Agenda Item:

Source: Nokia[1]

Title: Double data rate for FDD downlink through channel code puncturing in MIMO channels

Document for: Discussion

1. Introduction

The use of high-order modulation and layered schemes have been proposed for high-speed packet access. Both 16-QAM and dual-antenna layered schemes, such as BLAST, can be applied for achieving double data rate when compared to normal QPSK transmission in UTRA FDD downlink. We propose a simple scheme where the rate-1/3 channel code is punctured to rate 2/3 resulting in a double user data rate. The performance penalty is compensated for by applying STTD transmission and dual-antenna RAKE. In a (2, 2) MIMO-channel, the technique achieves better performance than a more complex layered scheme resembling so-called V-BLAST [3].

2. Punctured Scheme

The transmitter for the proposed punctured scheme is shown in Figure 1. We assume 1/3-rate convolutional channel code which is then punctured to rate 2/3 to double the user data rate. An optimized 2/3-rate convolutional code could also be used as well. However, with puncturing a different channel encoder/decoder is not necessary. After interleaving over one frame (10 ms), STTD encoder is used for transmit diversity. Two uncorrelated transmit antennas are used.

The receiver is a conventional dual-antenna RAKE, see Figure 2. No spatial processing is done for interference cancellation or other purposes; only maximal-ratio combining is applied over the antennas. The antennas are assumed to be uncorrelated. Channel is estimated using CPiCh the power of which is equally divided between the transmit antennas, which are assigned orthogonal pilot sequences. Signal processing at the receiver follows the normal approach applied for punctured channel codes.

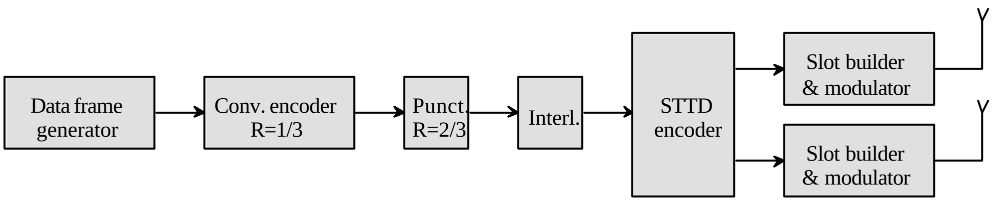

Figure 1. Transmitter for the punctured scheme achieving a double data rate.

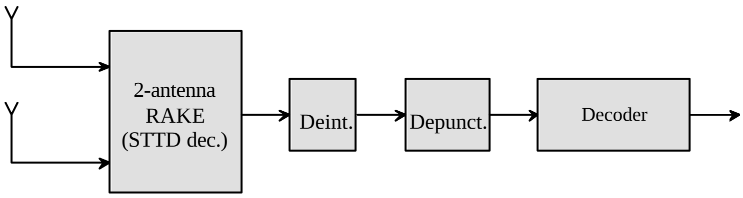

Figure 2. Receiver for the punctured scheme.

[1] Within METRA project (Multiple Element Transmit and Receive Antennas) of the framework of the European IST (Information Society Technologies) [1].

3. Layered Scheme

We compare the punctured scheme to a layered scheme also doubling the data rate. The transmitter for the layered scheme is shown in Figure 3. The input data bits are divided by serial-to-parallel converter (S/P) between two independent parallel streams, which are convolutionally encoded and transmitted from two uncorrelated antennas. This kind of technique is generally known as BLAST [2][3].

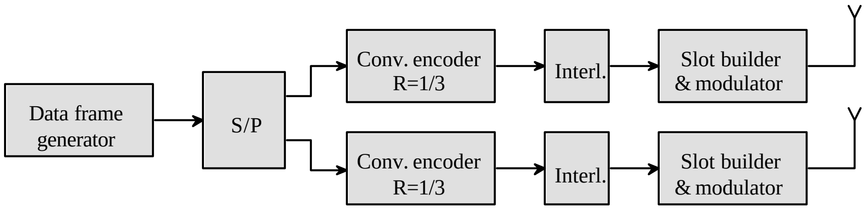

Figure 3. Transmitter for the layered scheme achieving a double data rate.

Receiver for the layered scheme is illustrated in Figure 4. Channel is estimated in the same way as for the punctured scheme (i.e. as for STTD). Since the two parallel data streams are strongly interfering with each other, we apply a dual-antenna linear minimum mean-square error (LMMSE) receiver to suppress the interference from the overlaying signal. The LMMSE-1 receiver selects which of the transmit antennas should be detected first. This is done by selecting antenna a_1 which is given by

$$a_1 = \arg\max_a \left\{ \left\| \begin{bmatrix} \mathbf{h}_{a,1} \\ \mathbf{h}_{a,2} \end{bmatrix} \right\|^2 \right\} \qquad (1)$$

where $\mathbf{h}_{a,b}$ is the estimated channel impulse response vector from TX antenna a to RX antenna b. This can be consided as a simple technique for near-optimal antenna selection in the sense that the post-detection MSE (mean-square error) is minimized. This is especially true in case of fading channels which are close to single-path channel (such as PedA). LMMSE-1 detects the signal from TX antenna a_1 by using the channel estimates and direct matrix inversion for the signal covariance matrix. The output signal of LMMSE-1 is then deinterleaved and channel decoded as normally.

