Source: **Ad Hoc #6**

Title: **Report from Ad Hoc #6: DL Tx diversity**

Agenda item: **8.8**

Document for:

Summary:

A comparison of ETSI and ARIB DL Tx diversity concepts is presented in this document. As a result of this comparison it is proposed that the 3GPP DL Tx diversity solution is based on ETSI scheme, i.e. as described in [2, 3]. Specifically, this means that the STTD is applied in the open loop mode and combined STD and Tx AA is used in the closed loop mode. For open loop mode the case of more than two diversity antennas requires further studies.

As the ETSI solution alone doesn't specify all the details, further proposals have been made regarding support of Tx diversity mode in UE/BS and application of Tx diversity mode on different DL physical channels. In addition, it has been reminded that the control of the various Tx diversity modes requires some further studies. Moreover, the use of open loop Tx diversity and/or SSDT when the UE is in SHO needs to be clarified.

1.

2. INTRODUCTION

Downlink Tx diversity have been under study in ARIB and ETSI for about one year. It is one of the techniques that can be used to improve the downlink performance. Several different solutions have been proposed by different companies including: Orthogonal Transmit Diversity (OTD), Time Switched Transmission Diversity (TSTD), Selective Transmit Diversity (STD), Space Time Transmit Diversity (STTD) and Transmit Antenna Array (Tx AA). They can be classified into open loop solutions which require no feedback information from User Equipment (UE) to Base Station (BS), and closed loop solutions, which take advantage of feedback information send from UE to BS. OTD, TSTD and STTD are open loop solutions and STD and Tx AA closed loop solutions.

In ARIB the TSTD and STD were combined into one single concept called Time Domain Transmit Diversity (TDTD) which was selected as the ARIB's DL Tx diversity solution in fall, 1998. The same concept was later on proposed to ETSI. After long technical discussion ETSI arrived at somewhat different solution which comprises of STTD as open loop mode and combined STD and Tx AA as closed loop mode.

In the first TSG-R WG1 meeting several Ad Hoc groups were established to work on the merging of the ARIB and ETSI solutions. Ad Hoc #6 scope was to consider the convergence of DownLink (DL) Tx diversity schemes. The common objectives of all of the Ad Hocs are as follows:

1. Collect the relevant information
2. Identify commonalities and differences between proposals
3. Identify pros and cons of the various proposals in case of differences
4. Report the results of the work to the 2nd WG1
5. If possible make a proposal for merging to the 2nd WG1 meeting
6. If possible prepare for the 2nd WG1 a text proposal for inclusion in the specification

Results of the Ad Hoc #6 are reported in this document.

3. COMPARISON OF ARIB AND ETSI SOLUTIONS

3.1 Relevant documents

Both in ARIB Sub Working Group 2 (SWG2) and ETSI L1 Expert Group there has been a number of contributions related to DL Tx diversity. For ARIB they are listed in the Table 1 and for ETSI in the Table 2. The approved ARIB DL Tx diversity solution is described in [1]. Similarly, current ETSI solution can be found from [2, 3].

Table 1. List of ARIB SWG2 DL Tx diversity contributions.

Title	Source	Date	Document #
Selective transmit diversity for WCDMA downlink	Nokia	14.5.1998	SWG2-19-26
A Comparison of Forward Link Transmit Diversity Schemes	Motorola	26.6.1998	SWG2-22-5
Proposed text on Downlink Time Domain Transmit Diversity (TDTD)	Nokia, Samsung	30.7.1998	SWG2-25-5
Forward link Time Domain Transmit Diversity (TDTD)	Nokia, Samsung	21.8.1998	SWG2-26-30
Correction of TDTD proposal regarding Perch channel diversity Tx	Nokia, Samsung	5.10.1998	SWG2-28-15
Space Time Block Coded Transmit Antenna Diversity for WCDMA	TI	5.11.1998	SWG2-30-35
Additional Comments on STTD proposal	TI	16.11.1998	SWG2-31-21
Consideration on TPC and Power balancing in TDTD/PD	Samsung	1.12.1998	SWG2-32-2
Comparison of TDTD/PD and STTD	Samsung	1.12.1998	SWG2-32-3
Discussion results on TDTD refinement	Samsung	16.12.1998	SWG2-33-7

Table 2. List of ETSI L1 Expert Group DL Tx diversity contributions.

