Agenda item:	AH24 : High Speed Downlink Packet Data Access
Source:	Lucent Technologies, Nokia
Title:	Text contribution on MIMO physical layer description
Document for:	Proposed text contribution for TR

1. INTRODUCTION

We propose text for sections 5.4 and 6.5 in the HSDPA TR [1].

2. PROPOSED TEXT: SECTION 5.4 [MULTIPLE INPUT MULTIPLE OUTPUT ANTENNA PROCESSING]

Diversity techniques based on the use of multiple downlink transmit antennas are well known; second order applications of these have been applied in the UTRA Release 99 specifications. Such techniques exploit spatial and/or polarisation decorrelations over multiple channels to achieve fading diversity gains.

Multiple input multiple output (MIMO) processing employs multiple antennas at both the base station transmitter and terminal receiver, providing several advantages over transmit diversity techniques with multiple antennas only at the transmitter and over conventional single antenna systems. If multiple antennas are available at both the transmitter and receiver, the peak throughput can be increased using a technique known as code re-use. With code re-use, each channelization/scrambling code pair allocated for HS-DSCH transmission can modulate up to M distinct data streams, where M is the number of transmit antennas. Data streams which share the same channelization/scrambling code must be distinguished based on their spatial characteristics, requiring a receiver with at least M antennas. In principle, the peak throughput with code re-use is M times the rate achievable with a single transmit antenna. Third, with code re-use, some intermediate data rates can be achieved with a combination of code re-use and smaller modulation constellations e.g. 16 QAM instaead of 64 QAM. Compared to the single antenna transmission scheme with a larger modulation constellation to achieve the same rate, the code re-use technique may have a smaller required Eb/No, resulting in overall improved system performance. The technique discussed so far is an *open-loop* technique since the Node B transmitter does not require feedback from the UE other than the conventional HSDPA information required for rate determination. Further performance gains can be achieved using *closed-loop* MIMO techniques whereby the Node B transmitter employs feedback information from the UE. For example, with knowledge of channel realizations, the Node B could transmit on orthogonal eigenmodes, eliminating the spatial multiaccess interference.

~~With conventional single antenna transmitters, a high data rate source is demultiplexed into N lower rate substreams, and the nth substream (n = 1 … N) is spread with spreading code n (where the spreading codes indexed by n = 1 … N are mutually orthogonal). These substreams are summed together, scrambled and transmitted. A multiple antenna transmitter with M antennas is shown in Figure 2. It represents a typical transmitter for the multiple-input multiple-output (MIMO) antenna processing technique. The high data rate source is demultiplexed into MN substreams, and the nth group (n = 1 … N) of M substreams is spread by the nth spreading code. The mth substream (m = 1 … M) of this group is transmitted over the mth antenna so that the substreams sharing the same code are transmitted over different~~

~~antennas. These M substreams sharing the same code can be distinguished based on their spatial characteristics at the receiver using multiple antennas and spatial signal processing. Typically, the receiver must have at least M antennas to detect the signals sufficiently well; however, it is possible to perform detection using fewer than M antennas if more sophisticated detection algorithms are used.~~ [Move transmitter block diagram to section 6.5].

3. PROPOSED TEXT SECTION 6.5 [PHYSICAL LAYER IMPACT OF MIMO]

We focus on the open loop MIMO implementation as a respresentative technology. The performance results given later are based on this implementation. In a conventional single antenna HSDPA transmission, a set of *N* downlink physical channels (codes) is shared among many users. Using an open loop MIMO architecture with *M* transmit antennas, the same set of codes is used; however each code is re-used *M* times and each modulates distinct data substreams. More specifically, a high rate data source is coded, rate-matched and interleaved. As seen in the figure below, this coded data stream is then demultiplexed into *MN* substreams, and the *n*th group ($n = 1 \dots N$) of *M* substreams is spread by the *n*th spreading code. The *m*th substream ($m = 1 \dots M$) of each group is summed and transmitted over the *m*th antenna so that the substreams sharing the same code are transmitted over different antennas. Mutually orthogonal dedicated pilot symbols are also added to each antenna's common pilot channel (CPICH) to allow for coherent detection. For $M = 2$ or 4 antennas, the pilot symbol sequences for, respectively, 2 antenna STTD or 4 antenna close-loop transmit diversity can be used.

