Agenda item:

Source: Lucent Technologies

Title: Further link level results for HSDPA using multiple antennas

Document for: Discussion

1. INTRODUCTION

In a previous contribution [1], preliminary link level results for high speed downlink packet access (HSDPA) demonstrated the gains of multi-input/multi-output (MIMO) transmission and detection techniques compared to conventional single antenna techniques. These results focused on flat Rayleigh fading channels with low doppler (3km/hr terminal), uncorrelated fading between antennas, and known channels (perfect channel estimation at the terminal).

In this contribution, we present further link level results which consider higher doppler rates, correlated fading, and channel estimation. We show that the overall performance is relatively robust with regard to these impairments, and that the gains compared to a conventional single antenna system are still significant.

2. TRANSMISSION TECHNIQUES

We focus on achieving data rates greater than or equal to 10.8Mbps. Using a conventional single antenna transmitter shown in Figure 1, 10.8Mbps can be achieved using $N = 20$ multicode substreams, each at 540Kbps using a 64QAM constellation and rate ¾ coding.

A multiple antenna transmitter with M antennas is shown in Figure 2. The signal is demultiplexed into MN substreams, and a group of M substreams is modulated by the same spreading code (from a set of N orthogonal codes) and transmitted over M antennas. The transmit power from each antenna is normalized by M so that the total transmit power is the same as in the single antenna case. For each group of M substreams sharing the same code, multiple receive antennas must be used to demodulate the signals based on their spatial characteristics. The table below summarizes the transmission option where a system with M transmitters and P recievers is denoted by (M,P). In each case, $N = 20$ codes are used.

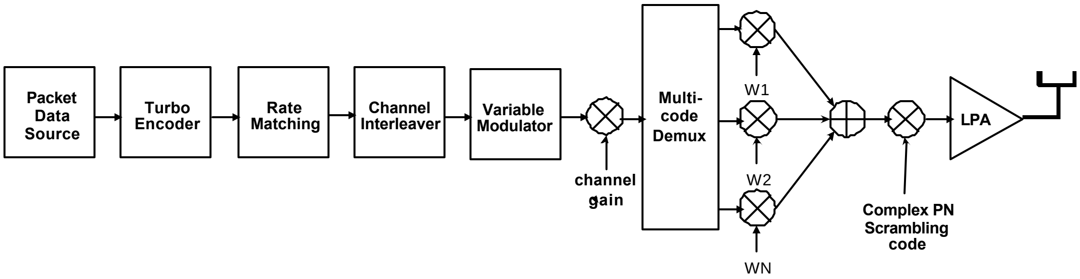

Figure 1. Conventional transmitter

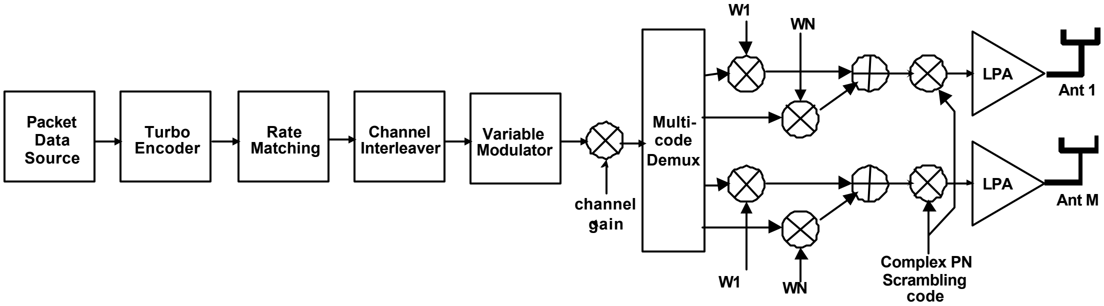

Figure 2. Code re-use transmitter with *M* antennas

(*M, P*)	Tx technique	Code rate	Modu-lation	Data rate per substream	# sub-streams	Total data rate
(1,1)	Conventional	¾	64QAM	540Kbps	20	10.8Mbps
(2,2)	MIMO	¾	8PSK	270Kbps	40	10.8Mbps
(2,2)	MIMO	¾	16QAM	360Kbps	40	14.4Mbps
(4,4)	MIMO	~½	QPSK	135Kbps	80	10.8Mbps
(4,4)	MIMO	¾	QPSK	180Kbps	80	14.4Mbps
(4,4)	MIMO	¾	8PSK	270Kbps	80	21.6Mbps

