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Source: Motorola

Title: Complexity of Multiple channel estimations at the SU

Document for: Discussion

1 Introduction

Document [1] presented in 3GPP RAN WG1#3 showed the benefits of implementing Transmit Diversity schemes in the TDD mode. Implementation of Tx Diversity schemes using channel information (i.e. STD, TxAA) in the TDD mode will need multiple channel estimations at the SU. Current system specifications need only one channel estimation at the SU since all codes are transmitted over the same channel. However, when considering the implementation of STD or TxAA at the BS and JD at the SU, the SU unit has to be able to perform a different channel estimation for each one of the users accessing the slot. That comes from the fact that the physical channel (the same for all the codes) has been modified applying weights at the Tx side which are user dependent and are unknown at the SU.

This document intends to answer some of the questions that were raised in last meeting about the complexity of the multiple channel estimation algorithm.

2 Multichannel estimation algorithm description

Multiuser channel estimation is already implemented in the uplink of the TDD mode. The proposed algorithm [2] is based on DFT computations. The received midamble sequence undergoes the following transformations:

- DFT of the sequence
- Weighting of the sequence in the frequency domain
- Inverse DFT

The complexity of this algorithm can be approximated as twice the complexity of a DFT (complexities of DFTs and inverse DFTs are the same).

3 Complexity of a DFT of N points

DFTs are easily implemented using FFTs when the number of points (N) is a power of 2. FFT implementation needs approximately of Nlog2(N) floating point operations. However, DFT implementation becomes more complex when N does not verify the property stated before. In the following two different DFT implementation methods are introduced:

- **Method 1:** Document [3] describes an algorithm which implements DFTs of sequence of length N with a complexity 4*Mlog2(M), where M is the nearest power of two bigger than N.
- **Method 2:** If N=X*Y were X,Y are integers and Y is a power of two, the DFT of N can be performed by means of X FFTs of Y points plus Y DFTs of X points. This method leads to lower complexities than the previous one if X is a small integer.

DFT algorithms can be easily parallelized and the resulting complexity in number of processor cycles can be significantly lower than the number of MIPS.

4 Complexity of the channel estimation algorithm

Two different types of burst have been standardized for the TDD mode. The first one has a midamble of 512 chips and the second one a midamble of 256 chips. Short midambles are used in the uplink when there is a small number of users (up to 3) and in the downlink when Tx Diversity is not used. Complexity of channel estimation using these sequences is studied in the following.

- The **long midamble** sequences are generated using a sequence of length N=456. This figure can be decomposed in 57*8 (X=57, Y=8). It can be seen that X is a quite big figure and will lead to high DFT implementation complexity. However, channel estimation complexity can be significantly reduced if the original sequence is reduced to N=448 chips, N=7*64 (X=7,Y=64).
- The **short midamble** sequences are generated using a sequence of length N=192. A priori, this sequences are not intended to be used for more than 3 users. However, they are long enough to provide 8 channel estimations of 24 chips (5.85μs) . This is sufficient in indoor and pedestrian A,B and vehicular A channels. In this case N can be decomposed in 3*64 (X=3, Y=64), leading to efficient DFT implementation.

  The drawback of using the short sequence to estimate 8 channels is that generated midambles are of length 215. That means that 41 midamble chips will have to be filled with dummy bits.

Error! Unknown switch argument. summarizes the number of operations needed to implement channel estimation (assumptions: Only one code is assigned to the user (i.e. only one channel estimation per frame), 6 instructions per complex multiply and add, When Tx Diversity is not implemented channel estimation is performed by means of a correlator):

*Estimated with method 1, * * Estimated with method 2*

	No Tx Diversity, short midamble	No Tx Diversity, long midamble	Tx Diversity, short midamble	Tx Diversity, long midamble	Tx Diversity, long midamble
Number of points	192	456	192	456	448
DFT complexity			1728**	18432*	5824**
MIPS approx.	**1.25**	**2.6**	**1.38**	**14.7**	**4.6**

Table Error! Unknown switch argument. **: Channel estimation complexity**

As an indication, the number of cycles needed for a 456 point DFT can be approximately estimated in about 5 Mcycles/s. Note that this has to be taken as an indicative figure and that may be reduced by DSP algorithm implementation experts. The complexity of a Joint Detector when there are 8 active users is approx. 70 MIPS.

5 Conclusion

This contribution analyzed the complexity of the multiple channel estimation algorithm used in the uplink of the TDD mode. This algorithm will have to be implemented at the SU if STD or TxAA are used at the BS.

It has been shown that reducing the long midamble sequences from 456 to 448 chips will lead to a significant complexity reduction of the channel estimation algorithm. Therefore, previous analysis strongly suggests to replace the long sequences specified in the S1 documents by a new set of length 448. That will lead to BS complexity reductions and, in the case that Tx diversity is accepted, we will find the same benefits at the SU.

6 References

[1] Motorola, R1-99186, "Tx Diversity schemes applied to the TDD mode"

[2] Steiner, Jung, "Uplink channel estimation in synchronous CDMA systems with Joint Detection" PIMRC'93, Yokohama.

[3] Bayley, Swarztrauber, "The fractional Fourier Transform and Applications". October 1990. http://science.nas.nasa.gov/Pubs/TechReports/RNRreports/dbailey/RNR-90-004/RNR-90-004.o.html