSDPA, the above MIMO transmitter scheme is valid both for UTRA/FDD and HSDPA.

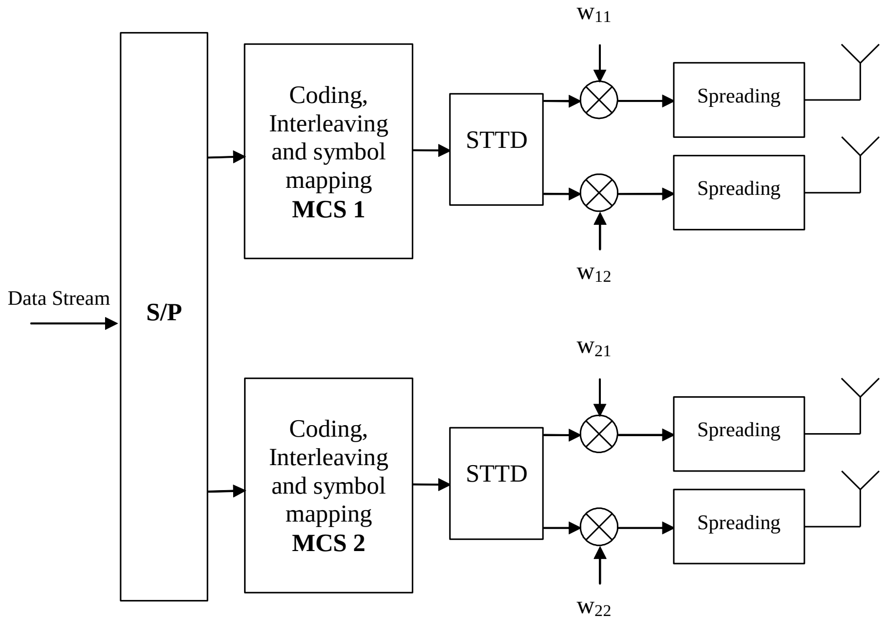


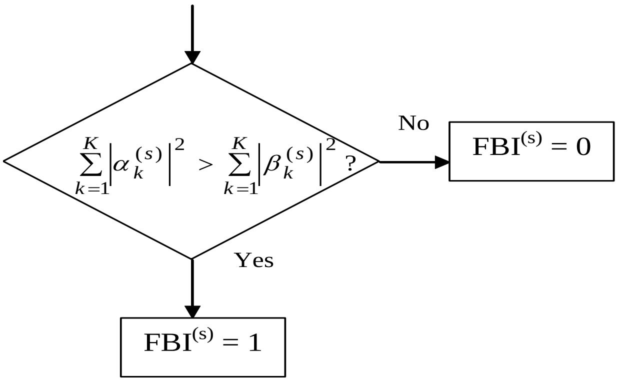
Figure 5.2.10.1: Transmitter structure for D-ASTTD.

The weights for a sub-group *s* are defined as

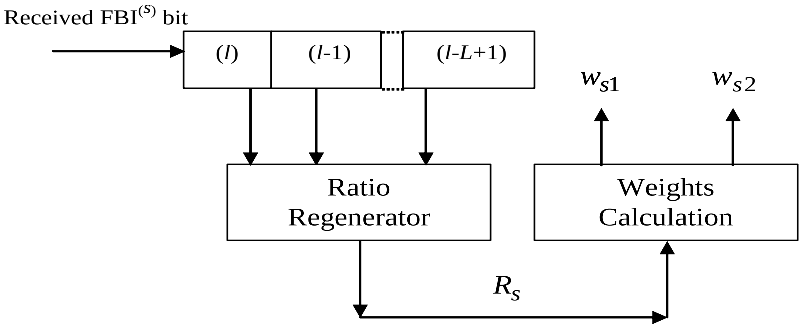
$$w_{s1} = \frac{1}{\sqrt{1+\frac{1}{{R_s}^2}}}, \quad w_{s2} = \frac{1}{\sqrt{1+{R_s}^2}}, \quad R_s = \frac{\sum_{k=1}^{K}\left|\alpha_k^{(s)}\right|^2}{\sum_{k=1}^{K}\left|\beta_k^{(s)}\right|^2}, \qquad (1)$$

where $\alpha_k^{(s)}$ is the complex amplitude of propagation path k from the STTD branch weighted by w_{s1}, while $\beta_k^{(s)}$ is the complex amplitude of propagation path k from the other STTD branch weighted by w_{s2}; K is the total number of multipath components.

The FBI bit generation (encoding) in the UE is shown in Fig.5.2.10.2(a), while the corresponding FBI decoding in the Node B is shown in Fig.5.2.10.2(b). Each sub-group has its own encoder/decoder.



(a) FBI encoding for sub-group *s* in the UE



(b) FBI decoding for sub-group s in the Node B

Figure 5.2.10.2: ASTTD feedback quantization method.

The FBI decoder for each sub-group consists of a delay-line buffer for storing a number of most recently received FBI bits, and the ratio regenerator. The ratio regenerator is a look-up table, shown in Table 5.2.10.1 for the FBI decoding length L=1. Once the power ratio is regenerated as $R_s=R_{sq}$, where $R_{sq}=10^{\text{Ratio(dB)/10}}$, the weights w_{s1} and w_{s2} are calculated according to equation (1).

Table 5.2.10.1 Mapping table for power ratio regenerator with FBI decoding length *L*=1

FBI(*l*)	Ratio [dB]
1	6
0	-6

In the case of 4x2 and 4x4 MIMO configurations, there are two independent FBI bits that are transmitted from the UE, one for each sub-group of transmit antennas. Depending on the used DPCCH slot format, these two FBI bits can be transmitted either both in the same slot, in which case the minimum feedback delay is 1 slot, or in alternating slots, in which case the minimum feedback delay is 2 slots. In the other MIMO configurations, i.e. the 2x2, 2x4 and 4x1 configurations, there is only 1 FBI bit required per slot which limits the FBI feedback delay to 1 slot.

5.2.10.1 Transmitter with 2 antennas

The transmitter structure in Fig. 5.2.10.1 can straightforwardly be adapted to the case of NodeB with only two transmit antennas, by using only one of the subgroups, as is done in DSTTD-SGRC.

5.2.10.2 4x1 D-ASTTD configuration

For the case of UE classes with one receive antenna, even if there are 4 antennas at the transmitter, it is only possible to have a single-stream transmission. The corresponding D-ASTTD transmitter for this 4x1 case is shown in Fig.5.2.10.2.1.

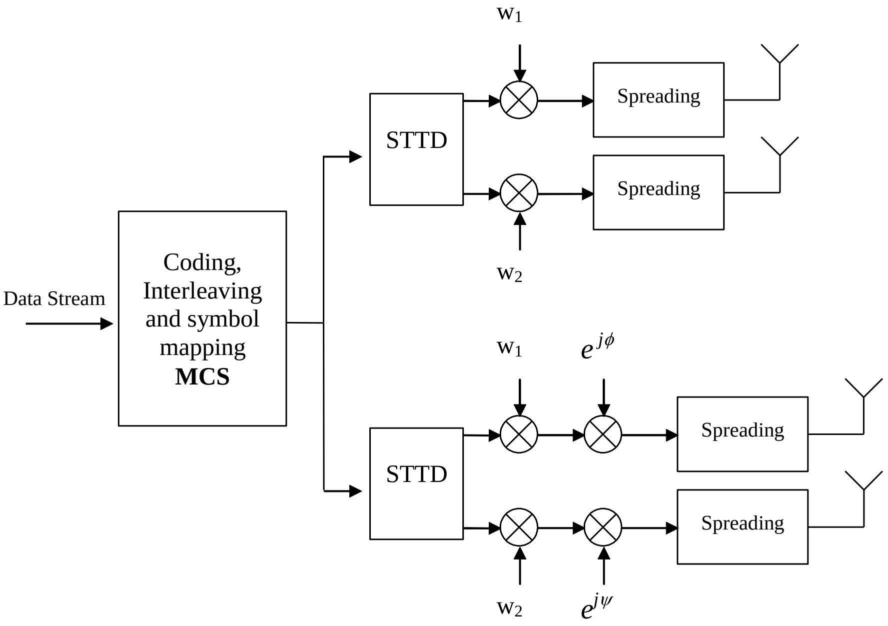


Figure 5.2.10.2.1: D-ASTTD transmitter for 4x1 MIMO configuration.

This scheme is equivalent to the transmit diversity scheme described in TR 25.869 under the name of closed-loop STTD with multiple antennas (i.e. CL-4-Tx-STTD). The periodic phase shift patterns ϕ and ψ are used to implement frequency offsets of transmitted signals, in order to emulate a fast time-varying fading channel at the receiver. Such emulated fast fading channels makes interleaving/de-interleaving signal processing more effective and improve the performance of slowly moving UE's even with small Doppler spread of the propagation channel. Since at any given time instant, the same symbol is transmitted from both the antennas 1 and 3 and weighted by the same weight w_1, and another symbol from antennas 2 and 4, weighted by w_2, a pair of antennas transmitting the same symbol can be seen as a single virtual STTD antenna weighted by corresponding ASTTD weight defined by (1).

A certain number, T, of consecutive STTD encoded symbols are rotated by using the same phase from the corresponding phase rotation pattern of length 8 (135 degrees increment, i.e ϕ[deg.]= 0,135,270,45,180,315,90,225; $\psi=\phi + 180°$). It has been found by simulation that T=20 symbols is close to an optimum value.

The 4x1 configuration of D-ASTTD should be applied only to UE's using lower code rates and/or at lower geometries, to ensure that the proposed scheme operates in conditions where large gains can be obtained. The current channel condition for a certain UE can be detected in the Node B for example on the basis of reported CQI values. For instance, if the reported CQI is lower than some threshold value, then the proposed 4x1 D-ASTTD scheme is used, otherwise, some other MIMO transmission method or STTD can be used. Since this CQI threshold is known to both UE and NodeB, the UE in each moment knows which MIMO option is used in the NodeB transmitter and thus can choose the appropriate receiver.

5.2.10.3 Receiver Structure

The receiver structure and post detection SINR for D-ASTTD with SGRC is the same as for the DSTTD-SGRC, with a single important adjustment that the complex amplitude coefficients $\alpha_k^{(s)}$, $\beta_k^{(s)}$ for the propagation path k corresponding to sub-group s are replaced by the respective complex amplitude coefficients $w_{s1}\alpha_k^{(s)}$, $w_{s2}\beta_k^{(s)}$, s=1,2, to take the ASTTD weighting at the transmitter antennas into account.

5.2.10.4 Adaptive Modulation and Coding for HSDPA mode with D-ASTTD

The modulation and coding scheme (MCS) for HSDPA, in the case of D-ASTTD, should be selected independently for each sub-group, on the basis of the CQI feedback from the UE. It can be done in the same way as in DSTTD-SGRC.

5.2.11 Proposal 11: Single & Multiple Code Word MIMO with Virtual Antenna mapping (SCW/MCW-VA)

The present proposal is intended to converge some of the previously presented MIMO techniques into a single proposal (CR-BLAST, S-PARC). Selection of the features of this proposal was driven by the following goals:

- The possibility to transmit with a spatial multiplexing order that can be adapted to the current channel conditions while preventing to switch transmit signals and their corresponding transmit powers between antennas. Furthermore, the reduction of the effect that switching power between transmit antennas or beams has on users suffering from such time-variant interference (“flashlight” effect).
- The possibility to transmit just a single block of encoded data over multiple transmit antennas at any given point in time, which requires no or only minimum changes to the HARQ processing, the CQI feedback and a the ACK/NACK signalling in conventional HSDPA. This design goal would make a migration very simple.
- The possibility to transmit multiple encoded blocks of data over multiple transmit antennas at the same time, which would allow to benefit from non-linear receiver architectures such as successive interference cancellation (SIC).

As a result of these design goals, the present proposal comprises two modes of operation:

- A Single Code Word mode (SCW) using a combination of a selection of the spatial multiplexing order and a cyclic spatial weighting with a predefined set of unitary weighting matrices, denoted as Space-Time Scrambling. This mode is an extension of CR-BLAST.
- A Multiple Code Word mode (MCW) using a combination of virtual antenna selection and time-variant permutation of virtual antenna ports, denoted as Pseudo Random Antenna Permutation. This mode is an extension of S-PARC.

5.2.11.1 Basic physical layer structure of HS-DSCH for MIMO

5.2.11.1.1 Virtual Antenna Concept

Let us assume that Node-B is equipped with M_t physical antennas. The virtual antenna design presented in this proposal allows the Node-B to effectively “appear” to the MIMO user as if it has $M_e \le M_t$ transmit antennas rather than M_t. This has the effect of decreasing the negative impact of channel estimation, however, it also limits the spatial diversity order.