Table 1. Antenna architectures

3. CHANNEL MODEL

We assume a flat fading channel model with possible correlation between the antenna array elements at both the base station and terminal. The correlation model is derived from [2] and is based on the illumination of elements from a ring of scatterers surrounding the receive array as shown in Figure 3. Let d_{BTS} and d_{UE} be the distance between antenna elements at the base station and terminal, respectively. The model assumes a uniform distribution of scatterers with angle $\in \left\{ _{\min}, _{\max} \right\}$ around the base and $\in \left\{ _{\min}, _{\max} \right\}$ around the terminal. The distances d_{BTS} and d_{UE} are small compared to the distance between the arrays and the distance between the scatterers and the arrays. Hence, each transmitter illuminates the same set of scatterers, and it follows that the correlation among the receive antennas is independent of the transmit antennas. Conversely, the correlation among the transmit antennas is independent of the receive antennas. Letting h_{mp} be the complex channel coefficient between transmitter *m* (*m* = 1 … *M*) and receiver *p* (*p* = 1 … *P*), the correlation between two coefficients is given by

$$E\left[h_{m_1 p_1} h^*_{m_2 p_2}\right] = E\left\{\exp\left(j2 \frac{d(m_1, m_2)\sin}{}\right)\right\} E\left\{\exp\left(j2 \frac{d(p_1, p_2)\sin}{}\right)\right\}$$

where $d(m_1, m_2)$ is the distance between transmit antennas m_1 and m_2, $d(p_1, p_2)$ is the distance between receive antennas p_1 and p_2, is the carrier wavelength, and the expectations are taken with respect to the uniformily distributed angles $\in \{ {}_{\min}, {}_{\max} \}$ and $\in \{ {}_{\min}, {}_{\max} \}$. We consider urban and indoor channel models whose parameters are given in the table below.

	Urban	Indoor
d_{BTS}	10	2
d_{UE}	0.5	0.5
${}_{\min}$	7.5°	-70°
${}_{\max}$	52.5°	70°
${}_{\min}$	0°	0°
${}_{\max}$	360°	360°

Table 2. Parameters for correlated channels

For a (2,2) system, we define the channel vector $\mathbf{h} \overset{\Delta}{=} \left[h_{11} \ h_{21} \ h_{12} \ h_{22} \right]^T$ (*T* denotes the matrix transpose) and the correlation matrix $\mathbf{R} \overset{\Delta}{=} E\left[\mathbf{h}\mathbf{h}^H \right]$ (*H* denotes the Hermitian transpose). Then for the urban channel

$$\mathbf{R} = \begin{bmatrix} 1 & 0.05e^{-j2.3} & 0.30e^{-j3.1} & 0.01e^{j0.9} \\ 0.05e^{j2.3} & 1 & 0.01e^{-j0.9} & 0.30e^{-j3.1} \\ 0.30e^{j3.1} & 0.01e^{j0.9} & 1 & 0.05e^{-j2.3} \\ 0.01e^{-j0.9} & 0.30e^{j3.1} & 0.05e^{j2.3} & 1 \end{bmatrix},$$

and for the indoor channel,

$$\mathbf{R} = \begin{bmatrix} 1 & -0.07 & -0.30 & 0.02 \\ -0.07 & 1 & 0.02 & -0.30 \\ -0.30 & 0.02 & 1 & -0.07 \\ 0.02 & -0.30 & -0.07 & 1 \end{bmatrix}.$$

For an uncorrelated channels, **R** is given by the identity matrix. Given the correlation matrix **R**, the correlated channel coefficients $\mathbf{h}_{corr}$ is given by $\mathbf{h}_{corr} = \mathbf{R}^{1/2}\mathbf{h}_{uncorr}$ where $\mathbf{R}^{1/2}$ is the matrix square root of **R**, and $\mathbf{h}_{uncorr}$ is the vector of uncorrelated channel coefficients. In the simulations, the components of $\mathbf{h}_{uncorr}$ are independent zero-mean, complex Gaussian random variables with unit energy whose time variations are governed by a Jakes fading process. For systems with 4 antenna, we assume linear arrays in computing the correlations.