Title	Source	Date	Document #
Proposal for Downlink Time Switched Transmission Diversity	Samsung	18-20.5.1998	091/98
Downlink Transmit Diversity	Nokia	18-20.5.1998	128/98
Selective Transmit Diversity for UTRA/FDD Downlink	Nokia	15-17.6.1998	167/98
UTRA transmission diversity	Nokia	15-17.7.1998	242/98
A Comparison of Forward Link Transmit Diversity Schemes	Motorola	15-17.7.1998	257/98
Improvement of UTRA FDD downlink by transmit diversity	Samsung	15-17.7.1998	259/98
Complexity of orthogonal transmit diversity	Motorola	15-17.7.1998	282/98
UTRA FDD Downlink Transmission Diversity Concept	Nokia, Samsung	8-11.9.1998	315/98
Complexity requirements of OTD and TSTD	Motorola	8-11.9.1998	317/98
Benefits of Coherent Transmission using Transmit Adaptive Array	Motorola	8-11.9.1998	318/98
Closed-loop transmit diversity schemes and power balancing	Motorola	8-11.9.1998	375/98
Consideration on power amplifier balancing in TX diversity	Samsung	14-16.10.1998	411/98
A performance and complexity analysis of transmit diversity	Samsung	14-16.10.1998	412/98
Further Considerations on the TX Diversity	Nokia	14-16.10.1998	422/98
Transmit Antenna Diversity (TAD)	Motorola	14-16.10.1998	481/98
Answers to Nortel questions on transmit diversity	Nokia, Samsung, Motorola	14-16.10.1998	497/98
Decision Criteria on UTRA transmit diversity	Samsung	9-12.11.1998	545/98
Power Balancing Analysis of TSTD	Motorola	9-12.11.1998	575/98
Power balancing analysis of TSTD for a small number of users	Motorola	9-12.11.1998	591/98
Space Time Block Coded Transmit Antenna Diversity for WCDMA	TI	17.12.1998	662/98

Performance comparison in forward link transmit diversity	Samsung	14-18.12.1998	672/98
Feedback Mode Transmit Diversity	Nokia, Motorola	14-18.12.1998	696/98
Comparison of Feedback Mode Transmit Diversity Methods	Nokia	14-18.12.1998	697/98
Feedback mode transmit diversity – Simulation results	Motorola	14-18.12.1998	730/98
Progress on Open Loop Mode Transmit Diversity	Motorola, TI	17.12.1998	739/98
Proposed text for feedback mode transmit diversity	Nokia, Motorola	14-18.12.1998	745/98
Progress on Open Loop Mode Transmit Diversity	Motorola, TI	18.12.1998	749/98
Additional results on Space Time Block Coded Transmit Antenna Diversity	TI	19.1.1999	25/99
Feedback Mode Transmit Diversity: Text Proposal for XX.03	Motorola, Nokia	18-20.1.1999	54/99
Feedback Mode Transmit Diversity: Text Proposal for XX.08	Motorola, Nokia	18-20.1.1999	55/99
Benefits of Transmit Diversity	Motorola	18-20.1.1999	56/99
Further clarification of feedback mode transmit diversity concept	Motorola, Nokia	18-20.1.1999	63/99
Performance comparison in forward link transmit open loop diversity	Samsung	18-20.1. 1999	73/99
Reply To Samsung’s comments in Tdoc 73/99	TI	19.1.1999	75/99

3.2 Comparison of solutions

3.2.1 Open loop mode

3.2.1.1 STTD in ARIB/ETSI

ARIB selected TDTD/PD mode for open loop transmit antenna diversity in 08/98. After that, Texas Instruments proposed space time block coding based transmit antenna diversity (STTD) to ARIB in 11/98 (AIF/SWG2-30-35) for open loop antenna diversity. Since it came a little late in standardization, ARIB proposed to reconsider STTD after the completion of version 1.0 specification. In the mean time, STTD was proposed to ETSI and it was accepted as the open loop transmit antenna diversity over TDTD/PD. The principal reasons for this ETSI decision were,

(a) Improved forward link performance and capacity of STTD over TDTD/PD

(b) STTD is a base station PA balanced scheme, as against TDTD/PD

(c) There is very little complexity in incorporating the STTD encoder at the base station.

(d) The increased mobile complexity for implementing STTD decoder is very small and does not significantly increase the overall mobile modem complexity.

