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Title: Delay diversity for the BCH of TDD

1.0 SUMMARY

In [1] space-time transmit diversity (STTD) has been proposed as the open-loop diversity technique for the downlink. As shown by the simulation results, STTD yields good diversity gains. However, the principal drawbacks of STTD for TDD are:

(1) Conjugates of the data symbols are transmitted on the second antenna, and a linear detector such as the ZF-BLE can not efficiently handle these conjugates. Hence, there is a significant increase in the mobile complexity.

(2) An extra channel estimate is required for each antenna of every user that is STTD encoded.

(3) When STTD is to be used for the dedicated physical channel, the mobiles need to know which channels are STTD encoded, so there must be a method for the base station to notify all the users which channels are STTD encoded. That is why STTD was only proposed for the broadcast channel (BCH) in [2].

(4) It is possible to slightly reduce the complexity of STTD ZF-BLE by implementing an approximate STTD ZF-BLE as proposed in [2]. However, when the STTD encoded channel has higher power than the rest of the channels, the entire STTD signal may not be cancelled by the approximate ZF-BLE. This leads to a loss in diversity gains for the approximate STTD ZF-BLE. Further, even implementing an approximate STTD ZF-BLE for the BCH gives about 25 % increase in the ZF-BLE complexity.

Hence a modification of the STTD, namely the block-level STTD was proposed in [3]. However the block level STTD continues to suffer from similar drawbacks ((2), increased complexity as in (4) above). Hence, we propose a new open loop diversity scheme for TDD mode based upon delay diversity (DD) [4] to solve the above problems. The advantages of this scheme are:

1) The diversity gain for DD with midamble-based channel estimation is about 0.5 dB for the Vehicular B channel and 2.5 dB for the Outdoor-to-Indoor and Pedestrian channel. *Thus the diversity gains of DD are comparable to those with STTD [1].*
2) Using DD for the BCH gives only a *0%-5% increase in ZF-BLE complexity* depending upon the number of traffic channels and the implementation of the ZF-BLE.
3) The DD *does not require an extra midamble position for the channel estimation* for the second antenna.
4) The use of *DD at the base station is transparent to the mobile*, implying that no signaling is required to notify the mobile about the presence/absence of the diversity antenna.
5) Based upon (3) and (4) above we can see that in addition to the BCH, it is possible to use the DD on the dedicated physical channels (DPCH). The use of DD on DPCH complements the closed-loop diversity techniques implying that DD can be used when closed-loop diversity is not feasible on DPCH due to high Doppler rate. *Since*

the use of both the DD and the closed-loop diversity is transparent to the user, the base station based on uplink measurements can employ the best diversity technique for the downlink.

Thus we obtain a significant diversity gain in E_b/N_o for the BCH with a small increase in mobile complexity and with no extra channel estimation. Hence we propose that delay diversity be chosen as the diversity technique for the BCH of the TDD systems.

2.0 DELAY DIVERSITY (DD) for the BCH

Delay diversity [4] is a diversity technique in which the information for the user is transmitted from two different antennas with a time delay between them. Figure 1 gives a block diagram of how delay diversity can be implemented at the base station for the BCH.

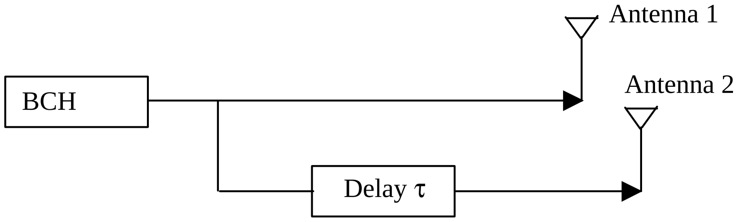

Figure 1: The delay diversity applied to the broadcast channel (BCH) is shown. The delay t is in chips and is set by the base station operator. It is set to 2 chips in the simulations.