In the sequel we describe one possible virtual antenna mapping method, which has the property that the transmit powers at the M_t physical transmit antennas stay constant. Let $\mathbf{H}(t)$ be the $M_\mathrm{r} \times M_\mathrm{t}$ MIMO channel (M_r being the number of receive and transmit antennas), let $\mathbf{x}(t)$ be the $M_\mathrm{e} \times 1$ vector to be transmitted on M_e effective (= virtual) transmit antennas for a given OVSF code. The transmitted vector after virtual antennas $\tilde{\mathbf{x}}(t) = \mathbf{U} \cdot \mathbf{P} \cdot \mathbf{x}(t)$, where $\mathbf{U} = \left[\mathbf{u}^{(1)}, \mathbf{u}^{(2)} \ldots \mathbf{u}^{(M_\mathrm{t})}\right]$ is an $M_\mathrm{t} \times M_\mathrm{t}$ orthonormal matrix with the property that the magnitude square of the entries of each row sum to a constant. A class of such matrices would be $\mathbf{U} = \Delta \cdot \mathbf{W}$, where $\Delta = \mathrm{diag}\left[e^{\mathrm{j}\theta_1}, e^{\mathrm{j}\theta_2} \ldots e^{\mathrm{j}\theta_{M_\mathrm{t}}}\right]$ is a diagonal matrix, and θ_i, $i = 1 \ldots M_\mathrm{t}$, are random phases. $\mathbf{W}$ is the $M_\mathrm{t} \times M_\mathrm{t}$ DFT matrix, and $\mathbf{P}$ is a $M_\mathrm{t} \times M_\mathrm{e}$ permutation matrix that selects which M_e columns of $\mathbf{U}$ to be used the current point in time. If we neglect spreading, scrambling and pulse shaping for the sake of simplicity, the noise free received vector would then be

$$\mathbf{r}(t) = (\mathbf{H}(t) \cdot \mathbf{U} \cdot \mathbf{P}) * \mathbf{x}(t) = \tilde{\mathbf{H}}(t) * \mathbf{x}(t),$$

where $\tilde{\mathbf{H}}(t) = \left[\mathbf{H}(t) \cdot \tilde{\mathbf{u}}^{(1)}, \mathbf{H}(t) \cdot \tilde{\mathbf{u}}^{(2)} \ldots \mathbf{H}(t) \cdot \tilde{\mathbf{u}}^{(M_\mathrm{e})}\right]$, and $\left\{\tilde{\mathbf{u}}^{(1)}, \tilde{\mathbf{u}}^{(2)} \ldots \tilde{\mathbf{u}}^{(M_\mathrm{e})}\right\} \subseteq \left\{\mathbf{u}^{(1)}, \mathbf{u}^{(2)} \ldots \mathbf{u}^{(M_\mathrm{t})}\right\}$.

That is, effectively, the MIMO system reduced to an $M_\mathrm{r} \times M_\mathrm{e}$ one as depicted in Fig.5.2.11.1.1.1. Note that we equally distribute the available power on the M_e in parallel transmitted modulation symbols per OVSF code. For simplicity of exposition, the power is assumed to be absorbed in the entries of $\mathbf{x}(t)$.

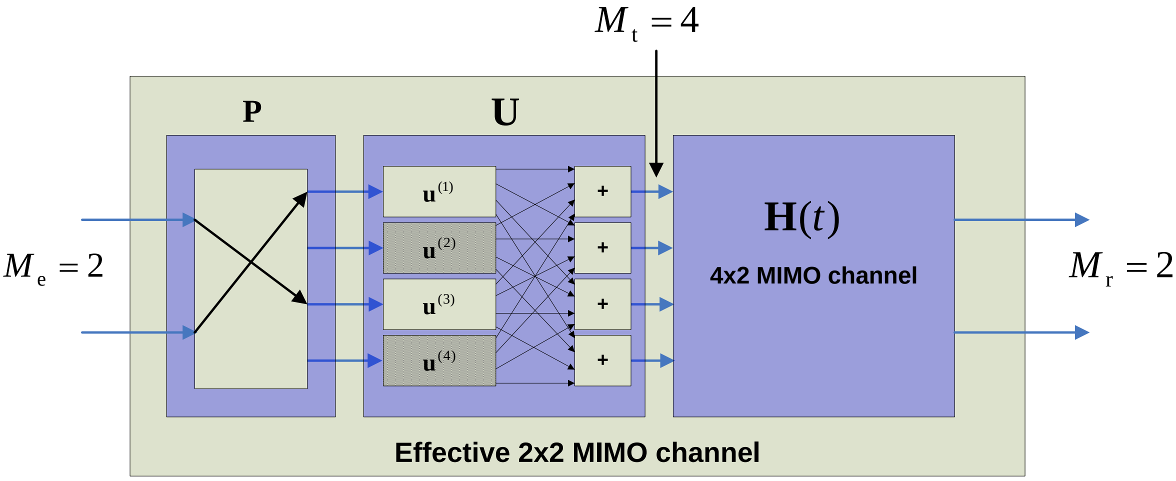


Figure 5.2.11.1.1.1: Example for virtual antenna mapping.

The virtual antenna mapping could be a static mapping or alternatively, it can also change over time. For instance, if the unitary weighting matrix $\mathbf{U}$ remains constant over time, the permutation or selection matrix $\mathbf{P}$ could be a function of a UE feedback that determines how to map the virtual antenna ports to the ports provided at the input (left side) of the centre blue box in Fig.5.2.11.1.1.1. In that sense the selection matrix $\mathbf{P}$ would be an inherent part of S-PARC, if S-PARC would select from the input ports of the centre blue box ($\mathbf{U}$) in Fig.5.2.11.1.1.1.

The virtual antenna mapping could also change over time in a deterministic pseudo random manner, for instance by changing the diagonal matrix Δ over time. This variation of the virtual antenna mapping is assumed to be known a-priori to the receiver as it would be synchronized to the TTI timing. If the variation is fast enough (e.g. a different weighting matrix every 8 symbols), this would have the advantage, that the radiation of energy would be approximately uniform across the sector if averaged over short time intervals (e.g. one TTI), thus reducing the potential impact to other users due to the "flashlight" effect that would happen in case a fixed beam or antenna would get selected.

5.2.11.1.2 Single Code Word Mode

As depicted in Figure 5.2.11.1.2.1, a single stream of turbo encoded data is transmitted in the SCW mode. At any given point in time, bits of only one encoded data block are transmitted. Based on a UE feedback, the spatial multiplexing order, M_e, to be used at the transmitter is determined. With M_c being the number of OVSF codes to be used for the currently scheduled user, the encoded data bits are passed into a set of M_e x M_c modulators. For each OVSF code, M_e modulators are used, each corresponding to one virtual antenna port. The M_e symbol streams for each OVSF code are then transformed into a set of M_t symbol streams, that corresponds to the M_t physical transmit antennas.

The preferred way of virtual antenna mapping for the SCW mode described in here is called Space-Time Scrambling and cycles through multiple permutations $\mathbf{P}$ of on ore more unitary weighting matrice(s) $\mathbf{U}$ that are designed to have the property to keep the transmit powers at the physical antennas constant, if the total power of the input signals to the virtual antenna ports is constant. See Section 5.2.11.1.1 for an example on how to construct such unitary weighting matrices.

The switching period for altering the spatial weighting shall be small enough to ensure an almost uniform spatial radiation behaviour over one TTI. Due to this, the impact on other users in the system that might get affected by a "flashlight" type of interference is reduced while the spatial diversity within the transmitted code block is maintained at a high level.

It is suggested to use a switching interval of 8 symbols at spreading factor 16, i.e. 33.33 µs, as this seems to be a good compromise between complexity and fast averaging.

In case of using all transmit antennas at all times without any virtual antenna mapping, the SCW mode is comparable with the well-known Code-Reuse BLAST scheme using a single stream of encoded data. In that sense the SCW mode described herein can be regarded as an extension of CR-BLAST.

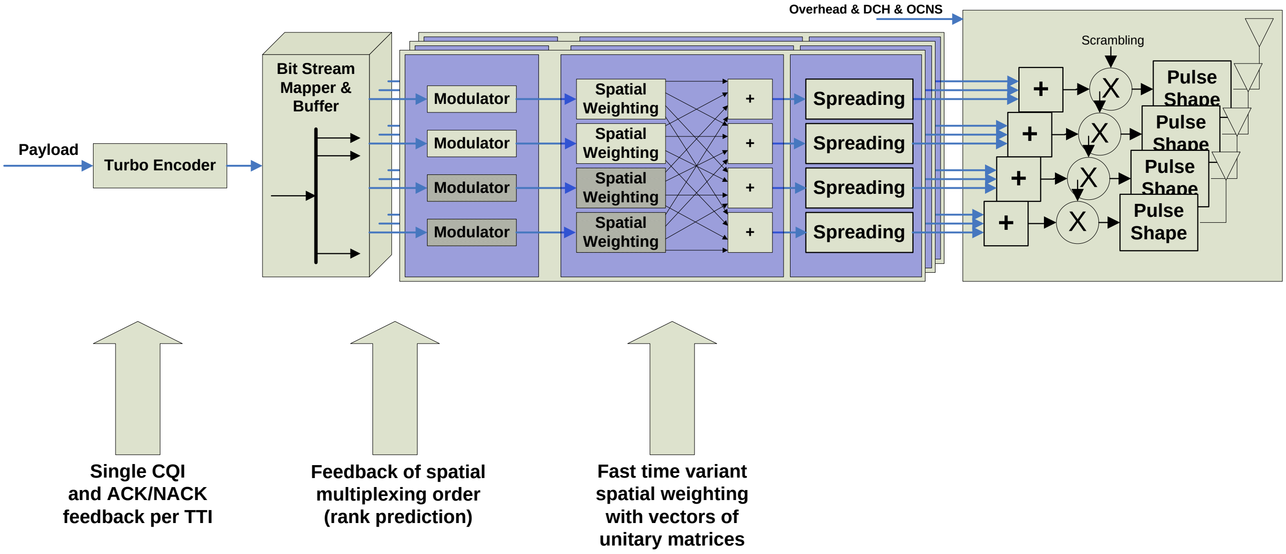


Figure 5.2.11.1.2.1: SCW mode with Space-Time Scrambling

5.2.11.1.3 Multiple Codeword Mode

As depicted in Figure 5.2.11.1.3.1, multiple streams of parallel turbo encoded data is transmitted in the MCW mode. At any given point in time, bits of multiple parallel encoded data blocks are transmitted. Based on a UE feedback, the spatial multiplexing order M_e and the selection of the virtual antennas to be used at the transmitter, is determined. The spatial multiplexing order is also the number of parallel encoded data streams. The virtual antenna ports that are referred to in this description of the MCW mode are actually corresponding to the input ports of the centre blue box ($\mathbf{U}$) in Fig.5.2.11.1.1.1. With M_c being the number of OVSF codes to be used for the currently scheduled user, the encoded data bits from each turbo encoder are passed into a set of M_c modulators, which results in a total number of M_e x M_c modulators. In Figure 5.2.11.1.3.1, the per-OVSF code processing is illustrated by multiple slices. For each OVSF code, M_e modulators are used, each corresponding to one selected virtual antenna port, carrying one of the spatially multiplexed and separately encoded data streams. The M_e symbol streams for each OVSF code are then transformed into a set of M_t symbol streams, that corresponds to the M_t physical transmit antennas.

The preferred way of virtual antenna mapping for the MCW mode described in here is time-variant. This way of performing virtual antenna mapping is called Pseudo Random Antenna Permutation (PRAP). It basically consists of cycling through multiple permutations $\mathbf{P}$ of one fixed unitary weighting matrix $\mathbf{U}$ that is designed to have the property to keep the transmit powers at the physical antennas constant. See Section 5.2.11.1.1 for an example on how to construct such unitary weighting matrices. If we cycle through a set of permutations $\mathbf{P}$ within one TTI in such a way that each stream of spatially multiplexed and separately encoded data was mapped at least once to each of the selected virtual antennas that shall be used according to the UE feedback on virtual antenna selection, then the effective SNIR per spatially multiplexed and separately encoded stream gets quite similar. This enables a reduction of CQI feedback as the only difference in the resulting CQI of the different streams is now originating from a possible SIC processing in the receiver.

The switching period for altering the permutation of the selected virtual antennas shall be small enough to ensure averaging behaviour over one TTI, but as large as possible in order to keep the receiver complexity of an SIC receiver that would need to keep track of multiple MMSE filters for each permutation at an acceptable level.

Depending on the number of selected virtual antennas, the switching between different permutation patterns should occur between 0 (for only 1 selected virtual antenna) and 24 times (for 4 selected virtual antennas) per TTI for 4 transmit antenna cases. When only two virtual antennas are selected, only 1 switching point per TTI needs to be used. It is expected that the case of 24 permutations per TTI is not really needed since in the case of 4 selected virtual antennas, it should not be necessary to go over all possible permutations in order to achieve a reasonable averaging effect.

Without PRAP, a CQI feedback would be needed per spatially multiplexed stream. With PRAP this could be reduced to one reference CQI and one or more Delta-CQI values that could be quantized with a smaller number of bits. It is actually also possible to use only one CQI plus one Delta-CQI value for feedback, even when more than 2 virtual transmit antennas are used.

The MCW mode described herein is basically an extension of the S-PARC scheme using the concept of PRAP as an add-on.