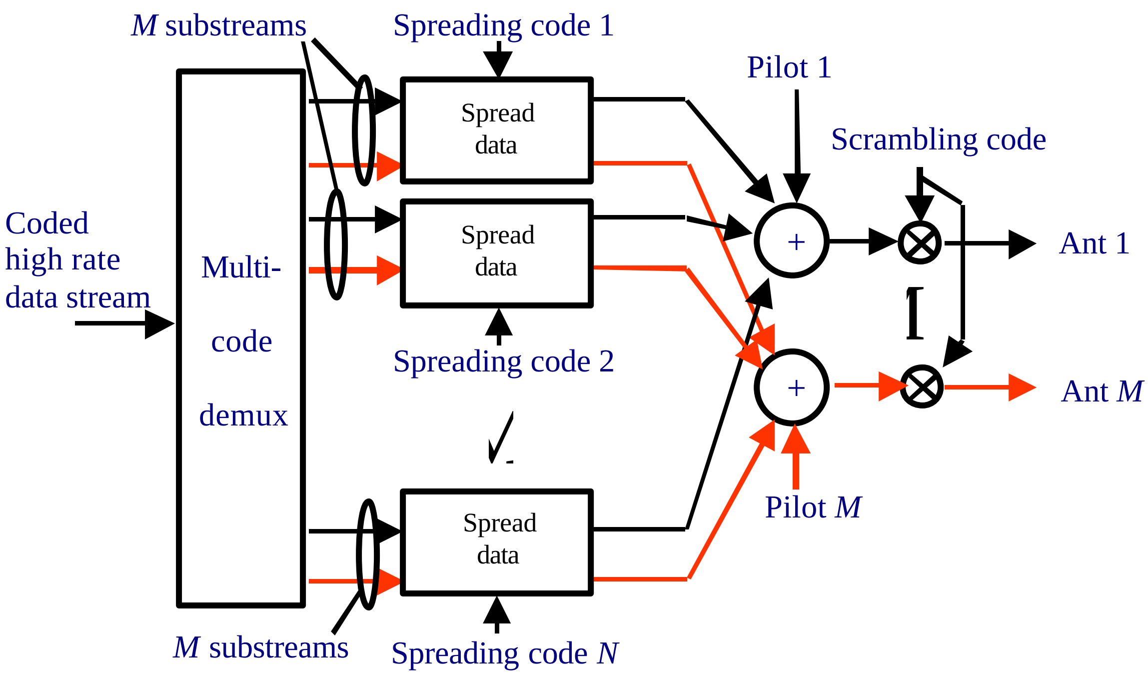

Figure X. Block diagram of MIMO transmitter

To distinguish the *M* substreams sharing the same code, the UE uses multiple antennas and spatial signal processing. A representative MIMO receiver with *P* antennas is shown in the figure below. For coherent detection at the UE, complex amplitude channel estimates are required for each transmit/receive antenna pair. In a flat fading channel, the channel is characterized by *MP* complex channel coefficients. In frequency selective channels, the channel is characterized by *LMP* coefficients where *L* is the number of rake receiver fingers. Channel estimates can be obtained by correlating the received signals with the *M* orthogonal pilot sequences. Compared to a conventional single antenna receiver, the channel estimation complexity is higher by a factor of *M*. For data detection, each antenna is followed by a bank of filters matched to the *N* spreading codes. In general, there would be *LN* despreaders per antenna. For each of the *MN* distinct data substreams, the *LP* corresponding despreader outputs are each weighted by the complex conjugate of its corresponding channel estimate and summed together to form a sufficient statistic. This procedure is known as a space-time rake operation and is simply the multiple antenna generalization of the conventional rake combiner.