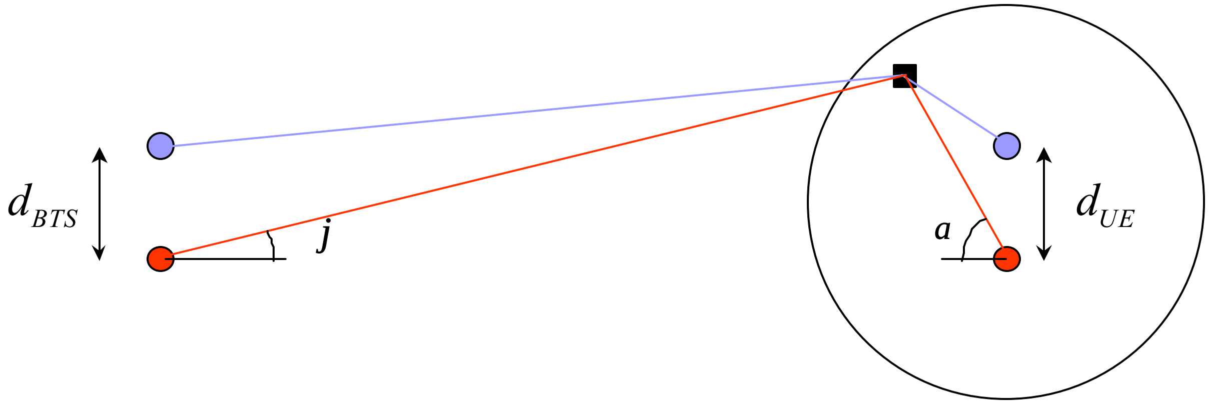

Figure 3. Model for deriving channel correlations

4. CHANNEL ESTIMATION

Each antenna transmits a code-multiplexed pilot channel with its N data channels, as shown in Figure 4. The data Walsh codes $W_1 \cdots W_N$ are mutually orthogonal sequences of length 32, and the pilot Walsh codes $W_{p(1)} \cdots W_{p(M)}$ are mutually orthgonal sequences of length 256 derived from a Walsh code of length 32 which is orthogonal to the data Walsh codes. (Recall that N = 20 so there are 12 remaining codes to choose from.) It follows that the data Walsh codes are orthogonal to each quarter of the pilot Walsh codes so that overall code orthogonality is maintained among pilot and data codes. The total pilot power is 10% of the total transmit power, and the pilots are equal power; hence for 2 and 4 antennas, each pilot is respectively 5% and 2.5% of the total transmit power. Additional overhead channels account for 10% of the total power, and the data traffic on the downlink shared channel accounts for the remaining 80%. Estimates of the channel coefficients $h_{m,p}$ are based on correlating the received signal with the pilot sequence. Each sequence is length 256 chips. Therefore in a 3.33ms frame at 3.84 Mcps, there are a total of 12800 chips per frame and 50 channel estimates per frame for each pair of transmit/receive antennas.

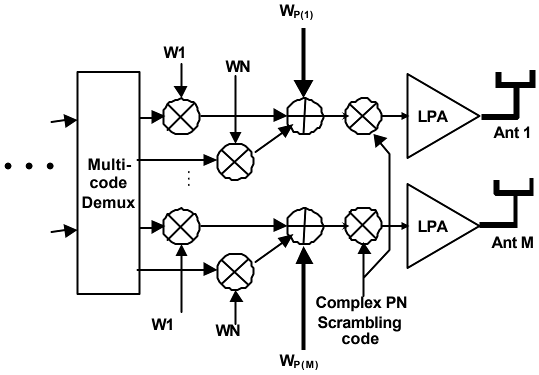

Figure 4. Transmitter with antenna pilot signals.

5. SIMULATION RESULTS

We perform link level simulations and measure the frame error rate versus Eb/N0 per receive antenna for a variety of system architectures and channel environments. Figure 5 shows the results for an uncorrelated channel at 3km/hr. The results for perfect channel knowledge were shown in [1] (except for the (2,2), 14.4Mbps case). With channel estimation, there is a slight degradation in performance for low Eb/N0, but at higher Eb/N0, the SNR of the pilot signals is also higher, resulting in less degradation. Figure 6 shows the results for faster doppler frequencies corresponding to a 30km/hr terminal. Increased time diversity acutally improves the performance of some system with respect to 3km/hr.

Figures 7 and 8 show the results for correlated channels. Under urban channel model, the degradation due to channel correlations is less than 1dB at 10% FER. For indoor channels, the loss is similar, indicating that base station antenna spacing of 2 does not degrade performance significantly as long as the angular spread around it is sufficient.