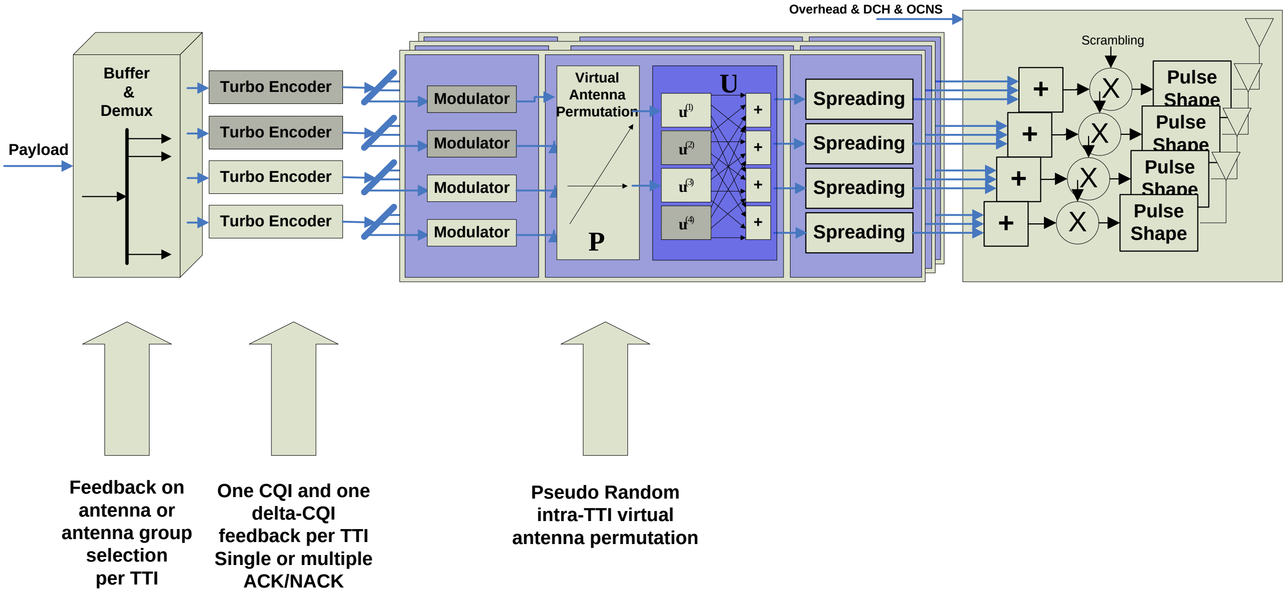


Figure 5.2.11.1.3.1: MCW mode with Pseudo Random Antenna Permutation

5.2.11.2 Adaptive modulation and coding schemes

5.2.11.2.1 Modulation and channel coding

Coding/Interleaving/Rate Matching:

This function includes CRC attachment, code block segmentation, interleaving, turbo encoding and rate matching, taking into account selected modulation and coding scheme, the size of the HARQ combining buffer of the served UE and the number of HS-PDSCH channelisation codes.

For the SCW Mode: A principal feature of the SCW mode is that only a single stream of encoded bits is generated which is distributed over the virtual transmit antennas at an equal data rate for each virtual transmit antenna stream. The number of virtual antennas to be used shall be signalled by the UE. A preferred way to get this information signalled to the Node B is to use the FBI bit fields in the existing R99 slot formats. All the remaining processing steps for Coding/Interleaving/Rate Matching will remain unchanged as compared to Rel-5, except that larger transport block sizes need to be defined. It is anticipated that the existing resolution of 5 bits per CQI report will be sufficient for the SCW mode. The UE would perform exactly the same procedure for CQI estimation and feedback as in previous Releases. The scheduler would decide on the resource allocation, taking into account the CQI feedback and possibly also the spatial multiplexing order feedback. After deciding upon the allocated resources, the processing chain for Coding/Interleaving/Rate Matching would be processed as in previous Releases.

For the MCW mode: A principal feature of the MCW mode is that multiple streams of separately encoded bits are generated which then are transmitted with one virtual transmit antennas each for any given point in time. The number and the indices of virtual antennas to be used shall be signalled by the UE. It needs to be evaluated if this information can be signalled to the Node B using the FBI bit fields in the existing R99 slot formats. All the remaining processing steps for Coding/Interleaving/Rate Matching are identical to the ones used in Rel-5, except that multiple instances have to be used in parallel. In particular the maximum transport block size per encoded stream is identical to the existing one for earlier Releases It is anticipated that a 5 bit CQI would be needed per spatially multiplexed stream if no PRAP was used. With PRAP, the amount of feedback could be reduced. The anticipated number of feedback bits are 5 for the reference CQI value and 3 for a Delta-CQI value, respectively. The UE would perform a similar procedure for CQI estimation and feedback as in previous Releases. For each of the spatially multiplexed streams, the UE would determine a CQI value taking into account possible performance enhancements due to SIC architecture. The scheduler would decide on the resource allocation, taking into account the CQI feedback and the spatial multiplexing order / virtual antenna selection feedback. After deciding upon the allocated resources, the processing chain for Coding/Interleaving/Rate Matching would be processed as in previous Releases, just on a per stream basis.

Modulation:

Selection between QPSK and 16-QAM modulation, and constellation for 16-QAM. Also this processing step is not changed from previous Releases.

5.2.11.2.2 Transmission algorithms

Virtual Antenna Mapping:

For SCW mode: The virtual antenna mapping is suggested to use a pseudo random cycling through an a-priori defined set of permutations of multiple unitary weighting matrices $\mathbf{U}$ as defined in Section 5.2.11.1.1. The feedback on the spatial multiplexing order is used to select the number of columns of the weighting matrices $\mathbf{U}$ that shall be used for a specific TTI.

It should be noted that in SCW mode we could also use a fixed virtual antenna mapping (time-invariant unitary weighting matrix $\mathbf{U}$) in combination with a feedback on selecting the subset of virtual antennas to be used for transmission. This would have the advantage to allow for a roughly quantized waterfilling across virtual antennas. However, the drawback is the larger variance in terms of interference to other users, i.e. the flashlight effect. Therefore, it is preferred to use only the feedback of the spatial multiplexing order for the SCW mode.

For MCW mode: The virtual antenna mapping is suggested to use cycling through multiple permutations $\mathbf{P}$ of one fixed unitary weighting matrix $\mathbf{U}$ that is designed to have the property to keep the transmit powers at the physical antennas constant. See Section 5.2.11.1.1 for an example on how to construct such unitary weighting matrices. This cycling should be done in such a way that each stream of spatially multiplexed and separately encoded data was mapped at least once to each of the selected virtual antennas.

Spreading:

The scheduler decides on the number L of length 16chips OVSF codes to be assigned to the UE that is scheduled. Spreading with *L* OVSF codes of length 16 chips is performed. Each OVSF code is reused M_t times for spreading each of the M_t symbol streams that are output from the virtual antenna mapping for that specific OVSF code. This is depicted as multiple code slices in Figure ? and Figure ?.

Power setting:

For SCW mode: Each spatially multiplexed symbol stream is transmitted with the same power.

For MCW mode: Each separately encoded and spatially multiplexed stream is transmitted with the same power.

Overlaying physical channels, scrambling, pulse shaping:

All simultaneously transmitted physical channels of each transmit antenna stream are summed up and then scrambled with the assigned scrambling code. Finally the SCH is added and pulse shaping is applied. Note that the use of different scrambling codes for different transmit antennas is possible and FFS.

5.2.11.2.3 Physical layer aspects for MCS Selection

5.2.11.2.3.1 SCW mode

Due to the possibility to transmit with spatial multiplexing order > 1, the transport block sizes relative to Rel-5 wil have to be increased if the principle of transmitting only one transport block per TTI should be kept. In general this should be fine. Just in case of extremely large transport block sizes, it is to be expected that due to the code block segmentation, a larger number of code blocks could be used in one TTI which in turn could affect the BLER since the likelihood of an block error will increase with the number of code blocks in one TTI. However, such effect should only become noticeable at extremely high data rates.

Besides providing the possibility to use larger transport block sizes, also the CQI reporting tables would have to be adjusted in order to reflect the increase in peak data rates. Different CQI tables would be needed for different spatial multiplexing orders.

Due to the increase of the spatial multiplexing order beyond one, the number of available encoded bits to be transmitted over the air can becomes significantly larger than in non-MIMO systems. For that reason is should be possible to use much lower code rates at similar or even higher data rates then in non-MIMO systems. This allows for increased efficiency, since the gap to capacity achieving coding is smaller for lower codes rates in HSDPA.

In order to benefit from this increase of dimensionality, the UE has to report to the Node B a CQI value that takes into account the possible spatial multiplexing and the UE performance when separating the spatially multiplexed streams. Furthermore, the UE also needs to take into account that the SNIR for different spatially multiplexed symbol streams are in general different, which will impact the turbo decoding performance. In the case of only two transmit antennas, the rather extreme distribution of SNIRs (only two values are possible for the transmitted symbols) can be smoothened by the fast Space-Time scrambling scheme described earlier. This smoothing of the SNIRs of different symbols within a TTI does not reduce the resulting variance of SNIR within the TTI, but it can help to improve the decoding performance in some high code rate cases. However, this seems to be a minor effect.

In order to provide a useful CQI feedback, the UE needs to perform a calculation of an effective SNIR at its equalizer output. Such a calculation needs to take into account the different SNIR levels seen for the different transmit symbols within one code block. Since such variations do have an impact on the decoding performance of a turbo decoder, it is rather important to do this mapping in a correct way. Various different mapping methods for deriving an effective SNIR have been discussed in 3GPP before [4][5][6]. A useful mapping method is the convex metric, which is based on the assumption that the sum of capacities for the individual SNIRs would be equal to the capacity for the resulting effective SNIR. The convex metric is given by

$$\gamma_{\mathrm{eff}} = \frac{2^{\bar{\gamma}} - 1}{Q}, \quad \text{with}$$

$$\bar{\gamma} = \frac{1}{N}\sum_{n=1}^{N} \log_2\left(1 + Q \cdot \gamma_n\right),$$

where γ_n is the individual SNIR per symbol within a TTI and Q is a penalty factor that can be used to model penalties due to non-Gaussian modulation, realistic code rate, packet size, channel estimation errors and channel variations.

Based on an estimated spatial multiplexing order and the knowledge of the performance of the UE receiver to separate spatially multiplexed symbol streams (i.e. the effective SNIR), the UE can derive a CQI feedback in a similar manner as in previous releases. The UE would pick an index to a CQI table such that the index points to the highest possible data rate for which the UE could guarantee that the BLER stays below a certain threshold, if the channel was static. The CQI feedback and – if applicable – the spatial multiplexing feedback will be used in the Node B scheduler to decide about the code and power allocation for the scheduled users. Since the Node B is applying a fast time variant Space-Time Scrambling, there is no need to identify a specific subset of virtual antennas. Only the number of virtual antennas to be used is important in that case.

5.2.11.2.3.2 SCW mode

In MCW mode of operation, each of the turbo encoded data streams uses the same Coding/Interleaving/Rate Matching as a conventional single antenna HSDPA transmitter. Therefore, the set of MCS to select from for each data stream is not changed relative to Rel-5. In order to allow for an appropriate MCS selection by the scheduler, the Node B needs information on the CQI per parallel encoded data stream. As described earlier, the amount of feedback can be reduced by the use of PRAP due to the averaging effect of the per-stream effective SNIR. On the other hand, this averaging effect will impact the performance slightly since the sum over the optimal MCSs for each stream could become larger if no PRAP was applied. The performance difference is, however, expected to be small.

One important aspect of the MCW mode is the correct determination of appropriate CQI values in the UE. The UE has to take into account the details of its receiver architecture. In case of a non-linear SIC receiver, the UE needs to account for the improved SNIR in case the cancellation of some inter-stream interference based on a successfully decoded block of one stream improves the effective channel quality for the next stream(s). Therefore, the UE has to base its CQI report on some assumption on how much of the inter-stream interference can be removed by SIC. Such a prediction is only possible, if the UE could rely on a certain power allocation for its own allocated OVSF codes and that all the codes it gets allocated on one antenna are also allocated on other antennas. If these assumptions on resource allocation in terms of power and codes are not met when the UE gets scheduled, the reported CQI values might become useless. This problem of predicting a per-stream CQI for UEs that use inter-stream interference cancellation is common to all MIMO schemes that rely on simultaneous transmission of multiple code words and SIC-type of receivers.

Because the CQI feedback in MCW schemes relies to some extend on assumptions on resource allocation, it seems attractive to schedule MIMO users operating in MCW mode exclusively, i.e. refrain from using the CDM capability of HSDPA. If this restriction would be acceptable for those TTIs in which MCW mode MIMO users get scheduled, such UEs could rely on the resource allocation and provide a meaningful CQI feedback.

The CQI tables that have been in use so far could be kept identical, as they are used on a per-stream basis. There would be no need to expand them.

Another important aspect of MCS selection in MCW mode – again this is a property common to all MIMO schemes using multiple code word transmissions – is the handling of retransmissions in the HARQ processing. Let us point out a simple example to demonstrate this complexity: For instance, if in a 2x2 system a data block A on the first stream, whose interference was intended to be removed from the second stream, did not decode successful, it needs to be retransmitted. Since the second stream was most likely scheduled with a more aggressive MCS (because in the CQI derivation it was assumed that the first stream got cancelled, thus, improving the SNIR of the second stream) it is rather unlikely that the corresponding data block B in the second stream could be decoded successfully. If the first block A now gets retransmitted at a later TTI, it might get decoded successfully. At that point, it would be possible to remove the interference that code block A caused to the other data stream during its initial transmission and the retransmission, provided that the received signals are buffered for a sufficient time window. So only after that retransmission of A and successful decoding, it would be possible to try to decode again the data block B on the second stream that was transmitted in parallel to the initial transmission of the successfully decoded block. If it turns out that this block B on the second stream has not decoded successfully even though the interference from the initial transmission of A was removed, the retransmission of B is triggered quite late. That could have the effect that the channel quality at the time when the retransmission of block B could be scheduled already degraded and the MCS might have to be selected quite differently, further impacting the performance of decoding block B.

This example illustrates that in some cases, the buffering and HARQ processing can get slightly more complex if SIC is used with MCW transmission. Therefore, it might be useful to restrict HARQ processing in some way in order to allow simpler MCS selection and lower complexity in the UE. On the other hand, there seem to be more simple HARQ processing methods available (joint ACK/NACK) that can help to avoid these problems.