The sufficient statistics of *M* substreams sharing the same code would each be contaminated by spatial multiaccess interference (MAI). However in flat fading channels, as a group, these substreams are not affected by the substreams transmitted on the other codes because the code orthogonality is maintained by the channel. For each group of *M* co-code substreams, a multiuser detector is used to remove the effects of the MAI. Examples include the maximum likelihood (ML) detector and the Vertical BLAST (V-BLAST) detector. The ML detector can be derived in a straightforward manner from the noise covariance of the sufficient statistic vector. Because the ML complexity is exponential with respect to *M*, the sub-optimal but less complex V-BLAST detector is a viable alternative. This well-known MIMO detector consists of two components: a linear transformation and an ordered successive interference canceller. The linear transformation eliminates MAI and can be based on a zero-forcing or minimum mean squared error (MMSE) criterion. Following the transformation, the coded symbols of the substream with the highest signal to noise ratio (SINR) are detected, and its signal is subtracted from the sufficient statistics. Using this revised sufficient statistic vector, the linear transformation and ordered successive interference cancellation are repeated until all substreams have been detected. Following the MIMO detector, the *MN* substreams are multiplexed into a single high data rate stream, demapped to bits, deinterleaved, and decoded.

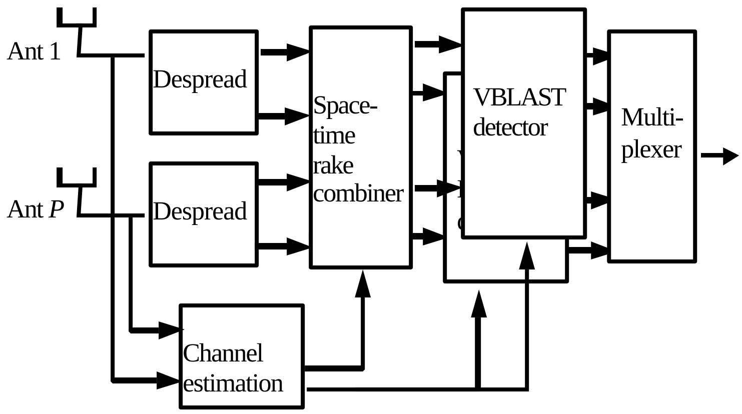

Figure Y. Block diagram of a MIMO receiver

Besides the method above there exists other solutions to implement MIMO. As another example figures a and b describes punctured scheme which operates without advanced receiver structures needed in the UE. STTD transmission is applied to compensate for the performance degradation due to puncturing. The receiver is a conventional dual-antenna RAKE, no spatial processing is done for interference cancellation or other purposes; only maximal-ratio combining is applied over the antennas.

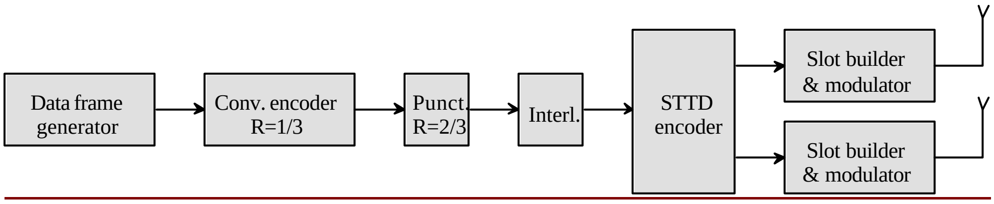

Figure a. Transmitter for the punctured scheme achieving a double data rate.

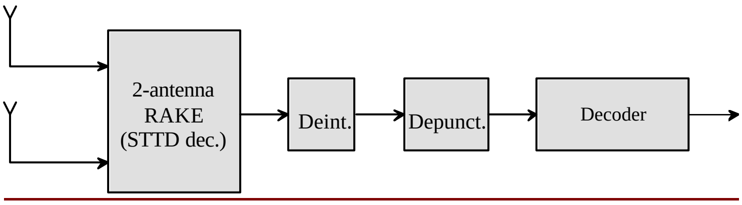

Figure b. Receiver for the punctured scheme.

Different methods are to be compared taken into account the receiver complexity and achievable performance. Unless otherwise noted, the simulation results presented in this TR are achieved with the ML receiver (for two antenna MIMO transmission) and the V-BLAST receiver (for four antenna MIMO transmission).

4. REFERENCES

[1] 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical Layer Aspects of UTRA High Speed Downlink Packet Access; (Release 2000), (3G Technical Report (TR) 25.848, version 0.2.1), Tdoc R1-01-0117, TSG-RAN WG1; January 15th-18th, 2001, Boston, USA.