3.0 SIMULATION RESULTS

Table 1 gives the simulation parameters used for the 5-user equal power case simulation:

	Vehicular	Outdoor-to-Indoor and Pedestrian
Velocity	120 kmph (Figure 2)	3 kmph (Figure 3)
Spreading gain (SF)	16	16
Number of users (all equal power)	5 1 BCH and 4 DPCH	5 1 BCH and 4 DPCH
Channel estimation	512 chip midamble	512 chip midamble
Delay diversity	Only on BCH	Only on BCH
Delay τ (chips)	2	2
Joint detection	ZF-BLE	ZF-BLE
Diversity gain for BCH over no-diversity (ND, Figures 2, 3)	***0.5 dB*** at raw BER = 0.1	***2.5 dB*** at raw BER = 0.01
Complexity increase for DD ZF-BLE over ND ZF-BLE (Tables 4, 5)	***5.1 %***	***5.1 %***

Table 1: The simulation parameters and results for DD for BCH

Figures 2 and 3 show the gain achieved by using delay diversity only on the broadcast channel. The other 4 channels have power equal to the broadcast channel and they do not use delay diversity. Figure 2 shows a diversity gain of 0.5 dB on the BCH for the Vehicular B channel. The other 4 DPCH channels show a small loss of 0.1 dB compared to the case where no delay diversity is used. This occurs because delay diversity introduces extra paths and thus more interference to the other users, and the ZF-BLE does not perfectly cancel this interference. Figure 3 shows a gain of 2.5 dB on the BCH when delay diversity is used on the BCH for the Outdoor-to-Indoor and Pedestrian channel. Also, there is a small loss of 0.2 dB on the other channels compared to the case where no delay diversity is used.

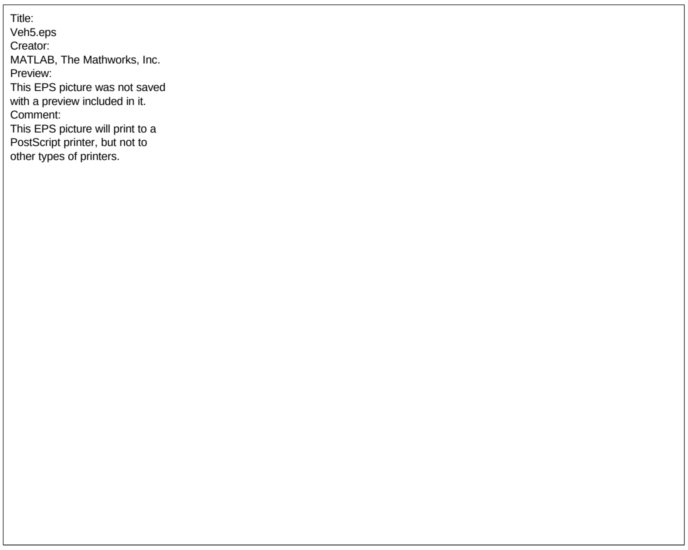

Figure 2: Link level simulations comparing the BER performance for the ZF-BLE with and without delay diversity on the BCH for the Vehicular B channel. The spreading gain is 16 and the total number of channels is 5. The gain for delay diversity is 0.5 dB at a BER of 0.10.

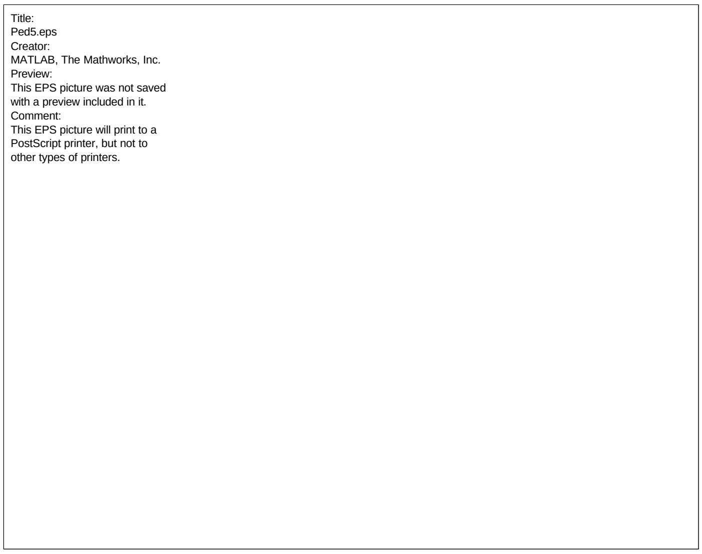

Figure 3: Link level simulations comparing the BER performance for the ZF-BLE with and without delay diversity on the BCH for the Outdoor-to-Indoor and Pedestrian channel. The spreading gain is 16 and the total number of channels is 5. The gain for delay diversity is 2.5 dB at a BER of 0.01.