For MCW mode of operation, there are also other means of improving the receiver performance without having to rely strictly on SIC. This could help to mitigate this issues of scheduler constraints and HARQ processing (e.g. soft cancellation, joint demodulation).

Finally it should be noted that the MCW mode – again this is common to all MIMO schemes with multiple transport block being transmitted simultaneously – could use the existing HS-SCCH signalling as a means to convey the information about the scheduling of more than one transport block needs to the UE. A simple way of doing that would be to use multiple HS-SCCHs as UE anyway have to be able to monitor up to four of them. Then the TFRI information and HARQ information about the parallel transmitted transport blocks could be signalled by parallel HS-SCCHs.

Also the on the uplink multiple ACK/NACK messages might be needed. This depends on how the HARQ processing is defined for the MCW mode and could be reduced at the expense of increase of retransmission rate.

5.2.11.3 Associated Signalling

5.2.11.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.11.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.2.11.4 UE Capability

{This section should describe the parameters (e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.2.11.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.2.11.5.1 Analysis of User Equipment Complexity

5.2.11.5.2 Analysis of Node B impacts

5.2.11.6 Backward compatibility

5.2.11.7 Overview of changes required in the specification

5.3 TDD DCH / DSCH channels

{It is assumed that techniques are applicable to both DCH and DSCH unless there are fundamental reasons why this should not be the case}

5.3.1 Proposal 1

5.3.1.1 Basic physical layer structure for MIMO

{This section should describe the DCH and / or DSCH physical layer structure which is distinct from the non-MIMO system.}

5.3.1.2 Associated Signalling

5.3.1.2.1 Downlink

{This section should describe the DCH and / or DSCH related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.3.1.2.2 Uplink

{This section should describe the DCH and / or DSCH related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.3.1.3 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.3.1.4 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.3.1.4.1 Analysis of User Equipment Complexity

5.3.1.4.2 Analysis of Node B impacts

5.3.1.6 Backward compatibility

5.3.1.7 Overview of changes required in the specification

5.4 TDD High Speed Channels

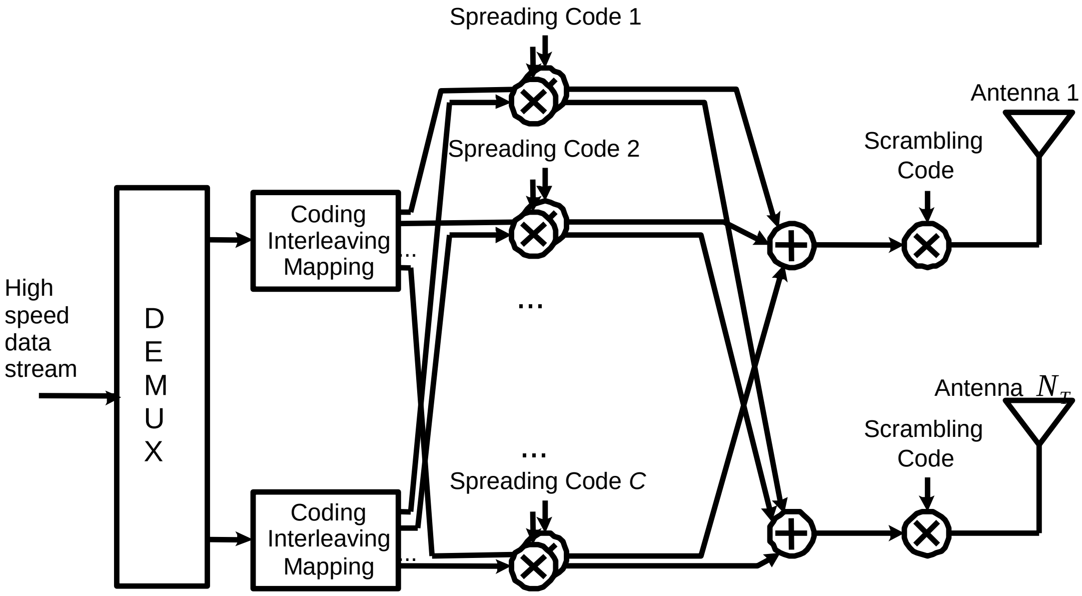
5.4.1 Proposal 1: Per-Antenna Rate Control for 1.28 Mcps and 3.84 Mcps TDD

Per-Antenna Rate Control (PARC) for UTRA TDD is motivated by its performance and the availability of receiver architectures that may be based on multi-user receivers widely used in UTRA TDD. Independently encoded and modulated data streams are transmitted from up to four antennas. The coding and modulation format for each stream is set by the Node B based either on feedback information reported by the mobile or measurements made on uplink channels. The mobile can jointly detect all physical channels using a linear space-time equaliser.

5.4.1.1 Basic physical layer structure of HS-DSCH for MIMO

The block diagram below shows the basic physical layer structure of the HS-DSCH for PARC. A block of data corresponding to a single high speed data stream is de-multiplexed into a maximum of N_T low-rate streams, where N_T is the number of transmit antennas. Each of these low-rate streams is turbo encoded, interleaved, and mapped to either QPSK or 16QAM symbols. Because different coding rates and symbol mappings can be used on each low-rate stream, the number of information bits assigned to each stream can be different. The symbols for a given low-rate stream are associated with a particular transmit antenna. They are further de-multiplexed into a maximum of C sub-streams, where C is the maximum number of HS-PDSCH defined by the UE capability. These sub-streams are spread using distinct OVSF channelisation codes, summed, and then modulated by a scrambling code. The resulting CDMA modulated low-rate stream is transmitted from it associated antenna.

Note that because of the flexibility of PARC, various options are available for partitioning the physical layer resources of channelisation codes, transmit antennas and timeslots. These options are discussed in the following subsections.



5.4.1.2 Adaptive modulation and coding schemes

5.4.1.2.1 Modulation and channel coding

The Node B selects a Modulation and Coding Scheme (MCS) for each transmit antenna. An example set of MCS levels that the Node B may choose is given in Table 3. The Node B may compute the best combination of MCSs either based on post-detection SNR measurements reported by the UE or by measuring the SNR of the (reciprocal) uplink channel. Note that the Node B may decide not to transmit on certain antennas, thus antenna selection is incorporated into the proposed scheme.

Table 3 Modulation and Coding Schemes

MCS Index	Modulation Scheme	Coding Rate
0 (No tx)	-	-
1	QPSK	1/3
2	QPSK	½
3	QPSK	¾
4	16-QAM	½
5	16-QAM	¾

5.4.1.2.2 Transmission algorithms

In terms of physical resource an allocation for a given UE will comprise a subset of the transmit antennas, a subset of the channelisation codes and a number of timeslots. However, as the Node B may serve multiple UEs simultaneously, different numbers of channelisation codes may be assigned to each transmit antenna for different numbers of timeslots. As non-MIMO-capable UE's will not be able to mitigate interference from MIMO transmissions, transmissions to non-MIMO-capable UE's should not be made in the same timeslot.

5.4.1.2.3 Physical layer aspects for MCS Selection

As described earlier, MCS selection may be done based on either feedback received from the UE or using measurements made on the uplink channel. The mobile may determine post-detection SNR for each physical channel (OVSF code) on each stream. It can report a CQI per stream based on the average SNR measured for each sub-stream. Alternatively the Node B can measure the SNR of each uplink channel and determine the appropriate MCSs. Note that this is an attractive option as it reduces the delay in adapting to channel conditions. However the Node B is only able to estimate the SNR of the channels connecting the Node B antennas to the antenna which the UE uses for transmission.

5.4.1.3 Associated Signalling

5.4.1.3.1 Downlink

{This section should describe the HS-DCH-related downlink signalling which is distinct from the non-MIMO HSDPA system.}

5.4.1.3.2 Uplink

{This section should describe the HS-DCH-related uplink signalling which is distinct from the non-MIMO HSDPA system.}

5.4.1.4 UE Capability

{This section should describe the parameters(e.g. number of antennas, modulation, codes etc.) based on which the UE capability are classified. It should also describe the receiver algorithms used for each antenna configuration and transmission algorithm.}

5.4.1.5 Complexity

{This section should describe the expected complexity impact on the UE (e.g. power consumption, RF, baseband, memory etc).}

5.4.1.5.1 Analysis of User Equipment Complexity

5.4.1.5.2 Analysis of Node B impacts

5.4.1.6 Backward compatibility

5.4.1.7 Overview of changes required in the specification

5.4.2 Midamble Allocation

It is assumed that the Node B will not make transmissions to MIMO-capable and non-MIMO-capable UEs within the same time slot. This ensures that non-MIMO-capable UEs are not affected by interference that cannot be mitigated by their conventional MUDs. Two candidate midamble schemes for MIMO transmissions are proposed below. For each proposed MIMO midamble scheme Common and Default midamble allocation may be applied.

5.4.2.1 Candidate Scheme A: Multiple Midamble Basecodes per cell

In this scheme midamble shifts of distinct basecodes are used on each transmit antenna in each cell. Common and Default midamble allocation can be defined for each transmit antenna as they are defined currently for Rel-5. This allows midambles sequences to carry the same information in the case of non-MIMO transmissions i.e.

- The common midamble allocation scheme may be used to map the midamble shift used on each transmit antenna to the number of physical channels transmitted on that transmit antenna for MIMO transmissions and

- The default midamble allocation scheme may be used to map midamble shifts used on each transmit antenna to the channelisation codes used on that transmit antenna.

As this scheme requires up to four midamble basecodes for each cell additional midamble basecodes with similar auto-correlation properties to those currently specified would need to be defined.

Allowing more than one midamble base code per cell will increase the complexity of the channel estimation process in the UE.

5.4.2.2 Candidate Scheme B: One Midamble Basecode per cell

In this scheme a single midamble basecode per cell is used, as in Rel-5. Depending on the number of transmit antennas, the midamble shifts are grouped into either two or four subsets. Each subset of midamble shifts are applied to bursts transmitted from the respective transmit antenna. As the same number of midamble shifts are shared among two or four transmit antennas, a reduced amount of information on the number of bursts (in the case of Common midamble allocation) and the channelisation codes used (in the case of Default midamble allocation) can be carried by midamble sequence compared with as in Rel-5.

5.4.3 Signalling Code Allocation Information

In order to perform optimal interference mitigation, a TDD MIMO receiver, for both the 3.84 Mcps and 1.28 Mcps options, needs knowledge of all the codes transmitted on each of the antennas. In Rel-5, the use of the *Default Midamble Allocation* scheme enables each UE to determine the set of channelisation codes allocated in a downlink timeslot by detecting the set of midamble sequences transmitted in that timeslot. It is not realistic to increase the number of midambles that are signalled via the default midamble allocation scheme since this will significantly reduce channel estimation performance. More efficient and flexible techniques for signalling of this information are:

Using a broadcast channel: In this technique, the Node B uses a separate broadcast channel to transmit code allocation information. The broadcast information consists of a bitmap describing the codes that are transmitted on each antenna in each MIMO timeslot.

Using the HS-SCCH: The Node B encodes the HS-SCCH such that all MIMO enabled UE's to which an allocation is made can decode allocations to all other MIMO enabled UE's that are simultaneously active. As in Rel-5, the allocation messages may contain a start code, a stop code and a bitmap to indicate the time slots in which the codes allocated to that UE are active. In addition to this a bitmap indicating the antennas on which these codes are active will need to be sent for MIMO transmissions.

6 Requirements for RAN WG2

7 Requirements for RAN WG3

8 Consolidation procedure

Due to the large number of different MIMO schemes described in Section 5 and due to the long time that this work item has been open, a consolidation towards a smaller number of proposals had to be achieved. In order to select suitable MIMO schemes for UTRA, it was agreed to refine the evaluation and deployment assumptions for MIMO as described in [7], which expresses operators' expectations for realistic MIMO deployment scenarios. One of the main objectives in this new reference scenario description was to focus on MIMO schemes with two transmit antennas.

After that, the discussion could reach to a limitation to two MIMO schemes, one was PARC and the other was Dual-Stream TxAA (not described in Section 5, see e.g. in [8]). During 2nd qauter of 2006, it was agreed by RAN1 and RAN to standardize MIMO as follows:

- For UTRA TDD: the PARC scheme was agreed.
- For UTRA FDD: Dual-codeword MIMO based on Dual-Stream TxAA, with the weights being signalled on the HS-SCCH in the downlink, was agreed.

The stage 3 work that followed after that focused on MIMO for UTRA FDD. All relevant L1 aspects were studied and solutions for possible precoding weights, uplink control signalling (HS-DPCCH), downlink control signalling (HS-SCCH), MIMO operation of HS-PDSCH, supporing definitions for phase references (P-CPICH and S-CPICH) as well as possible combinations with transmit diversity were proposed and agreed in RAN1.

A high level description of the agreed MIMO scheme for UTRA FDD is given in the following paragraphs starting with the generic downlink transmitter structure in Figure 8.1.