3.2.1.2 Impact on mobile complexity by using STTD

The mobile complexity for STTD is a little more than that for TDTD/PD, although the overall increase in the modem complexity is very small. The only significant increase in complexity for STTD over TDTD/PD (Table 10 of [5]) is the increase in finger complexity, which requires an extra complex multiply and an extra complex add per symbol, per diversity path. This increase comes about because STTD exploits full path diversity, implying that the number of fingers in the mobile maximal ratio combiner (MRC) is doubled. Notice that the despreader and the searcher complexities are unchanged for STTD over TDTD/PD. Hence, the overall increase in the mobile complexity for STTD is not significant.

3.2.1.3 Summary of STTD comparison with TDTD/PD

In appendix 1 an analysis of STTD advantages over TDTD/PD is presented. The summary of that is presented in the Table 3.

Table 3. Summary of STTD comparison to TDTD/PD.

Distinguishing	**points**		**Comments**
	STTD	TDTD/PD	
Forward link performance	0.6-1.0 dB better than TDTD/PD		
Forward link capacity, number of voice users/cell	17 % to 24 % more than TDTD/PD		
Forward link performance gains over ***no-diversity*** systems (vehicular, soft handoff)	0.6 dB, 1.25 dB gain	***0.0 dB, 0.2 dB gain***	Simulation results are by TI only
Base station PA balance	No issue	***Needs a controlled user assignment scheme for PA balance (not clear if it will work in practice)***	
Roundtrip power control delay	Less than 1 time slot (same as ND)	***Greater than 1 time slot***	
Power control during soft handoff from diversity to ND base station	Very simple No impact on ND power control	***Complicated: Needs two slot averaging even for ND base station***	
Reverse link performance	Up to 0.5 dB better		
Forward link rate determination	Better because of increased diversity for RI bits		
Robustness to single antenna failure	More robust: Automatic transition from STTD to ND mode	***Not robust: Transition from TDTD/PD to ND mode not automatic.***	
Diversity for perch channel/PCCPCH	Can be used	***Not proposed so far.***	
Capacity of closed loop antenna diversity systems on DPCH (when using STTD for perch channel/PCCPCH)	Higher capacity: Perch channel/PCCPCH pilot power not required to be increased by 3 dB.	***Lower capacity: Perch channel/PCCPCH pilot power required to be increased by 3 dB.***	Nominal improvement
Notification of diversity mode	Blind detection (on perch/ PCCPCH) or L3 can be used	***Only L3 mechanism proposed so far.***	
Channel estimation complexity	*Higher: 38.4 K operations/s*	Lower: 12.8 K operations/s	
MRC complexity per symbol	*Higher: 2L complex multiply, 2L complex add. L is number of paths*	Lower: L complex multiply, L complex add	
Common	**Points**		
Searcher complexity	Same	Same	
Despreading complexity	Same	Same	
Compatibility with ND systems	Same	Same	
Use on DPCH, common control channel/SCCPCH	Same	Same	

Compatibility with closed loop mode	Same	Same	
BS optional, UE mandatory	Same	Same	

3.2.1.4 Conclusions of open loop comparison

We can see that STTD has several advantages over TDTD/PD in terms of forward link capacity increase, base station PA balance, no impact on soft handoff and power control, use of diversity for perch channel/PCCPCH, improved reverse link performance and robustness to antenna failure. The increased mobile complexity for implementing STTD is very small and STTD is as compatible with feedback (closed loop antenna diversity) systems as TDTD/PD. Thus STTD will significantly enhance the system performance over no-diversity systems, when closed loop antenna diversity may not be used (high Doppler, soft handoff conditions).

On the other hand, TDTD/PD does not give any significant gains (only 0.0-0.2 dB gains) over ND systems for high Doppler and soft handoff conditions, the *critical* cases when closed loop antenna diversity may not be used. Further, there is the additional complexity of base station PA imbalance, increased forward link power control delay and degraded soft handoff (between diversity and ND base stations) performance.

3.2.2 Closed loop mode

A comparison of ETSI and ARIB closed loop downlink Tx diversity solutions is presented in the Table 4 [1, 2, 3]. Shadowed rows represent cases where a difference between the solutions have been identified.