The BCH may sometimes be at a much higher power than the DPCH. Table 2 and

Figures 4 and 5 give the simulation results for this case:

	Vehicular	Outdoor-to-Indoor and Pedestrian
Velocity	120 kmph (Figure 4)	3 kmph (Figure 5)
Spreading gain (SF)	16	16
Number of users BCH 10 dB higher, all DPCH equal power	5 1 BCH and 4 DPCH	5 1 BCH and 4 DPCH
Channel estimation	512 chip midamble	512 chip midamble
Delay diversity	Only on BCH	Only on BCH
Delay τ (chips)	2	2
Joint detection	ZF-BLE	ZF-BLE
Diversity gain for BCH over no-diversity (ND, Figures 4, 5)	***0.7 dB*** at raw BER = 0.1	***3.0 dB*** at raw BER = 0.01
Complexity increase for DD ZF-BLE over ND ZF-BLE (Tables 4, 5)	***5.1 %***	***5.1 %***

Table 2: The simulation parameters and results for DD for BCH with 10 dB higher power than the DPCH

Figures 4 and 5 show the diversity gain achieved by using delay diversity on the BCH with 10 dB higher power. The other 4 channels have equal power and they do not use delay diversity. Figure 4 shows a diversity gain of ***0.7 dB*** on the BCH for the Vehicular B channel. The other 4 DPCH channels show a loss of 0.3 dB compared to the case where no delay diversity is used on BCH. This occurs because delay diversity introduces extra paths and thus more interference to the other users, and the ZF-BLE does not perfectly cancel this interference. Figure 5 shows a gain of ***3.0 dB*** on the BCH when delay diversity is used on the BCH for the Outdoor-to-Indoor and Pedestrian channel. Also, there is a loss of 0.4 dB on the other channels compared to the case where no delay diversity is used on BCH.

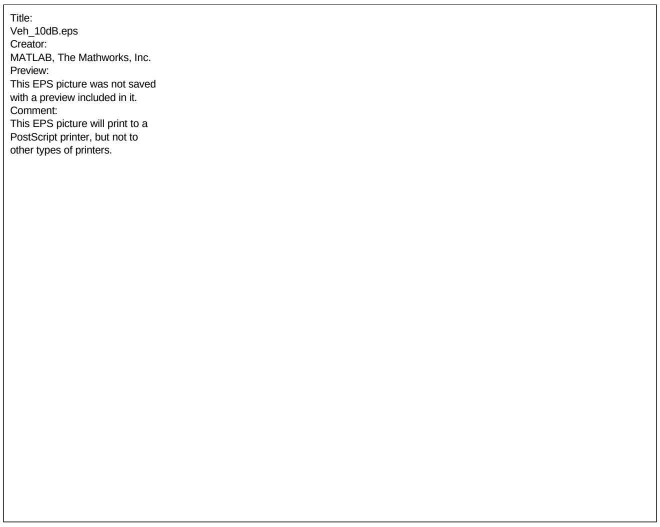

Figure 4: Link level simulations comparing the BER performance for the ZF-BLE with and without delay diversity on the 10 dB higher BCH for the Vehicular B channel. The spreading gain is 16 and the total number of channels is 5. The gain for delay diversity is 0.7 dB at a BER of 0.10.