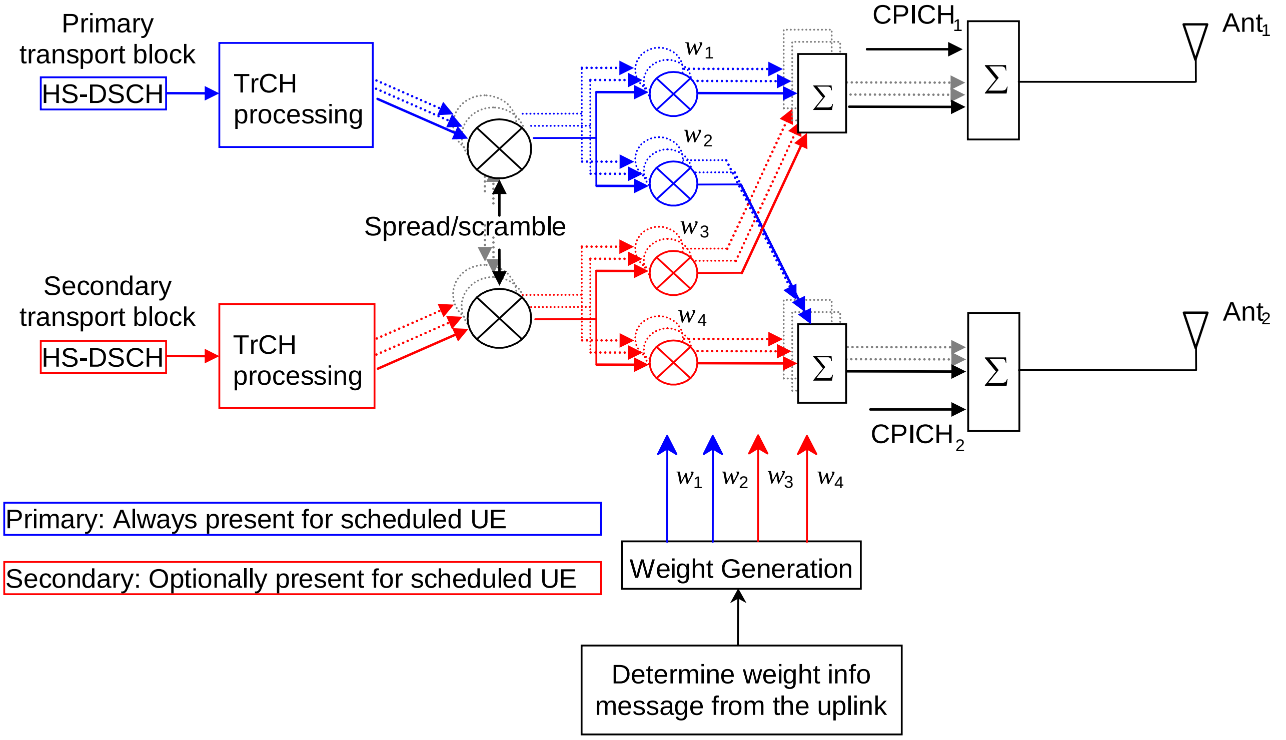


Figure 8.1: Generic downlink transmitter structure to support MIMO operation for HS-PDSCH transmission in UTRA FDD.

Channel coding, interleaving and spreading are done as in non-MIMO mode. The Node B scheduler can decide to transmit one or two transport blocks to a UE in one TTI. The spread complex valued signals are fed to both TX antenna branches, and weighted with precoding weights w_1, w_2, w_3 and w_4. The precoding weights w_1 and w_3 are constant real valued scalars and the precoding weights w_2 and w_4 are variable complex valued scalars. The precoding weights w_1, w_2, w_3 and w_4 are defined as follows:

$$w_3 = w_1 = 1/\sqrt{2}\,,$$

$$w_4 = -w_2\,,$$

$$w_2 \in \left\{ \frac{1+j}{2},\quad \frac{1-j}{2},\quad \frac{-1+j}{2},\quad \frac{-1-j}{2} \right\}.$$

If Node B schedules a single transport block to a UE in one TTI, it uses the precoding vector ($w_{1,}\, w_2$) for transmission of that transport block on the HS-PDSCH sub-frame. If UTRAN schedules two transport blocks to a UE in one TTI, it uses two orthogonal precoding vectors to transmit the two transport blocks. The precoding vector ($w_{1,}\, w_2$) is called the primary precoding vector which is used for transmitting the primary transport block and the precoding vector ($w_{3,}\, w_4$) is called secondary precoding vector which is used for transmitting the secondary transport block, respectively.

The UE uses the CPICH to separately estimate the channels seen from each antenna. One of the antennas will transmit the Antenna 1 modulation pattern of the P-CPICH. The other antenna will transmit either the Antenna 2 modulation pattern of the P-CPICH or the Antenna 1 modulation pattern of a S-CPICH. The Pilot configuration in support of MIMO operation of HS-DSCH in the cell is signalled by higher layers.

The UE determines a preferred primary precoding vector $\left(w_1^{\mathrm{pref}}, w_2^{\mathrm{pref}}\right)$ and signals it to the Node B. The signalled information about the preferred primary precoding vector is termed precoding control indication (PCI). The PCI is signalled to the Node B together with channel quality indication (CQI) as a composite PCI/CQI report. The UE transmits the composite PCI/CQI report to the Node B using the CQI field on the HS-DPCCH. Based on the composite PCI/CQI reports, the Node B scheduler decides whether to schedule one or two transport blocks to a UE in one TTI and what tranport block size(s) and modulation scheme(s) to use for each of them.

The Node B signals to the UE the precoding weight w_2 applied on the HS-PDSCH sub-frame using the precoding weight indication bits of part 1 of the corresponding HS-SCCH sub-frame. The precoding weight adjustment of each HS-PDSCH is done at the HS-PDSCH sub-frame border.

Also all relevant L2/L3 and Iub/Iur-Protocol aspects have been studies and appropriate solutions have been provided (signalling phase reference information to the UE, entering and leaving MIMO operation etc).

Two new UE categories have been defined to support MIMO. These are termed 9M and 10M in RAN1 specifications. They are based on the corresponding non-MIMO categories 9 and 10 with some slight modification of e.g. supported code rate [21].

9 Conclusion

An enormous amount of work has been done in RAN1 to find out what would be realistic conditions to evaluate the potential benefits of MIMO in UTRA and to characterize the potential benefits as well as the required complexity for a number of MIMO schemes. Based on the findings on the potential benefits and the required complexity, RAN1 and RAN have already agreed in the 2nd quarter of 2006 that MIMO should be standardized for UTRA TDD and UTRA FDD.

After that RAN1, RAN2 and RAN3 have focused on studying and identifying feasible solutions to implement the operation of Dual-Stream TxAA as the MIMO scheme for UTRA-FDD. As a result of that a set of CRs to 25.201, 25.211, 25.212, 25.214, 25.306, 25.308, 25.321, 25.331, 25.413, 25.423, 25.433 has been drafted in the past working group meetings (see [9] through [20]). It is recommended that this set of CRs is approved by RAN plenary. With that, the implementation of MIMO as a new feature in UTRA-FDD for Rel-7 would be completed.

Annex A: FDD Simulation assumptions

While eventually MIMO schemes will be combined with the H-ARQ schemes it is expected that because of complexity the initial simulations will not incorporate the H-ARQ aspects. We propose three sets of simulations to focus on : link, single-user throughput, system. The spatial channel models for link and single-user throughput simulations are specified in [1]. A summary of the simulation assumptions is given in the table below.

Table A.1 – FDD simulation assumptions

Item	Requirement	Comment
Number of Antennas (# @ NodeB x # @ UE)	Base case (1x1), 1x2, 1x4, 2x1, 2x2, 2x4, 4x1, 4x2, 4x4	Antenna configuration to be specified by proponent
Feedback bits on UL	Max 2 bits/slot 4% or 10% bit error rate	Feedback bits are incremental to HARQ, and includes Channel Quality Metric (Need to be specified in proposal) and antenna mode indication (if needed). Additional bits may be allowed if they result in significant performance gains
MCS	The maximum number of MCS levels is 32 levels for 2 transmit antenna systems and 64 levels for 4 transmit antenna systems	Max rate over 4x4 (~21.6 Mbps).
		.

A.1 Link-level simulations

Link-level simulations provide frame error rate versus I_{or}/I_{oc} for any of the proposed transmitter and receiver options. The spatial channel model is specified in [1]. The following assumptions are also made.

- A maximum 70% of the total downlink power is used for the downlink shared channel.
- A spreading factor 16 is used, and a maximum of 15 orthogonal spreading codes can be used for the downlink shared channel.
- The maximum fraction of recovered power is 98%. This translates to a specified maximum instantaneous "C/I" per receive antenna. Note that receive antenna combining can result in instantaneous "C/I" higher than prior to receive antenna combining.

A.2 System-level simulations

System-level simulations to obtain performance metrics such as Packet Call, Service, OTA etc. are performed according to the system-level simulation assumptions below (antenna response pattern, traffic model, scheduler etc.) inline with the HSDPA TR [2]. Relevant assumptions for the link-level and single-user throughput simulations are made for the system-level simulations.

In addition to the link level simulation assumptions made above, we assume the following.

- A maximum of 2 bits per 0.667ms slot of feedback information from the UE to the Node B is used. These feedback bits are a generalization of the channel quality indication bits used in single-antenna HSDPA systems, and the interpretation of these bits shall be specified by the proponent of the proposal. Note that these bits could be used jointly over multiple slots to indicate a message. Also the bits specified here do not include the bits required for signalling for hybrid ARQ, such as ACK/N-ACK bits. Additional bits may be allowed if they result in significant performance gains.

- The total round-trip feedback delay is 7 slots. If the delay is different for a given proposal, the proponent will include a timing diagram to justify its value of round-trip feedback delay.

A.2.1 System simulation assumptions for FDD MIMO

The scope of this section is to propose a set of definitions and assumptions on which MIMO system simulations shall be based. The initial objective of such system simulations should be to illustrate/verify the potential performance gains from the proposed MIMO schemes.

A.2.1.1 Common system level simulation assumptions

The MIMO system simulations shall be done based on the channel models and assumptions stipulated in 25.996. However, the evaluation of some requirements for MIMO system evaluation requires additional specfications to the the channel models and assumptions as given below.

A.2.1.2 Basic system level parameters

As system level simulation tools and platforms differ between companies very detailed specification of common simulation assumptions is not feasible. Yet, basic simulation assumptions and parameters should be harmonized as proposed in the subsequent chapters.

A.2.1.2.1 General parameters

Table A 2.1.2.1.1 Basic system level simulation parameter assumptions

Parameter	Value	Comments/Description
Cellular layout	Hexagonal grid, multi-sector sites	Two reference layouts shown in Figures A.2.1.2.1.1 and A.2.1.2.1.2.
Site to Site distance	Urban microcell: 1.0 km Urban macrocell: 2.8 km Suburban macrocell: 2.8 km	As recommended in the SCM Section 5.2 and in TR25.848 [2]
Propagation model	As specified in the SCM	Section 5.2
CPICH power	10% for primary legacy channels. Between 0% and 10% for the pilots for antennas 3 and 4.	The pilot structure for antenna 3 and 4 is part of the proposed MIMO scheme.
Other common channels	-10 dB	
Slow fading	As specified in the SCM	Table 5.1
Std. deviation of slow fading	As specified in the SCM	Table 5.1
Shadowing correlation between sites	As specified in the SCM	Section 5.2 (0.5)
Correlation distance of slow fading	As specified in the SCM	Section 5.1 (Shadowing is uncorrelated between UEs)
Carrier frequency	2150 MHz	
BS antenna gain pattern	As specified in the SCM	Section 4.5.1
LOS model	As specified in the SCM	Section 5.5.3
NLOS multipath model	As specified in the SCM	Time dispersion statistics specified in Table 5.1
UE noise figure	9 dB	
Fast HARQ scheme	Chase combining	For initial evaluation of fast HARQ;
BS maximum total Tx power	43 dBm	
Active set size	3	Maximum size
Fast Fading model	As specified in the SCM	Section 5.4
BS antenna gain	As specified in the SCM	Section 4.5.1 (14 dBi)
UE antenna gain	As specified in the SCM	Section 4.6.1 (-1 dBi)
MCS update rate	At most once per sub-frame	
CPICH measurement transmission delay	1 sub-frame	

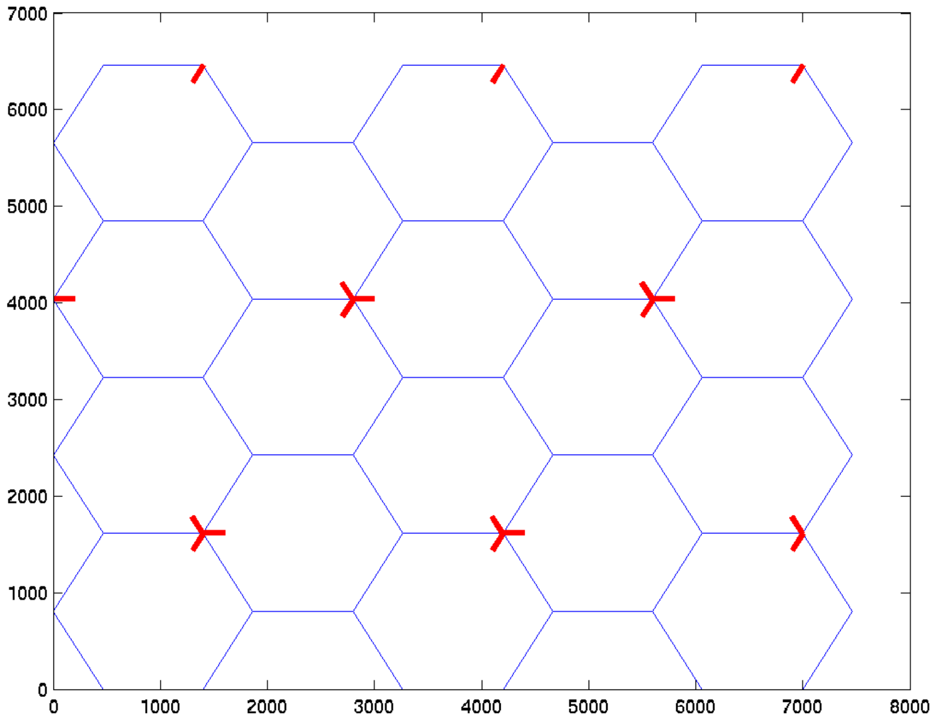


Figure A.2.1.2.1.1: Cellular layout 1 of adjacent tiers of neighbouring cells, sectors, and Node-Bs