Clearly, a lot of commonalities between the ARIB and ETSI solutions exist. Main differences are the number of closed loop operating modes and related parameters, antenna switching point in mode 1, Feed Back Information (FBI) signaling method and optionality of implementing the closed loop mode in mobile terminal.

In ARIB concept only one closed loop operation mode is defined. It is based on the so called Selective Transmit Diversity (STD) technique originally proposed in [11]. In ETSI the same solution is incorporated in mode 1. In addition, there are two other operation modes (modes 2 and 3) in ETSI scheme. They utilize phasing and/or amplitude weighting between the transmit antennas, and have been shown to provide better performance in certain radio channels when compared to mode 1 (e.g. for low speeds and/or with correlated fading between antenna branches). Unlike the other modes, Mode 2 also ensures the power is balanced between transmission antennas. Therefore we can say that ARIB solution is a subset of ETSI solution. Furthermore, ETSI solution is more flexible giving better overall performance.

One difference between ARIB and ETSI schemes is the antenna switching point in mode 1. In both cases, however, the switching is done in front of the pilot symbols and the difference exists only because of different slot structures of ARIB and ETSI concepts.

FBI, which corresponds to Antenna Selection (AS) command in ARIB, signaling method is also different. In ARIB solution the AS bit is punctured into TPC command. This preserves the format of other fields of the DPCCH with the drawback of higher error rate for TPC command. In ETSI solution a separate field is reserved for FBI command. The TPC command field remains intact but rest of the DPCCH needs to be reconfigured in order to incorporate the FBI field. This ETSI approach is more flexible, and in addition allows for future evolutions where more uplink signaling may be desirable e.g. in the case of more than two transmission antennas

Use of DL Tx diversity closed loop mode has been defined as an optional feature in Base Station (BS) both in ARIB and ETSI concepts. In UE, ARIB specification states that closed loop mode is mandatory for high-end terminals and optional for low cost terminals. Yet, this is still pending depending on the complexity studies of the closed loop mode.

In ETSI description there exist no definition whether the closed loop mode should be a mandatory or a optional feature in UE.

Table 4. Comparison of ETSI and ARIB DL Tx diversity closed loop modes. Shadowed rows indicate differences in the solutions.

Item	ETSI	ARIB	Comment
To be used on	Dedicated channels	Dedicated channels	
FBI signaling method	Separate FBI field	TPC puncturing	
Closed loop modes	1, 2, 3	1	
FBI command length	Mode 1: 1 bit Mode 2: 2 bits Mode 3: 4 bits	Mode 1: 1 bit Mode 2: N/A Mode 3: N/A	In ARIB term Antenna Selection (AS) command is used
FBI command rate	Mode 1: 1.6 kHz Mode 2: 0.8 kHz Mode 3: 0.4 kHz	Mode 1: 1.6 kHz Mode 2: N/A Mode 3: N/A	
Antenna switching point in mode 1	At slot boundary	In front of pilot field	Difference due to different slot format
UE: mandatory/optional	Not specified	Low end UE: optional Other UE: mandatory	
BS: mandatory/optional	Optional	Optional	
Antenna specific pilot pattern for mode 1	Yes	Yes	In ETSI the pattern is unspecified
Parallel pilots on PCCPCH	Yes	Yes	In ARIB term Perch channel is used
Mode control	Higher layer signaling	Higher layer signaling	

4. MERGE PROPOSAL FOR DL TRANSMIT DIVERSITY OF 3GPP

4.1 Basic proposal

It is proposed that both the open and closed loop DL Tx diversity modes are based on ETSI scheme, i.e. as described in [2, 3]. Specifically, this means that the STTD is applied as the open loop mode and combined STD and Tx AA is used in the closed loop mode. For open loop mode the case of more than two diversity antennas requires further studies.

4.2 Further considerations of the details of the basic proposal

As the ETSI scheme alone does not describe some of the items included in the ARIB specification and some of the details are missing further considerations are needed.

Regarding the signaling of FBI bits from UE to BS the ETSI description states that a separate FBI field is used. In Ad Hoc #7 there has been discussions about this same issue. The proposal from Ad Hoc #6 is to follow the ETSI solution, i.e. additional FBI field will be defined to uplink DPCCH and no puncturing of TPC command is done. If no closed loop Tx diversity is used the length of the FBI field is zero. If closed loop mode Tx diversity is applied one bit of information is transmitted per slot (in two antenna case). If there are more than two diversity antennas the number of FBI information bits per slot requires further studies. What is the actual slot format and length of the FBI field in time (or in number of channel bits) is outside the scope of Ad Hoc #6.