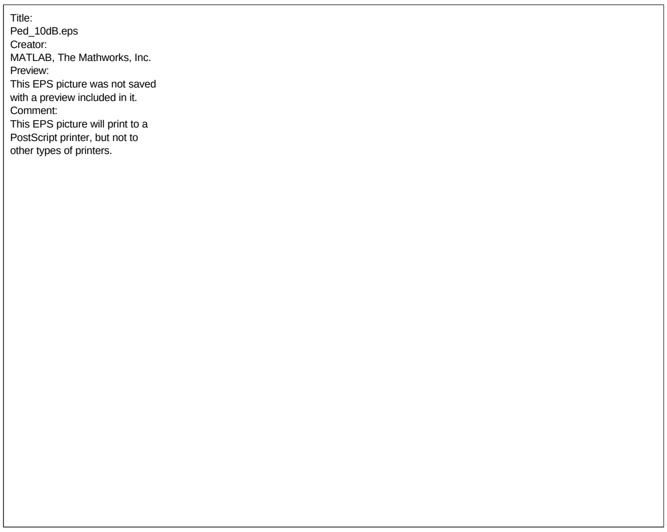

Figure 5: Link level simulations comparing the BER performance for the ZF-BLE with and without delay diversity on the 10 dB higher BCH for the Outdoor-to-Indoor Pedestrian A channel. The spreading gain is 16 and the total number of channels is 5. The gain for delay diversity is 3.0 dB at a BER of 0.01.

4.0 COMPLEXITY ANALYSIS

The parameters used for calculating the complexity are given in Table 3.

Parameter	
Number of fingers	4
Spreading gain	16
Number of slot/sec.	100
Operations for one complex add	2
Operations for one complex multiply	4
Operations for one divide	10
Number of channels	5
Number of symbols /slot	122
Impulse response length (chips)	57

Table 3: The parameters used in the computation of the complexity for the ZF-BLE are shown.

Table 4 gives an analysis of the complexity for the ZF-BLE with and without the DD on BCH if the mobile takes a ***finger based approach for joint detection***.

	Million operations/sec. (MOPS) for no-DD for BCH		Million operations/sec. (MOPS) for DD for BCH	
Despreading (AH*e) (finger approach)		7.8		9.4
Computation of AH*A		1.8		1.8
Cholesky(block KL*KL)		2.0		2.0
Solving for d (forward equation)				
Multiplication	6.1		6.1	
Subtraction	3.0		3.0	
Division	0.6		0.6	
Total for forward equation (Multiplication + Subtraction + division)		9.7		9.7
Total for backward equation (Multiplication + Subtraction + division)		9.7		9.7
Total MOPS		***31.0***		***32.6***

Table 4: Complexity analysis of using delay diversity for the broadcast channel (BCH) when the mobile takes a finger based approach for joint detection. We can see that the total complexity increase for the DD ZF-BLE over the no-DD ZF-BLE is 5.1 %. A similar analysis for 8 channels (1 DD BCH + 7 DPCH) shows that the complexity increase of the ZF-BLE by employing DD on BCH is only 2%.

Table 5 gives an analysis of the complexity for the ZF-BLE with and without the DD on BCH if the mobile takes a ***thresholding approach for joint detection***.

	Million operations/sec. (MOPS) for no-DD for BCH		Million operations/sec. (MOPS) for DD for BCH	
Despreading (AH*e) (thresholding approach)		17.8		17.8
Computation of AH*A		1.8		1.8
Cholesky(block KL*KL)		2.0		2.0
Solving for d (forward equation)				
Multiplication	6.1		6.1	
Subtraction	3.0		3.0	
Division	0.6		0.6	
Total for forward equation (Multiplication + Subtraction + division)		9.7		9.7
Total for backward equation (Multiplication + Subtraction + division)		9.7		9.7
Total MOPS		***41.0***		***41.0***

Table 5: Complexity analysis of using delay diversity for the broadcast channel (BCH) when the mobile takes a thresholding approach for joint detection. We can see that the total complexity increase for the DD ZF-BLE over the no-DD ZF-BLE is 0 %.

5.0 Comparison of DD to block-level STTD

Table 6 below gives the comparison of the DD to the block-level STTD applied to the BCH.

	DD	Block-level STTD
Channel estimation	***1 midamble sufficient for both the antennas***	2 midambles are needed
Complexity increase for ZF-BLE using finger based approach (5 users)	***5 %***	4 %- 20% depending upon impulse response length
Complexity increase for ZF-BLE using threshold based approach (5 users)	***0 %***	4 % to 20 % depending upon impulse response length
Performance gain over ND , Pedestrian A with midamble based channel estimation (same power allocated for channel estimation for both schemes)	2.5 dB gain	2.6 dB gain
Performance gain over ND , Vehicular B with midamble based channel estimation (same power allocated for channel estimation for both schemes)	0.5 dB	0.7 dB
Transparency to mobile	***Transparent***	Not transparent
Use on DPCH	***Possible***	Not possible

Table 6: Comparison of the DD to the STTD scheme applied to the BCH is shown.