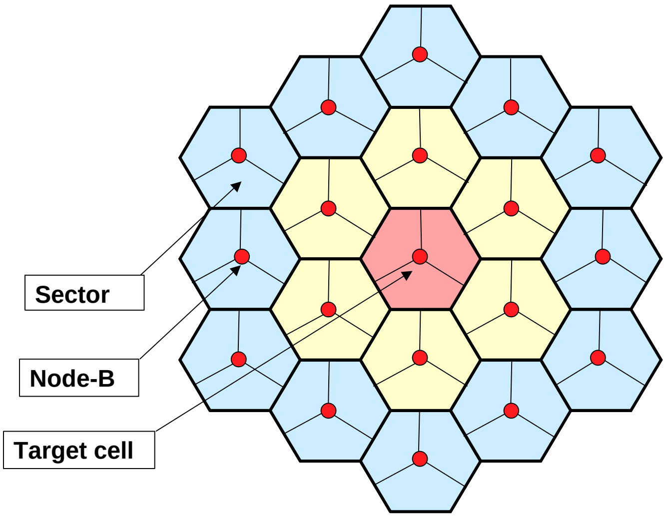


Figure A.2.1.2.1.2: Cellular layout 2 of adjacent tiers of neighbouring cells, sectors, and Node-Bs

A.2.1.2.2 Parameters related to HSDPA

In all simulations, also the HS-SCCH should be explicitly simulated in order to take into account the effect of errors on this channel as well as the effects of HS-SCCH power overhead.

Parameter	Explanation/Assumption	Comments
Power reserved for HSDPA transmission, including associated signalling	-	Shall be able to handle the UE population distribution specified in section A.2.1.5
Number of reserved HS-PDSCH codes	-	Shall comply with the UE population distribution specified in section A.2.1.5
Max. number of retransmissions	Specify the value used	Retransmissions by fast HARQ

A.2.1.2.3 Parameters related to dedicated channels

[Editor's note: Simulation parameters for the non-MIMO UE's with dedicated channels are to be described here]

A.2.1.2.4 Parameters related to voice traffic channels

[Editor's note: Simulation parameters for the non-MIMO UE's with voice traffic are to be described here.]

A.2.1.3 Data traffic models

A.2.1.3.1 Data traffic models for HSDPA traffic

Four different traffic types are suggested for evaluation purposes. The traffic models are derived from those in [2,4].

A.2.1.3.1.1 HTTP Traffic Model Characteristics

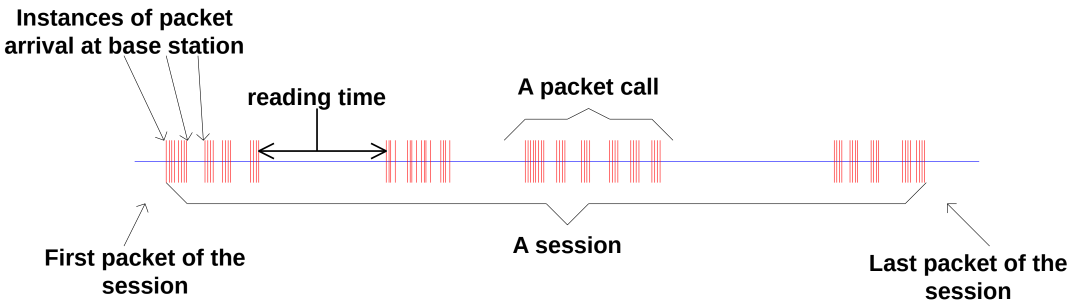


Figure A.2.1.3.1.1.1: Packet Trace of a Typical Web Browsing Session

Figure A.2.1.3.1.1.1 shows the packet trace of a typical web browsing session. The session is divided into ON/OFF periods representing web-page downloads and the intermediate reading times, where the web page downloads are referred to as packet calls. These ON and OFF periods are a result of human interaction where the packet call represents a user's request for information and the reading time identifies the time required to digest the web page.

As is well known, web-browsing traffic is self-similar. In other words, the traffic exhibits similar statistics on different timescales. Therefore, a packet call, like a packet session, is divided into ON/OFF periods as in Figure A.2.1.3.1.1.2.

Unlike a packet session, the ON/OFF periods within a packet call are attributed to machine interaction rather than human interaction. A web-browser will begin serving a user's request by fetching the initial HTML page using an HTTP GET request. The retrieval of the initial page and each of the constituent *objects* is represented by ON period within the packet call while the parsing time and protocol overhead are represented by the OFF periods within a packet call. For simplicity, the term "page" will be used in this paper to refer to each packet call ON period.

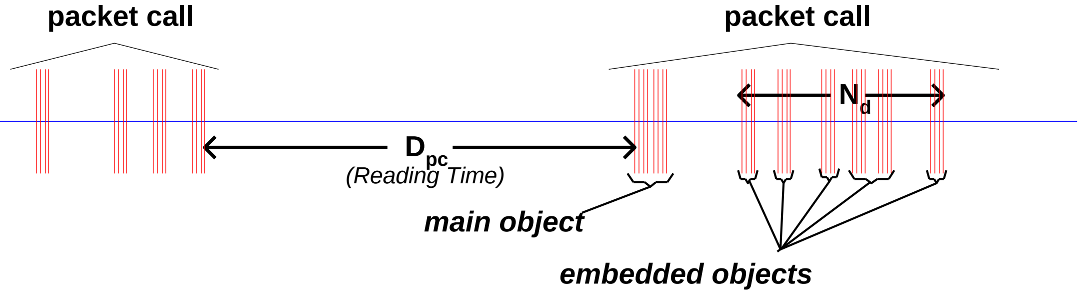


Figure A.2.1.3.1.1.2: Contents in a Packet Call

The parameters for the web browsing traffic are as follows:

- S_M: Size of the main object in a page
- S_E: Size of an embedded object in a page
- N_d: Number of embedded objects in a page
- D_{pc}: Reading time
- T_p: Parsing time for the main page

HTTP/1.1 persistent mode transfer is used to download the objects, which are located at the same server and the objects are transferred serially over a single TCP connection. The distributions of the parameters for the web browsing traffic model are described in Table A.2.1.3.1.1.1. Based on observed packet size distributions, 76% of the HTTP packet calls should use an MTU of 1500 bytes, with the remaining 24% of the HTTP packet calls using an MTU of 576 bytes. These two potential packet sizes also include a 40 byte IP packet header (thereby resulting in useful data payloads of 1460 and 536 bytes, respectively), and this header overhead for the appropriate number of packets must be added to the object data sizes calculated from the probabilistic distributions in Table A.2.1.3.1.1.1.

Component	Distribution	Parameters	PDF
Main object size (S_M)	Truncated Lognormal	Mean = 10710 bytes Std. dev. = 25032 bytes Minimum = 100 bytes Maximum = 2 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \geq 0$ $\sigma = 1.37, \mu = 8.35$
Embedded object size (S_E)	Truncated Lognormal	Mean = 7758 bytes Std. dev. = 126168 bytes Minimum = 50 bytes Maximum = 2 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \geq 0$ $\sigma = 2.36, \mu = 6.17$
Number of embedded objects per page (N_d)	Truncated Pareto	Mean = 5.64 Max. = 53	$f_x = \frac{\alpha k^\alpha}{x^{\alpha+1}}, k \leq x < m$ $f_x = \left(\frac{k}{m}\right)^\alpha, x = m$ $\alpha = 1.1, k = 2, m = 55$ Note: Subtract k from the generated random value to obtain N_d
Reading time (D_{pc})	Exponential	Mean = 30 sec	$f_x = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 0.033$
Parsing time (T_p)	Exponential	Mean = 0.13 sec	$f_x = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 7.69$

Table A.2.1.3.1.1.1: HTTP Traffic Model Parameters

A.2.1.3.1.2 FTP Traffic Model Characteristics

In FTP applications, a session consists of a sequence of file transfers, separated by *reading times.* The two main parameters of an FTP session are:

1. S : the size of a file to be transferred
2. D_{pc}: reading time, i.e., the time interval between end of download of the previous file and the user request for the next file.

The underlying transport protocol for FTP is TCP. The packet trace of an FTP session is shown in Figure A.2.1.3.1.2.1.

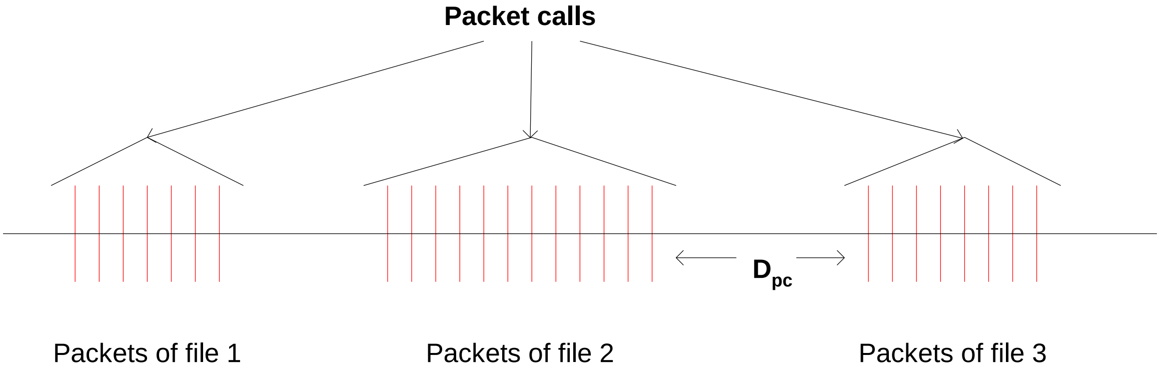


Figure A.2.1.3.1.2.1: Packet Trace in a Typical FTP Session

The parameters for the FTP application sessions are described in Table A.2.1.3.1.2.1.

Component	Distribution	Parameters	PDF
File size (S)	Truncated Lognormal	Mean = 2Mbytes Std. Dev. = 0.722 Mbytes Maximum = 5 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \geq 0$ $\sigma = 0.35, \mu = 14.45$
Reading time (D_{pc})	Exponential	Mean = 180 sec.	$f_x = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 0.006$

Table A.2.1.3.1.2.1: FTP Traffic Model Parameters

Based on the results on packet size distribution, 76% of the files are transferred using and MTU of 1500 bytes and 24% of the files are transferred using an MTU of 576 bytes. Note that these two packet sizes also include a 40 byte IP packet header (thereby resulting in useful data payloads of 1460 and 536 bytes, respectively) and this header overhead for the appropriate number of packets must be added to the file sizes calculated from the probabilistic distributions in the Table A.2.1.3.1.2.1. For each file transfer a new TCP connection is used whose initial congestion window size is 1 segment (i.e. MTU).

A.2.1.3.1.3 NRTV (Near Real Time Video) Traffic Model Characteristics

This section describes a model for streaming video traffic on the forward link. Figure A.2.1.3.1.3.1 describes the steady state of video streaming traffic from the network, as seen by the base station. Latency at call start-up is not considered in this steady-state model.

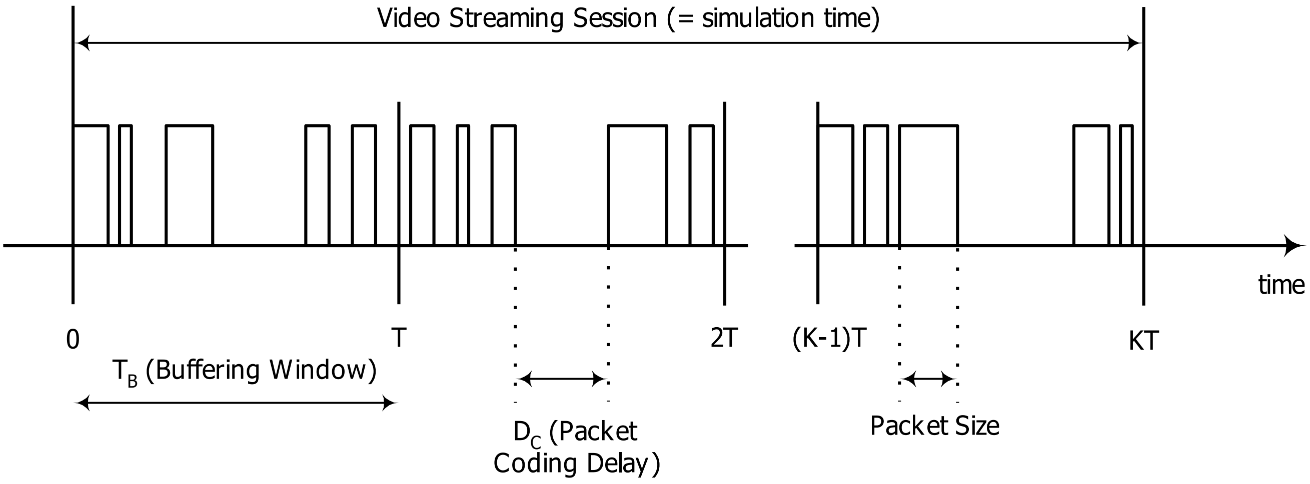


Figure A.2.1.3.1.3.1: Video Streaming Traffic Model

A video streaming session is defined as the entire video streaming call time, which is equal to the simulation time for this model. Each frame of video data arrives at a regular interval T determined by the number of frames per second (fps). Each frame is decomposed into a fixed number of slices, each transmitted as a single packet. The size of these packets/slices is distributed as a truncated Pareto distribution. Encoding delay, Dc, at the video encoder introduces delay intervals between the packets of a frame. These intervals are modelled by a truncated Pareto distribution.