Another issue which was decided already in ARIB is whether open/closed loop modes should be mandatory features in UE/BS. Both in ARIB and ETSI there seem to be a wide consensus that DL Tx diversity should be an optional feature in BS. For UE, ARIB decided that support of open loop mode is mandatory. For closed loop the decision was to have it as a mandatory feature in high end terminals and as a optional feature in other terminals. What is high end terminal was not defined, though.

When considering the support of DL Tx diversity modes in UE an important factor is the possible additional implementation complexity. Earlier studies both in ARIB and ETSI have indicated that the additional base band implementation complexity due to open loop mode is very small. As some of the common DL channels may use open loop Tx diversity it is a natural requirement that all terminals must support the open loop Tx diversity operation. Therefore, it is proposed that in minimum, all the UEs must support the open loop DL Tx diversity.

When it comes to the closed loop mode in ARIB the additional UE implementation complexity of the RAKE was analyzed for TDTD/FB mode in [9]. The analysis indicated that for RAKE implementation the additional complexity if both open and closed loop modes are implemented is 18 %. As this is only for the RAKE implementation the complexity increase for the whole UE is much less, in the order of a few percentages. Yet, as the analysis was about the ARIB solution the results don't give a conclusive answer for the combined STD and Tx AA scheme. Therefore, our proposal is as shown in the Table 5.

Table 5. Proposed support of open and closed loop modes in UE and BS.

	UE	**BS**	**Comment**
Open loop	Mandatory	Optional	
Closed loop (modes 1, 2, 3)	Mandatory (see comment)	Optional	For UE this is the working assumption requiring further studies

Another issue is the application of the Tx diversity on different DL physical channels. In ETSI description it is stated that closed loop mode can be used on dedicated channels. Same solution has been adopted by ARIB. Moreover, in ARIB specification it has been defined that open loop can be used on dedicated channels and on common control physical channel(s) (i.e. SCCPCH). On Perch channel no Tx diversity was allowed.

The situation is now more complicated with the merged ETSI/ARIB baseline text draft. In Table 6, all the existing DL physical channels are listed according to [10]. Entries in the Table

6 with value X or N/A represent a merged ARIB/ETSI proposal. Entries with X* or N/A* indicate cases where no definitions can be found either from ETSI or ARIB specification except for PCCPCH for which ARIB solution exist. Thus, they can be considered as working assumptions on how to apply the open/closed loop modes on those channels. Clearly, those cases are FFS.

Table 6. Proposed application of open and closed loop modes on different downlink physical channels when UE is not in soft handover.

	PCCPCH	SCH	SCCPCH	DPCH	PDSCH	PSCCCH	AICH
Open loop	X*	N/A	X	X	X*	X*	X*
Closed loop	N/A	N/A	N/A	X	X*	N/A*	N/A*

N/A = Not applied
X = Can be applied
X* = Can be applied but requires further studies (working assumption)
N/A* = Not applied but requires further studies (working assumption)

Management of the use of various Tx diversity modes has not been described well neither in ETSI nor in ARIB specification. Both specifications state, however, that the decision of applying the Tx diversity on different DL channel is made by UTRAN access point. UE may assist the decision by sending higher layer commands/measurement reports to UTRAN access point. What kind of information is transmitted from UE to UTRAN access point is FFS.When UE is in Soft HandOver (SHO) both ETSI and ARIB specifications define that closed loop mode will not be used. Only open loop mode can be applied. A related optional technique, so called Site Selection Diversity Transmit (SSDT) power control has also been defined by both ARIB and ETSI. Control of both the DL Tx diversity and SSDT in the case of SHO is for FFS.

5. CONCLUSIONS

A comparison of ETSI and ARIB DL Tx diversity concepts is presented in this document. As a result of this comparison it is proposed that the 3GPP DL Tx diversity solution is based on ETSI scheme, i.e. as described in [2, 3]. Specifically, this means that the STTD is applied in the open loop mode and combined STD and Tx AA is used in the closed loop mode. For open loop mode the case of more than two diversity antennas requires further studies.