As shown in Table 6, DD applied to the BCH gives a *slightly lower diversity gain* (0.1-0.2 dB) as compared to the STTD applied to the BCH. *However, the advantage of the DD applied to the BCH is the single midamble required for channel estimation, its lower complexity and its transparency to the mobile.*

6. 0 CONCLUSION

Application of delay diversity on the BCH shows significant diversity gains comparable to STTD (0.5 dB for the Vehicular and 2.5 dB for the pedestrian channel) without significant increase in the ZF-BLE complexity (0%-5.1 % increase for 5 channels and 0%-2 % for 8 channels). The application of DD for the BCH thus solves the following problems, which are present when STTD is used:

(1) The complexity increase for the DD ZF-BLE is lower than the complexity increase of the approximate ZF-BLE for block STTD.
(2) A single midamble position is required for the channel estimation from both the antennas as against STTD for which 2 midamble positions are required.
(3) No notification to the mobiles about the presence/absence of the diversity antenna is required implying that application of DD is transparent to the user.

Thus, since we obtain a significant diversity gain in E_b/N_o for the BCH with no extra channel estimation and for a small increase in mobile complexity, we propose that delay diversity be chosen as the diversity technique for the BCH of the TDD systems.

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[1] Texas Instruments, “Open loop downlink transmit diversity for TDD: STTD for)572, Cheju, Korea, June 1-4, 1999.

[2] Texas Instruments, “STTD for the BCH of TDD”, TSGR1#6(99)971, Espoo, Finland, July 13-16, 1999.

[3] Motorola and Texas Instruments, “STTD applied to broadcast channels of the TDD)994, Espoo, Finland, July 13-16, 1999.

[4] N. Seshadri and J. Winters, “Two signaling schemes for improving the error performance of frequency-division-duplex (FDD) transmission systems using transmitter antenna diversity,” Vehicular Technology Conference, 1993, pp. 508-511.

------------------------Text proposal for S25.224--

4.8 Downlink Link Transmit Diversity

Transmit diversity in the forward link provides means to achieve similar performance gains as the mobile-station receiver diversity without the complexity of a second mobile-station receiver. Furthermore, transmit diversity improves the SIR and increases the system capacity. Depending on the mobile station’s distance to the base station, its speed, and the asymmetry ratio, selective transmit diversity (STD) can be employed.

With STD, the received signal power of uplink is measured for each of the antennas at the BTS over every single uplink interval (1 slot). The antenna with the highest signal level is used to transmit the downlink information for that link during the next interval over which the carrier is used for the downlink (1 or more slots). The basis for the gains from this type of diversity is the availability of information on the channel due to the use of the same frequency for uplink and downlink. STD is applied only to dedicated physical channels. STD can be applied if the distance between the different transmit antennas is small enough so that the delay profile from each antenna is almost the same.

<Editors Note: Other TX diversity schemes such as ~~schemes for common channels and~~ TXAA are ffs>

4.8.1 Downlink Transmit Diversity for Common Channels

Delay diversity (DD) is used for the common control channels. The DD scheme is shown in the following figure:

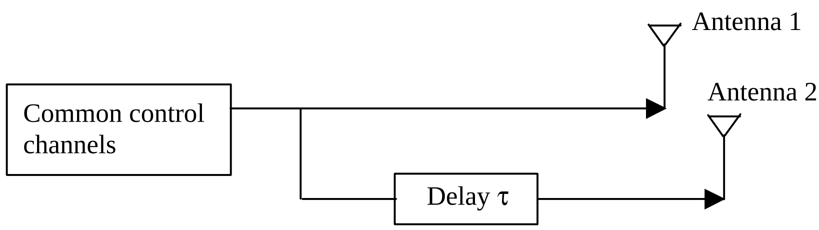

Figure: Application of delay diversity to common control channels is shown. The delay t is set by the base station operator and can range from 2-8 chips.