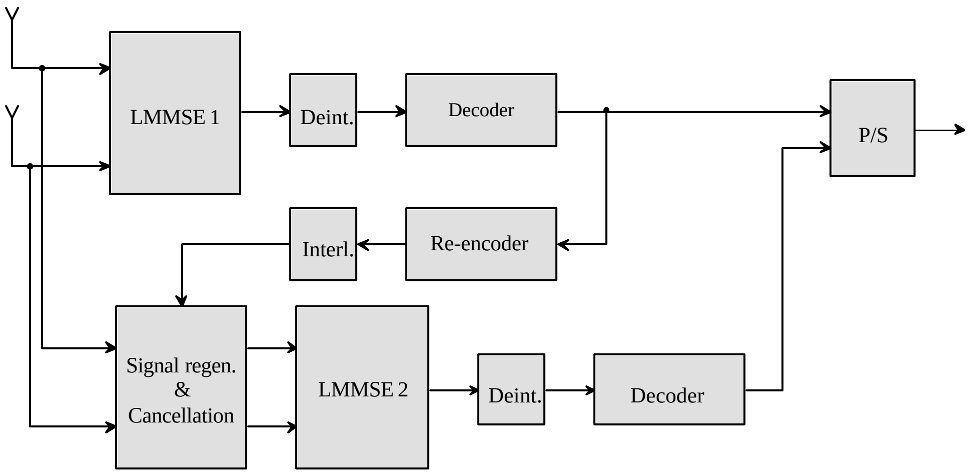

Figure 4. Receiver for the layered scheme.

The signal transmitted from antenna a_1 and received by the RX antennas is regenerated by re-encoding the bits detected by LMMSE-1, re-interleaving the coded bits, regenerating the slot structure, and finally by applying channel filters (based on the channel estimates) to the regenerated signal to imitate the channel distortion. It should be noted that we assume the power difference between CPiCH and the dedicated channel to be *ideally* known to be able to properly scale the channel estimates. The regenerated signal is then subtracted from the signals received by the two RX antennas. LMMSE-2 receiver detects the signal transmitted from the remaining TX antenna. After normal decoding process the two parallel data streams are combined by the parallel-to-serial (P/S) converter to a single frame.

3. Performance Comparison

The punctured scheme is compared to the layered scheme by using the simulation parameters shown in Table 1. The performance of these two techiques are shown in Figure 5 (frame error rate as a function of TX power for the desired user relative to the total base station TX power, pedestrian A channel, 3 km/h, no power control). The performance with a single transmit antenna and a single receive antenna without puncturing is also shown. This traditional scheme offers only half of the data rate of the other techniques. Layered scheme suffers from a low diversity order and non-ideal interference suppression/cancellation. With puncturing no interfering signals need to be generated and full diversity order is achieved (due to fully exploited TX and RX diversity) which results in a clearly steeper FER curve in the studied pedestrian channel.

Table 1. Simulation parameters

Chip rate	3.84 Mchip/s
Channel symbol rate	120 ksps
Power control	not used
Channel estimation	From CPICH
Channel modeling	modified PedA channel, 3 km/h (tap powers: 0 dB, -12.8 dB)
Convolutional code rate	1/3 (possibly punctured to 2/3)
G	9 dB
Spreading factor in DPDCH	32
Spreading factor in DPCCH	32
Spreading factor in CPiCH	256
Total CPiCH power	-10 dB
Interleaver length /depth	10 ms
Interference	19 interfering users with spreading factor 32
Antenna correlation	uncorrelated antennas

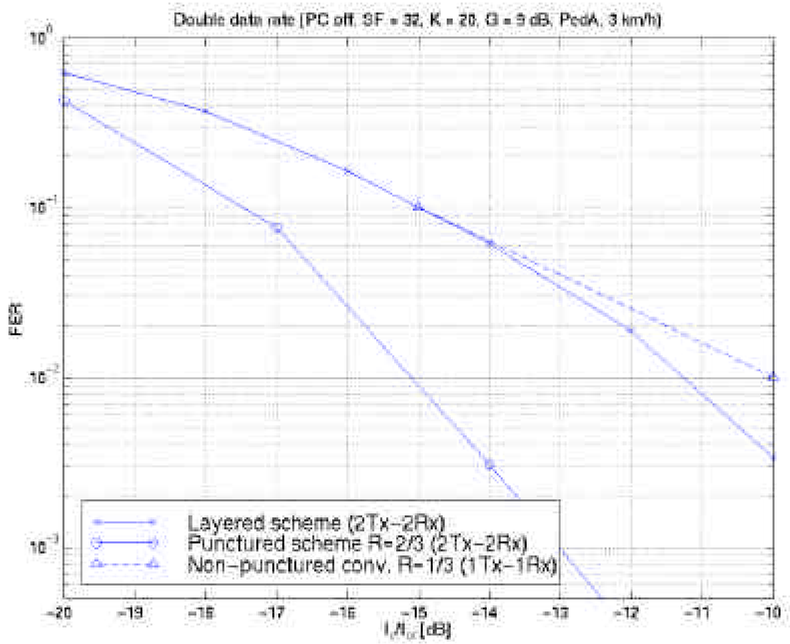

Figure 5. Performance of the punctured sheme and the layered scheme (2TX, 2RX) both achieving double data rate compared to conventional transmission (1 TX, 1 RX).

4. Conclusions

We have compared two techniques to double the data rate in FDD downlink when two TX and two RX antennas are available. The punctured scheme achieves a better performance with a significantly lower receiver complexity than the used layered BLAST scheme. The punctured scheme closely follows the current UTRA FDD specifications.

5. References

[1] http://www.ist-metra.org

[2] G. J. Foschini, "Layered Space-Time Architecture for Wireless Communication in a Fading Environment When Using Multiple Antennas," *Bell Laboratories Technical Journal*, Vol. 1, No. 2, Autumn, 1996, pp. 41-59.

[3] P. W. Wolniansky et al. "V-BLAST: An Architecture for Realizing Very High Data Rates over the Rich-Scattering Wireless Channel," *URSI International Symposium on Signals, Systems, and Electronics*, 1998, pp. 295-300.