As the ETSI solution alone doesn't specify all the details, further proposals have been made regarding: support of Tx diversity mode in UE/BS and application of Tx diversity mode on different DL physical channels. In addition, it has been reminded that the control of the various Tx diversity modes requires some further studies. Moreover, the use of open loop Tx diversity and/or SSDT when the UE is in SHO needs to be clarified.

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APPENDIX 1. STTD ADVANTAGES OVER TDTD/PD

We now summarize all the STTD advantages over TDTD/PD based upon [4, 5].

1) ***Forward link capacity of STTD for voice users 17% to 24 % more than TDTD/PD:***

Link level simulations show that STTD outperforms TDTD/PD consistently by 0.6-1.0 dB (refer sections 4.0-4.8 in [5] and 3.0 in [4]). The link level simulations were done for a variety of environments namely, single path, two equal paths, indoor-to-outdoor pedestrian and the vehicular environment. Different framing conditions were simulated with rate matching including repetition and puncturing. The simulations included WMSA/Wiener channel estimation, power control and soft-handoff between two base stations. A summary of all the results is included in Table 7 of the present report. System level simulations based upon link level simulations showed that this translated into a forward link capacity gain for STTD over TDTD/PD by 17% to 24 % for voice users.

2) ***TDTD/PD has negligible capacity gains over no-diversity (ND) systems during soft handoff and high Doppler conditions:***

STTD has a performance gain of 0.6 dB and 1.3 dB over ND systems for high Doppler and soft handoff conditions (Figures 9 and 10 of [5]). On the other hand, the equivalent numbers for TDTD/PD over ND systems are 0.0 dB and 0.2 dB respectively (Figures 9 and 10 of [5]). This implies there is no advantage to using TDTD/PD, *even over ND systems*, for high Doppler and soft handoff conditions. Note that these are the two scenarios *where closed loop antenna diversity techniques are not applicable* and hence open loop diversity techniques may be preferred.

3) ***STTD is a power amplifier (PA) balanced scheme unlike TDTD/PD:***

STTD is a power-balanced technique therefore, base station PA balance is not an issue like the TDTD/PD scheme. For the TDTD/PD a symmetric/controlled time assignment [6, 7] scheme has been proposed to reduce the PA balance, but even then the peak to average ratio (PAR) for TDTD/PD is 0.5 dB worse than STTD. Notice that this requires additional overhead at the base station to find symmetric users. This could be a significant problem in practice because the symmetric/controlled time offset assignment has to be done dynamically. Thus it is unclear based on the results presented in [6, 7], if it is always possible to find a symmetric user due to conditions such as soft handoff and power variation amongst users due to shadowing and power control. Further, simulations in [8] indicate that even with symmetric time offset assignment, TDTD/PD PAR could be as worse as 2.0 dB with respect to power balanced schemes, for a small number of users.

4) ***Forward link power control delay for STTD is less than 1 time slot unlike TDTD/PD:***

The TPC bit for the forward link power control of STTD is generated in exactly the same way as the no-diversity (ND) systems by using a *one slot averaging*. Thus STTD maintains a less than 1 time slot roundtrip delay for forward link power control (like ND systems). On the other hand TDTD/PD needs to do a *two slot* averaging. Since two consecutive slots are used to generate the TPC bit, it gives rise to an additional *measurement* delay. Thus TDTD/PD cannot maintain a 1-time slot roundtrip power control delay even in the case of the mobile being near the base station. This results in an additional degradation for TDTD/PD (see power control simulations of section 4.3 of [5]). This degradation reduces the TDTD/PD capacity, which in turn affects cell coverage area, because of the reduced number of users that it supports.

5) ***STTD power control is transparent to soft handoff to/from diversity to no-diversity(ND) base stations unlike TDTD/PD***:

There is no impact on the STTD power control when doing a soft handoff to/from *diversity to non-diversity* base stations (section 5.1 of [5]). On the other hand, proponents for TDTD/PD do not give a concrete solution for TDTD/PD power control during diversity to ND base station soft handoff. The possible solution proposed in [7] for TDTD/PD is to have a two slot averaging even for the ND base station. But this will increase the forward link power control delay even for the ND base station, thus unnecessarily degrading its performance.

6) ***STTD on forward link improves reverse link performance over TDTD/PD***:

STTD yields full path diversity for the TPC symbol transmitted on the forward link, thus reducing the reverse link power control TPC errors. This results in improved reverse link performance of up to 0.5 dB (section 5.2 of [5]).