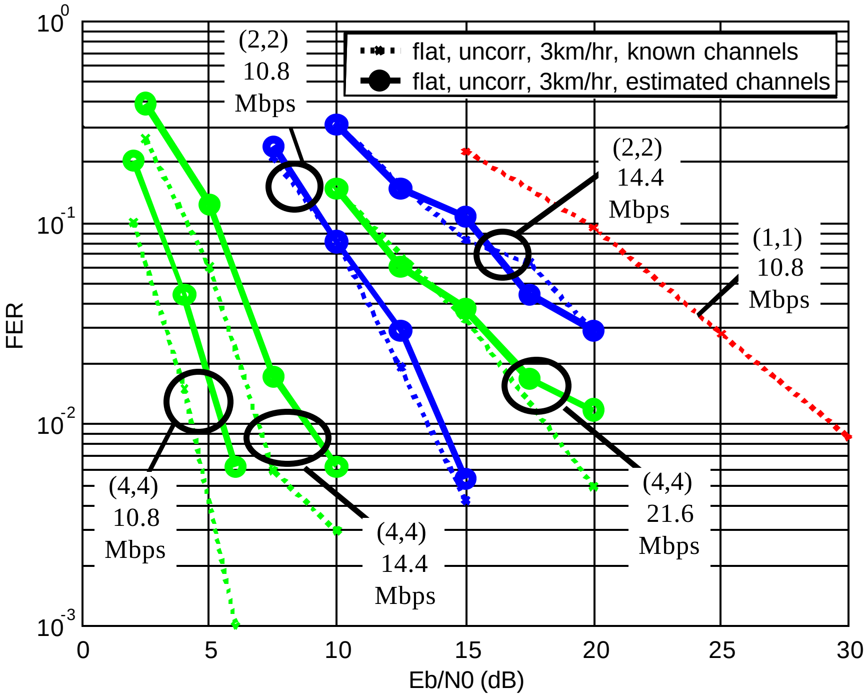

Figure 5. FER for flat fading, uncorrelated channels, 3km/hr

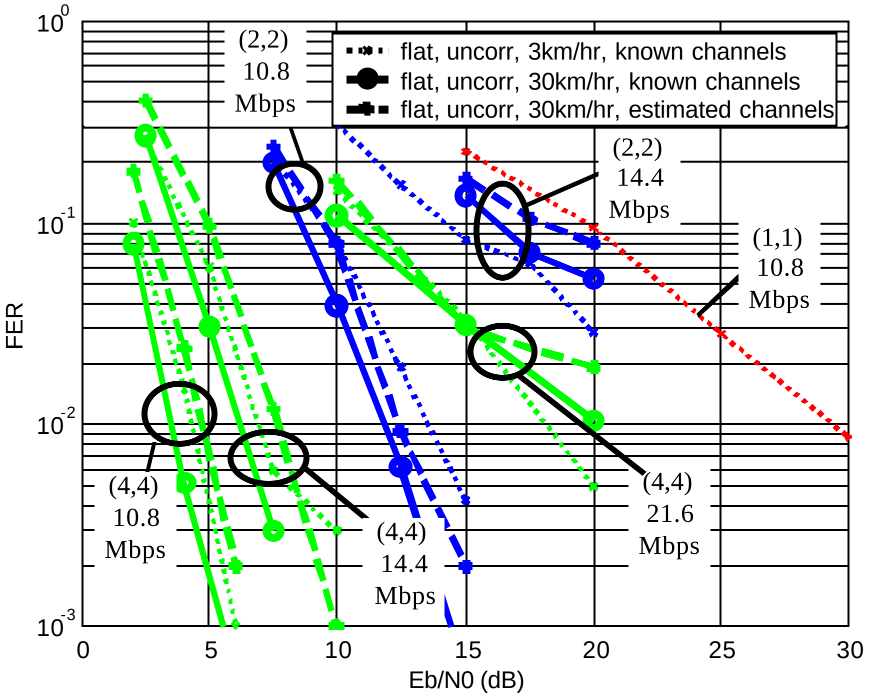

Figure 6. FER for flat fading, uncorrelated channels, 30km/hr

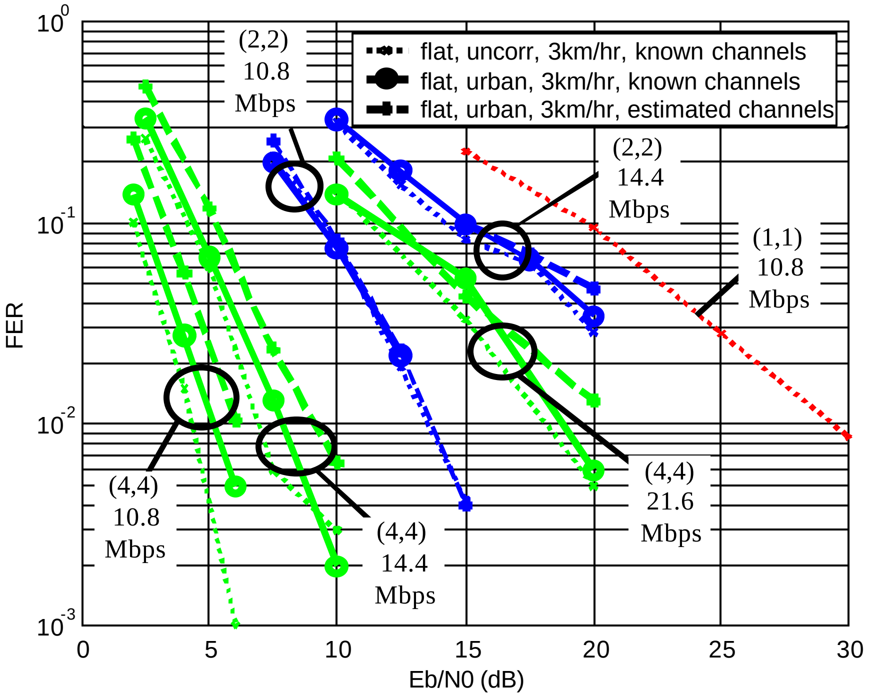

Figure 7. FER for flat fading, urban channels, 3km/hr

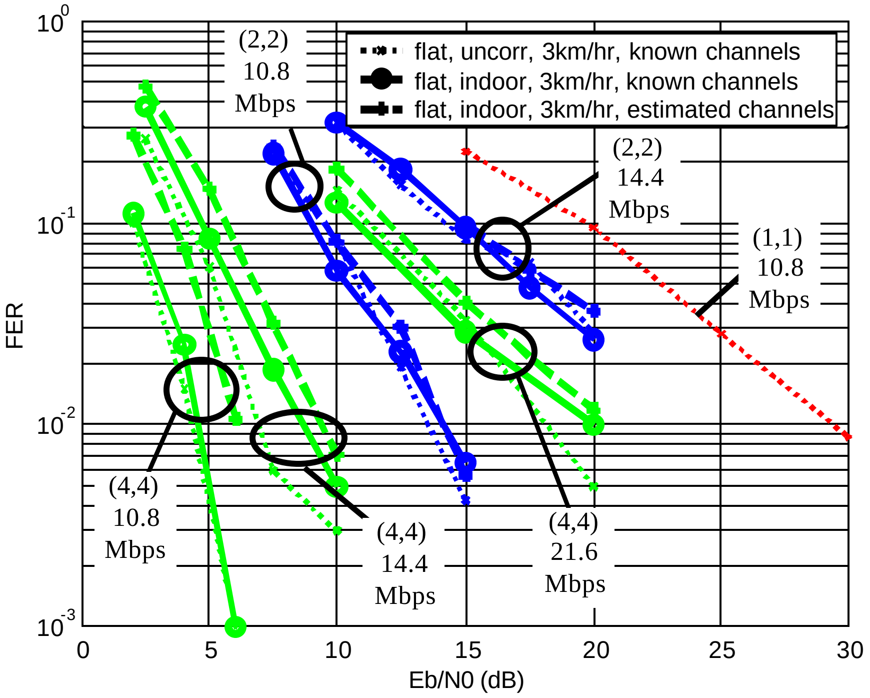

Figure 8. FER for flat fading, indoor channels, 3km/hr

6. CONCLUSIONS

We have presented link level results for a MIMO architecture considering higher doppler frequencies, channel estimation, and correlated channels. At 10% FER, compared to a baseline with low doppler, perfect channel estimation, and uncorrelated channels, the worst case loss in required Eb/N0 is about 2dB, occuring in an indoor channel with channel estimation. With regard to these impairments, we conclude that the MIMO architecture is a robust technique for providing high speed downlink packet service in excess of 10.8 Mbps. Future investigations will address the performance in frequency selective channels.

7. REFERENCES

[1] Lucent. Preliminary link level results for HSDPA using multiple antennas. TSG_R WG1 document TSGR1#16(00)1218, 10-13th, October 2000, Pusan, Korea.

[2] Siemens. Channel model for TX diversity simulations using correlated antennas. TSG_R WG1 document TSG1#15(00)1067, 22-25th, August 2000, Berlin, Germany.