The parameter T_B is the length (in seconds) of de-jitter buffer window in the mobile station, and is used to guarantee a continuous display of video streaming data. This parameter is not relevant for generating the traffic distribution, but it is useful for identifying periods when the real-time constraint of this service is not met. At the beginning of the simulation, it is assumed that the mobile station de-jitter buffer is full with (T_B x source video data rate) bits of data. Over the simulation time, data is "leaked" out of this buffer at the source video data rate and "filled" as forward link traffic reaches the mobile station. As a performance criterion, the mobile station can record the length of time, if any, during which the de-jitter buffer runs dry. The de-jitter buffer window for the video streaming service is 5 seconds.

Using a source video rate of 64 kbps, the video traffic model parameters are defined in Table A.2.13.1.3.1.

Information types	Inter-arrival time between the beginning of each frame	Number of packets (slices) in a frame	Packet (slice) size	Inter-arrival time between packets (slices) in a frame
Distribution	Deterministic (Based on 10fps)	Deterministic	Truncated Pareto (Mean= 50bytes, Max= 250bytes)	Truncated Pareto (Mean= 6ms, Max= 12.5ms)
Distribution Parameters	100ms	8	K = 40 bytes $\alpha = 1.2$	K = 2.5ms $\alpha = 1.2$

Table A.2.1.3.1.3.1: Video Streaming Traffic Model Parameters.

Only system-level simulations with homogenous traffic mixes are to be conducted. That is, for a particular simulation, all users will either have all FTP traffic, all HTTP traffic, or all NRTV traffic. There is no mixing of different traffic types within a single simulation.

A.2.1.3.1.4 HSDPA Type Traffic Model

This section describes a traffic model that has been used in HSDPA system simulations, and may be used to evaluate system capacity gains from MIMO. The traffic model parameters are given in Table A.2.1.3.1.4.

Table A.2.1.3.1.4: HSDPA Type Traffic Model

Process	Random Variable Distribution	Parameters
Packet calls size	Pareto with cut-off	A=1.1, k=4.5 Kbytes, m=2 Mbytes, μ = 25 Kbytes
Time between packet calls	Geometric	μ = 5 seconds
Packet size	Segmented based on MTU size	(e.g. 1500 octets)
Packets per packet call	Deterministic	Based on Packet Call Size and Packet MTU
Packet inter-arrival time	Geometric	μ = MTU size /peak link speed (e. g. [1500 octets * 8] /2 Mbps = 6 ms)
Packet inter-arrival time (closed-loop)	Deterministic	TCP/IP Slow Start (Fixed Network Delay of 100 ms)

A.2.1.3.2 Traffic models for Rel 99 voice traffic

These details are FFS.

A.2.1.4 UE mobility model

Results for the following distributions shall be used.

	3 km/h	30 km/h	70 km/h	120 km/h
Mobility Distribution 1	20%	10%	40%	30%
Mobility Distribution 2	30%	40%	20%	10%
Mobility Distribution 3	100%	-	-	-
Mobility Distribution 4	-	100%	-	-
Mobility Distribution 5	-	-	-	100%

The mobility distribution of the UE shall be independent of the transmission mode.

Mobility Distribution 1 shall be used with the suburban channel model.

Mobility Distribution 2 shall be used with the urban channel model.

A.2.1.5 UE population distributions

Results for two mandatory reference scenarios shall be provided.

	Rel 99 UEs with voice traffic	Rel 5 UEs with HSDPA traffic	MIMO UEs with HSDPA data channel
Population Distribution 1	50	35	15
Population Distribution 2	50	0	50

UE Antenna Configuration**:**

Results for UEs with two and results for UEs with four receive branches shall be presented for Distribution 2.

Node B Antenna Configuration**:**

The impact of the antenna configuration shall be covered within the limits of the SCM model. An antenna spacing of either $\lambda/2$ or 4 λ shall be used in the SCM to represent the different correlation properties

A.2.1.6 HSDPA packet schedulers

Multiple types of packet schedulers may be simulated. However, initial results may be provided for the three schedulers: the Round Robin (RR) scheduler, Max-Net-Rate and proportional fair scheduler.

The Max-Net-Rate scheduler provides maximum system capacity at the expense of fairness, because all sub-frames can be allocated to a single user with good channel conditions. Note that the Max-Net-Rate scheduler reduces to the Max C/I scheduler for single stream transmission.

A fairness measurement benchmark must be provided when the proportional fair scheduler is used. The details of the scheduler and the fairness measurement are left to the proponents and shall be described when providing the results.

All scheduling methods obey the following rules:

An ideal scheduling interval is assumed and scheduling is performed on a TTI by TTI basis.

A queue is 'non-empty' if it contains at least 1 octet of information.

Packets received in error are explicitly rescheduled after the ARQ feedback delay consistent with the HSDPA definition.

A high priority queue is maintained to expedite the retransmission of failed packet transmission attempts. Entry into the high priority queue will be delayed by a specified time interval (e.g. 5 frame intervals) to allow for scheduler flexibility[1]. If the packet in the high-priority queue is not rescheduled after a second time interval (e.g. 10 frame intervals) it is dropped.

Packets from the low priority queue may only be transmitted after the high-priority queue is empty.

Transmission during a frame cannot be aborted or pre-empted for any reason.

The Max-Net-Rate scheduler obeys the following additional rules, similar to those specified for the Max C/I scheduler.

At the scheduling instant, all non-empty source queues are rank ordered by the scheduler based on the estimated net rate of transmission during a sub-frame. Net rate is defined as the sum of the rates achievable by the individual streams spatially multiplexed. The algorithm for estimating the net rate shall be specified in enough detail so as to be verifiable by others. Estimation may be based on CPICH measurement info, MCS levels may directly be fed back by MIMO UEs themselves.

The scheduler may continue to transfer data to the UE with the highest net rate until the queue of that UE is empty, data arrives for another UE with higher net rate, or a retransmission is scheduled taking higher priority.

Both high and low priority queues are ranked by net rate.

The RR scheduler obeys the following rules:

At the scheduling instant, non-empty source queues are serviced in a round-robin fashion.

All non-empty source queues must be serviced before re-servicing a user.

Therefore, the next sub-frame cannot service the same user as the current sub-frame unless there is only one non-empty source queue.

---

[1] The delayed entry into the high priority queue can be used to reduce compulsory retransmission of a single packet. A fast retransmission mechanism, such as N-channel stop-and-wait ARQ, would provide one packet to the high priority queue if the delayed entry mechanism were not provided. As a result, this single packet would be retried in lieu of all other packets regardless of the channel conditions. Note that the case when retransmitted packets always have priority over new transmissions is included in this description as a special case.

A.2.1.7 Outputs and performance metrics

The outputs and the performance metrics described in this section are used to evaluate the improvement of the service availability, increase in maximum data rate per cell and the impact on non-MIMO UEs.

The following performance metrics should be provided either for the entire system or the center site taken over each simulation run. In all cases throughput is considered based on the user net data rates and a packet is as defined by the traffic model.

- **Average cell throughput [kbps/cell]** is used to study the network throughput performance, and is measured as

  $$R = \frac{b}{k \cdot T}$$

  where b is the total number of correctly received data bits in all data UEs in the simulated system over the whole simulated time, k is the number of cells in the simulation and T is the simulated time. In the case of only evaluating the center cell site, k is the number of sectors.

- **Average packet call throughput [kbps]** for user i is defined as

  $$R_{pktcall}(i) = \frac{\sum_k \text{good bits in packet call } k \text{ of user } i}{\sum_k \left(t_{end\_k} - t_{arrival\_k}\right)}$$

  where k = denotes the k^{th} packet call from a group of K packet calls where the K packet calls can be for a given user i , $t_{arrival\_k}$ = time that the first packet of packet call k arrives in queue, and t_{end_k} = time that the last packet of packet k is received by the UE. Note for uncompleted packet calls, t_{end_k} is set to simulation end time. The mean, standard deviation, nth percentile and the distribution of this statistic are to be provided. The distribution of the average packet call throughput of all users across the cell and the number of users as a function of a particular packet call throughput shall also be provided.

- **The packet service session FER** is calculated for all the packet service sessions. A packet service session FER is defined as the ratio

  $$FER_{session} = \frac{n_{erroneous\_frames}}{n_{frames}}$$

  where $n_{erroneous\_frames}$ is the total number of erroneous frames in the packet service session and n_{frames} is the total number of frames in the packet service session. These individual packet service session FERs from all packet service sessions form the distribution for this statistic. The mean, standard deviation, and the distribution of this statistic are to be provided.

  A Definition of a Packet Service Session: A Packet Service Session contains one or several packet calls depending on the application. Packet service session starts when the transmission of the first packet of the first packet call of a given service begins and ends when the last packet of the last packet call of that service has been transmitted. (One packet call contains one or several packets.) Note, that FER statistics are only collected from those frames during which UE is receiving data.

- **The residual FER** is calculated for each user for each packet service session. A packet service session residual FER is defined by the ratio

  $$FER_{residual} = \frac{n_{dropped\_frames}}{n_{frames}}$$

  where $n_{dropped\_frames}$ is the total number of dropped frames in the packet service session and n_{frames} is the total number of frames in the packet service session. A dropped frame is one in which the maximum ARQ or HARQ re-transmissions have been exhausted without the frame being successfully decoded. It does not include the RLC initiated re-transmissions. The mean, standard deviation, and distribution of this statistic over all the packet service sessions in the simulation are to be provided.

The averaged packet delay per sector is defined as the ratio of the accumulated delay for all packets for all UEs received by the sector and the total number of packets. The delay for an individual packet is defined as the time between when the packet enters the queue at transmitter and the time when the packet is received successively by the UE. If a packet is not successfully delivered by the end of a run, its ending time is the end of the run.

A.2.1.8 Compatibility analysis

MIMO techniques shall not have any significant negative impact on features available in earlier releases. This shall be verified by measuring the impact of MIMO transmission on non-MIMO UEs in representative link level scenarios. However, there are cases when link analysis may not show the whole picture: then system analysis on the impacts should be carried out. In the case of negative link affects for legacy terminals, this performance evaluation could also be extended to be performed at system level.

The scope of this section is to propose a methodology for the evaluation of the impact of MIMO techniques on features available in earlier releases. The objective of the compatibility analysis and simulations is to guarantee that MIMO techniques have no significant negative impact on these features.

The compatibility analysis considers the demodulation performance of physical channels introduced in earlier releases as well as physical layer measurements and procedures that are necessary for the system operation. It is assumed that if the physical layer processing is not significantly degraded by the introduction of MIMO techniques a negative impact on higher layer procedures does not have to be expected.

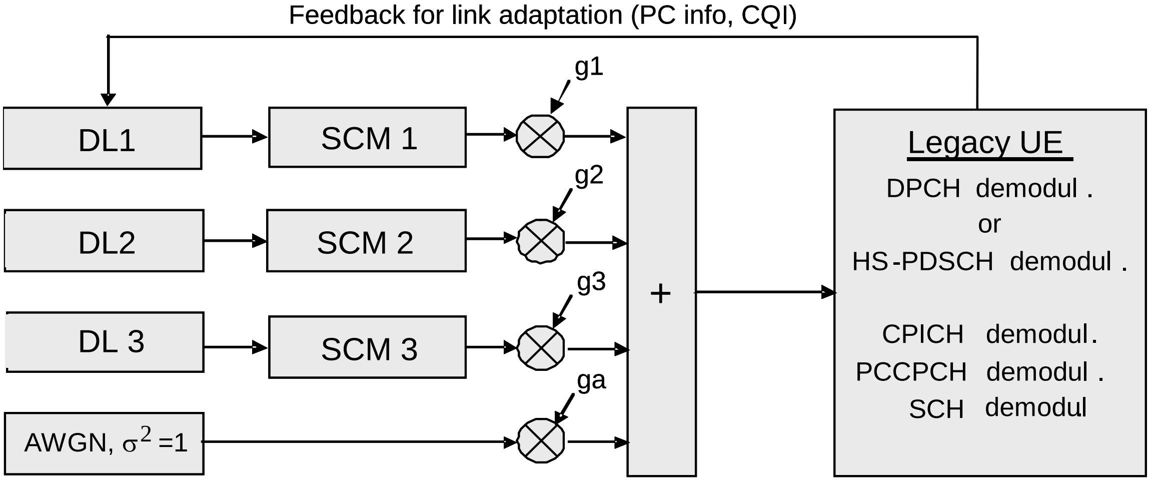


Figure A.2.1.8.1: Simulator Setup for Compatibility Assessment

The compatibility analysis is based on multi-cell link level simulations for representative scenarios where the downlink signal of three cells is modeled explicitly and the impact of other cells is modeled by AWGN. A possible setup of the simulator is shown in Figure A.2.1.8.1.