7) ***STTD improves forward link rate determination over TDTD/PD***:

STTD yields full path diversity to rate information (RI) bits, thus improving the probability of correct rate determination and thereby the quality of the link (section 5.3 of [5]).

8) ***Robustness to not receiving one of the diversity antenna paths over TDTD/PD***:

The only effect on STTD is loss of path diversity. The mobile would still be able to successfully receive data from the other diversity antenna path, implying that the STTD mode automatically shifts into a ND mode. On the other hand, in the case of TDTD/PD, this leads to an additional loss of 1.5 dB from the rate 1/3 to rate 2/3 code rate change. Further, the forward link rate determination and the reverse link power control are affected as half of the RI bits and TPC symbols are incorrect. This will cause major problems between the time the antenna failure is detected and the TDTD/PD mode is switched to the ND mode. Thus, the transition from TDTD/PD mode to ND mode is *not* automatic.

Some of the other salient points of STTD are as follows:

1) STTD uses the same orthogonal variable spreading factor (OVSF) code as ND scheme.
2) STTD can be used for the Dedicated Physical Data Channels and the common control channel of ARIB/the Secondary Common Control Physical Channel (SCCPCH) of ETSI. STTD may *also* be used for the perch channel of ARIB/the primary common control physical channel of ETSI (PCCPCH).

3) STTD is *as compatible* with the closed loop antenna diversity schemes proposed to ARIB/ETSI *as* TDTD/PD. In fact, the pilot symbol pattern when using STTD on the perch channel of ARIB/ PCCPCH of ETSI is the same, as that required for the closed loop mode to work on the dedicated physical channels. This would mean that the closed loop diversity schemes are not required to increase the pilot symbol power for the perch channel/PCCPCH by 3 dB. This will further (though nominally) increase the capacity of closed loop antenna diversity systems (when STTD is used over perch channel/PCCPCH) as against TDTD/PD.
4) STTD is backward compatible with ND systems (section 5.1 of [4]).

Summary of forward link performance gain of STTD over TDTD/PD based upon link and system level simulations [4, 5] is given in the following Table 7.

Table 7. Summary of STTD forward link performance gains over TDTD/PD based upon link/system level simulations [4, 5].

STTD gain over	Channel estimation	Power control	Soft handoff	Model	Data rate (kbps)	Physical channel rate (KSPS)	STTD gain (dB)	STTD capacity, voice users/cell	TDTD/PD, ND capacity voice users/cell	***STTD capacity increase, number voice users/cell***
TDTD/PD	Perfect	No	No	1	32	64	0.5			
TDTD/PD	Perfect	No	No	2	32	64	0.25			
TDTD/PD	Perfect	No	No	1	8	32	0.4			
TDTD/PD	Perfect	No	No	2	8	32	0.25			
TDTD/PD	WMSA	No	No	1	8	32	0.4			
TDTD/PD	WMSA	No	No	2	8	32	0.25			
TDTD/PD	Wiener	No	No	4	8	32	0.4			
TDTD/PD	Wiener	Yes	No	1	8	32	0.8			
TDTD/PD	WMSA	Yes	No	1	32	64	0.9			
TDTD/PD	WMSA	Yes	No	2	32	64	0.5			
TDTD/PD	WMSA	Yes	No	3	16	32	0.9			
TDTD/PD	WMSA	Yes	No	4	16	32	0.8			
TDTD/PD	WMSA	Yes	No	3	8	32	0.7	133	107	***26***
TDTD/PD	WMSA	Yes	No	5	8	32	0.6	120	100	***20***
TDTD/PD	WMSA	Yes	No	4	8	32	0.6	116	99	***17***
TDTD/PD	WMSA	Yes	Yes	3	8	32	1.0			
ND	Wiener	No	No	4	8	32	1.0			
ND	WMSA	Yes	No	3	8	32	3.0	133	57	***76***
ND	WMSA	Yes	No	5	8	32	1.25	120	87	***33***
ND	WMSA	Yes	No	4	8	32	0.6	116	99	***17***
ND	WMSA	Yes	Yes	3	8	32	1.25			

Model 1: 1 path, 3 Km/h
Model 2: 2 Equal paths 120 Km/h
Model 3: Indoor to outdoor Pedestrian, 3 Km/h
Model 4: Vehicular, 120 Km/h
Model 5: Vehicular 60 Km/h