The key idea of the compatibility assessment is to simulate a data transmission from base station 1 (using DL1) to a legacy UE by legacy channels (Release '99 DCH and Release 5 HS-DSCH) for two setups: in Setup 1 (Legacy Setup), only legacy channels are transmitted by the three base stations; in Setup 2 (MIMO Setup), the base stations transmit in MIMO mode, too. The demodulation performance for these two scenarios is compared.

Table A.2.1.8.1 lists the scenarios and the received power spectral densities Îor1,2,3 of the explicitly modeled downlink signals and the AWGN source with respect to Ioc. The gain factors g_1,2,3,awgn in the simulator setup (Figure A.2.1.8.1) have to be selected accordingly. It is assumed that the considered legacy UE is served by downlink DL1. Note that Îor2 + Îor3 + Ioc_awgn=Ioc.

Table A.2.1.8.1: Reference Scenarios for Compatibility Study

Scenario	Îor1/ Ioc = Îor /Ioc = G [dB]	Îor2 / Ioc [dB]	Îor3 / Ioc [dB]	Ioc_awgn/Ioc [dB]
1	12	-3.5	-6.12	-5.1
2	3	-5.1	-5.10	-4.18
3	3	-3.0	-8.95	-4.3
4	0	-4.6	-4.60	-5.14
5	0	-2.5	-14.00	-4.0

In the simulations, the three explicitly modeled downlink signals are transmitted over independent spatial channel models (SCM 1,2,3 in Figure 1). The spatial channel models are defined in TR25.996.

Table A.2.1.8.2 lists the physical channels of the downlink signal for the two setups (Legacy and MIMO).

Table A.2.1.8.2: Setup of explicitly modelled physical channels.

		Legacy Setup		**MIMO Setup**				
Channel		power allocation			power allocation			
		Ant 1	Ant 2		Ant. 1	Ant. 2	Ant. 3	Ant. 4
CPICH *)	CPICH_Ec/Ior [dB]	-13	-13		-13	-13	-16	-16
P-CCPCH	P-CCPCH_Ec/Ior [dB]	-15 (STTD)	-15 (STTD)		-15 (STTD)	-15 (STTD)	-	-
SCH **)	SCH_Ec/Ior [dB]	-12 (TSTD)	-12 (TSTD)		-12 (TSTD)	-12 (TSTD)	-	-
HS-DSCH ***)	HS-PDSCH_Ec/Ior [dB]	-7 (STTD)	-7 (STTD)	STTD	-7.5	-7.5	-	-
				MIMO	-10.5	-10.5	-10.5	-10.5
	HS-SCCH_Ec/Ior [dB]	-13 (STTD)	-13 (STTD)	STTD	-13	-13	-	-
DCH ****)	DPCH (STTD mode)	Test specific, power control on.		STTD	Test specific, Power control on.		-	-

OCNS	4 DPCHs with SF=256	Necessary power so that total transmit power spectral density adds to one.	STTD	Necessary power so that total power spectral density adds to one.
			MIMO	50 % for STTD, 50 % for MIMO DPCHs.

Note:

- All legacy channels are transmitted in transmit diversity mode (Release '99 and 5).

*) Common pilots on antennas 3 and 4 use C_256,x and the transmit div. mode defined for antennas 1 and 2.

**) Mean power level on antennas 1 and 2 for SCH and P-CCPCH is -12 dB. SCH includes P- and S-SCH, with power split between both.
DL1: P-SCH code is S_dl,0 as per TS25.213. S-SCH pattern is scrambling code group 0.

***) HS-PDSCH use C_16,12 - C_16,16.
Four UEs are served. The scheduling is random, the UEs are scheduled with the same probability. In the MIMO Setup, two UEs are assumed to be served by MIMO transmissions. All transport formats of the MIMO scheme are assumed to be equally probable.

****) 12.2 Kbps DL reference measurement channel as specified in TS 25.101, A.3.1.

For each scenario in Table A.2.1.8.1, simulations are performed for the Legacy and the MIMO Setup. The quantities defined in Table A.2.1.8.3 are logged for the legacy UE. Only if significant discrepancies between the results of the two setups (Legacy and MIMO) are found, the impact of the MIMO transmissions on legacy terminals should be modeled in system level simulations.

Table A.2.1.8.3: Estimated quantities for each scenario

Physical Channel	Estimated quantity	Note
CPICH – Ant 1& 2	Received CPICH_Ec, CPICH_Ec/Io	Average over 200 ms. Logged for all explicitly modeled base stations.
SCH – Ant 1& 2	Received SCH_Ec, SCH_Ec/Io	Average over k x 10 ms, k=2,20. Logged for all explicitly modeled base stations.
P-CCPCH – Ant 1& 2	Received P-CCPCH_Ec/Io	Average over 10 ms
DPCH – Ant 1 & 2	DPCH_Ec/Ior @ BLER_target	Reference channel
HS-PDSCH – Ant1&2	Throughput	Reference channel
HS-SCCH – Ant 1&2	1- Prob. of error free demodulation	Reference channel

A.2.1.9 Reference cases

For an accurate and realistic estimate of potential benefits from MIMO, it is crucial to quantify the benefits via performance comparisons with existing WCDMA systems. One or more of the following cases shall be evaluated.

A.2.1.9.1 Increased Cell Sectoris Incorporated Text proposals from R1-050723, R1-050849, R1-050890, R1-050935, R1-050937, R1-050912ation

Sectorisation using 6 sectors and 2 Rx LMMSE is to be used.

A.2.1.10 Simulation cases

In order to evaluate the performance of the basic features proposed for HSDPA MIMO, at least the simulation cases described below shall be conducted. In all cases the performance reference is the reference cases.

A.2.1.10.1 Case 1 (Link calibration)

Link level cases should be used for calibration, introduction of the schemas, impact to legacy terminal. Proponents are welcome to provide other methods.

- Introduction of the schema
- Impact to legacy terminal
- Calibration

Link-level simulations provide frame error rate versus I_{or}/I_{oc} for any of the proposed transmitter and receiver options. The spatial channel model is specified in [1]. The following assumptions are also made.

- A maximum 70% of the total downlink power is used for the downlink shared channel.
- A spreading factor 16 is used, and a maximum of 15 orthogonal spreading codes can be used for the downlink shared channel.

A.2.1.10.2 Case 2 (MIMO HSDPA UEs with mixed traffic interference)

The absolute gains of the proposals over the reference cases shall be presented.

The following parameters will be used:

Adaptive Modulation and fast HARQ are modelled.

Uniform UE distribution is used.

Full Buffer traffic model is used.

CQI may be selected based on CPICH measurement, e.g. RSCP/ISCP, or power control feedback information. CPICH measurement and reporting scheme and parameters shall be explicitly indicated. Realistic delays and errors shall be considered.

MCS update rate: once per 2 ms (3 slots)

Selected MCS applied with 1 frame delay after receiving measurement report

Frame length for fast HARQ: 2 ms

Feedback bit error rate: 0%, 1% or 4 %.

UE population distribution (Section A.2.1.5) shall be used.

A.2.1.10.3 Case 3 (Full statistics from mixed UE-scenario)

The simulations shall model the following list of functionalities:

- Full UE mobility
  - o UE movement during simulation
  - o Handovers (e.g. SHO, inter frequency, inter RAT).
- Link adaptation
  - o Adaptation of MIMO technique e.g. due to changing radio conditions and/or UE movement
  - o Dynamic power control, e.g. for associated DPCCHs (considering also e.g. power control failure).
  - o Asymmetry between UL and DL.

More advanced traffic model (HTTP, FTP, NRTV)

The details of the models are left to the proponents.

The absolute gains of the proposals over the reference cases shall be presented.

Annex B: TDD Simulation assumptions

While eventually MIMO schemes will be combined with the H-ARQ schemes it is expected that because of complexity the initial simulations will not incorporate the H-ARQ aspects. We propose three sets of simulations to focus on : link, single-user throughput, system. The spatial channel models for link and single-user throughput simulations are specified in [1]. A summary of the simulation assumptions is provided in Table B.1 below.

Table B.1 – TDD simulation assumptions

Item	Requirement	Comment
Number of Antennas (# @ NodeB x # @ UE)	Base case (1x1), 1x2, 1x4, 2x1, 2x2, 2x4, 4x1, 4x2, 4x4	Antenna configuration to be specified by proponent
Feedback bits on UL	Number of feedback bits for proposal must be specified (4% and 10% error rate may be assumed). Proposals may optionally require no feedback	Feedback bits are incremental to HARQ, and includes Channel Quality Metric (Need to be specified in proposal) and antenna mode indication (if needed).
Feedback Delay	Function of timeslot assignment. Proposals shall not unduly restrict possible timeslot assignments	Each proposal shall include a timing diagram to justify the value of round-trip feedback delay.
Channel Model	Initially 1 Path Rayleigh and IID	1 path Rayleigh used for calibration of results. Use test cases as specified in the MIMO channel model
Doppler	Base cases 3 Km/h, 30 Km/h, and 120 Km/h	
MCS	The maximum number of MCS levels is 32 levels for 2 transmit antenna systems and 64 levels for 4 transmit antenna systems	Max rate over 4x4 (~21.6 Mbps).
TTI	HS channels : fixed (10ms at 3.84Mcps, 5ms at 1.28Mcps)	Proposal needs to specify whether scheme imposes a restriction on TTI for non-HS channels
midamble allocation scheme	Any	Proposal shall specify whether there are restrictions in midamble allocation scheme
Scheduler	As in [2].	

B.1 Link-level simulations

Link-level simulations provide frame error rate versus I_{or}/I_{oc} for any of the proposed transmitter and receiver options. The spatial channel model is specified in [1].

B.2 System-level simulations

System-level simulations to obtain performance metrics such as Packet Call, Service, OTA etc. are performed according to the system-level simulation assumptions (antenna response pattern, traffic model, scheduler etc.) in the HSDPA TR [2]. Relevant assumptions for the link-level and single-user throughput simulations are made for the system-level simulations.

There is no a-priori assumption that feedback information bits are required for TDD MIMO operation, however proposals that require feedback may assume that feedback information bits from the UE to the Node B are used. These feedback bits may be a generalization of the channel quality indication bits used in single-antenna HSDPA systems, and the interpretation of these bits shall be specified by the proponent of the proposal. Note that these bits could be used jointly over multiple slots to indicate a message. Any proposal that restricts the physical channels on which feedback bits may be transmitted shall clearly quantify the physical layer performance gain associated with such a restriction. The feedback information bits referred to here do not include the bits required for signalling for hybrid ARQ, such as ACK/NACK bits.

The round trip feedback delay may depend on the timeslot assignment. Proposals shall not unduly restrict possible timeslot assignments. Any proposal that restricts timeslot assignment shall clearly quantify the gain associated with this restriction.

Annex C: History

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2001-08					Presented at RAN WG1 #21 Turino as R1-01-0879		0.0.0
2001-11					Presented at RAN WG1 #22 Jeju as R1-01-1127 Incorporate minor revisions from reflector and RAN WG1 #21 meeting	0.0.0	0.0.1
2001-12					Approved at RAN #14 Kyoto	0.0.1	1.0.0
2002-02					Presented at RAN WG1 #24 Orlando as R1-02-0486 Incorporate new requirements	1.0.0	1.0.1
2002-03					Approved at RAN #15 Jeju	1.0.1	1.1.0
2003-10					Presented at RAN WG1 #34 Seoul as R1-031136 The evaluation requirements are revised to reflect broadened scope of MIMO WI to include DCH and TDD. The TR is divided into FDD DCH, FDD HSDPA and TDD parts covering layers 1, 2 & 3	1.1.0	1.1.1
2003-12					Approved at RAN#22 Maui	1.1.1	1.2.0
2004-02					Presented at RAN WG1 #36 Malaga as R1-040205 Incorporate PARC FDD proposal and RC-MPD FDD proposal. Add TDD high speed channels and TDD simulation assumptions	1.2.0	1.2.1
2004-02					Agreed after RAN WG1 #36 Malaga 1.Correction to the Table of Contents between Section 5.2.1.2.1 and Section 5.2.1.2.2 2.Correction to the location of Plenary#22, from Honolulu to Maui 3. R1-040290: DSTTD-SGRC text proposal for TR 25.876	1.2.1	1.3.0
2004-05					Presented at RAN WG1 #37 Montreal as R1-040603 - Editorial	1.3.0	1.3.1
2004-05					Agreed after RAN WG1#37 Montreal as R1-040661 - Editorial	1.3.1	1.5.0
2004-05					Presented at RAN WG1#38 Prague Following Text Proposals from WG1#37 were accepted: R1-040436, R1-040419, R1-040420, R1-040566, and R1-040486	1.5.0	1.5.1
2004-08					Agreed at RAN WG1#38 Prague as R1-041021 - Editorial	1.5.1	1.6.0
2004-08					Incorporated Text proposals from R1-041022, R1-041023, R1-041034	1.6.0	1.6.1
2004-09					Draft available as R1-041057	1.6.1	1.7.0
2005-10					Presented at RAN WG1 #42bis San Diego as R1-051204 Incorporated Text proposals from R1-050723, R1-050849, R1-050890, R1-050935, R1-050937, R1-050912	1.7.0	1.7.1
2007-03	RAN_35	RP-070141	-	-	TR 25.876 version provided to RAN #35 for approval.	1.7.1	2.0.0
16/03/07	RAN_35	RP-070141	-	-	Doc in REL-7 under change control further to approval decision	2.0.0	7.0.0