Agenda item: AH24 : High Speed Downlink Packet Data Access

Source: Lucent Technologies

Title: Link level results for HSDPA using multiple antennas in correlated channels

Document for: Discussion

1. INTRODUCTION

In previous contributions [1][2], 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. While the results in [1] assumed uncorrelated channels, contribution [2] used the model given in [3] for correlated channels and considered link level performance in typical urban and indoor environments. The performance degradation due to channel correlations was negligible.

In this contribution, we present further link level results for more highly correlated channels. For a MIMO system with two transmit and two receive antennas, the performance is very robust to channel correlations. For a MIMO system with four transmit and four receive antennas, the performance is more sensitive to channel correlation. However by transmitting from two of the four antennas with the same total data rate, robustness can be achieved with minimal loss in required Eb/N0.

2. TRANSMISSION TECHNIQUES

The table below gives the transmission techniques considered in this contribution. The actual techniques are described in [2].

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

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 1. 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 $\in \{ {}_{\min}, {}_{\max} \}$ around the base and $\in \{ {}_{\min}, {}_{\max} \}$ 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 uniformly distributed angles $\in \{ {}_{\min}, {}_{\max} \}$ and $\in \{ {}_{\min}, {}_{\max} \}$. We consider two channels with increasing channel correlation whose parameters shown in Table 2 below. Note that the parameters are not meant to represent any actual channel. Rather, they were chosen arbitrarily to give a desired range of antenna correlations.

	Channel A	Channel B
d_{BTS}	0.3	0.2
d_{UE}	0.3	0.2
${}_{\min}$	$0°$	$0°$
${}_{\max}$	$360°$	$360°$
${}_{\min}$	$0°$	$0°$
${}_{\max}$	$360°$	$360°$
Avg. cross-corr (2,2)	0.22	0.57
Max. cross-corr (2,2)	0.29	0.64
Avg cross-corr. (4,4)	0.16	0.26
Max cross-corr. (4,4)	0.40	0.64

Table 2. Parameters for correlated channels

Denoting a system with M transmitters and P receivers as (M, P), for a (2,2) system we define the channel vector $\mathbf{h} \triangleq \left[h_{11}\ h_{21}\ h_{12}\ h_{22}\right]^T$ (T denotes the matrix transpose) and the correlation matrix $\mathbf{R} \triangleq E\left[\mathbf{h}\mathbf{h}^H\right]$ (H denotes the Hermitian transpose). For channel A,

$$\mathbf{R} = \begin{bmatrix} 1 & 0.29 & 0.29 & 0.08 \\ 0.29 & 1 & 0.08 & 0.29 \\ 0.29 & 0.08 & 1 & 0.29 \\ 0.08 & 0.29 & 0.29 & 1 \end{bmatrix}.$$

The average cross-correlation is given by the average of the off-diagonal element magnitudes. For **R** above, the average is 0.22. The last two rows of Table 2 give the average cross-correlations for the (2,2) and (4,4) systems. For 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.

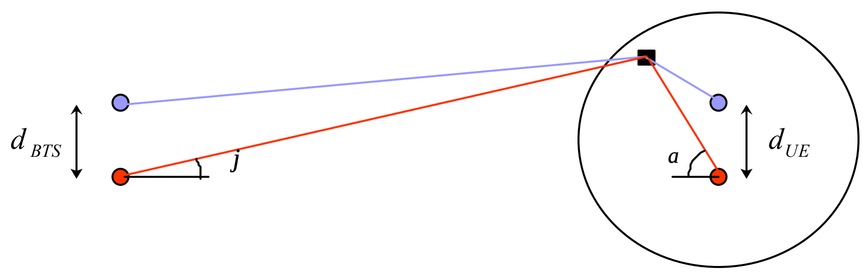

Figure 1. Model for deriving channel

4. RESULTS

We perform link level simulations and measure the frame error rate versus Ior/Ioc per receive antenna. We assume a flat fading channel where temporal variations are generated using Jake's time fading model at 3km/hr. At this velocity, the performance degradation due to channel estimation is negligible [2]; hence we assume perfect channel estimates.

Figure 2 gives the performance for the (2,2) system at 10.8Mbps. As references, the red curve gives the performance of a conventional (1,1) system using 64QAM, and the green curve corresponds to a (2,2) system with uncorrelated channels. The performance in correlated channels is very robust. Under channel A, the performance degradation is negligible. With higher correlation in channel B, the performance loss is less than 2dB. Some of this performance loss is due to the loss in diversity which is inherent in any receiver with multiple antennas.

Figure 3 gives the performance of the (4,4) system at 10.8 Mbps. The red curve is the (1,1) reference, and the green curve is the performance of the (4,4) system in uncorrelated channels.

The performance of the (4,4) system is not as robust to correlated channels due to unfavorable eigenvalue distribution of the correlation matrix **R**. In other words, the low rank of the channel matrix results in poor performance of the detector. This problem can be solved by transmitting on fewer antennas to better match the rank of the channel. We choose to transmit with two antennas so that the rates and transmission techniques in Table 1 can be used. One would expect that transmitting on the two outer antennas would lead to the best performance. However, as shown by the dashed lines in Figure 3, the performance is satisfactory even if we transmit from the *worst* antenna pair (worst in the sense of highest average cross-correlation). Hence *any* antenna selection algorithm, even a random one, would result in better performance. Since a channel's angle spread is largely a function of the antenna heights and scatterer density, it will basically remain fixed for a given environment (e.g., urban or suburban). Therefore the channel correlations will also remain fixed. It follows that in situations with high channel correlation, the decision to operate in 'choose two of four antennas' mode could be done very infrequently, for example at call setup only, resulting in minimal control overhead.

Figure 4 gives the performance of the (4,4) system at 14.4 Mbps. As in the (4,4) 10.8Mbps case, the performance with four transmit antennas is sensitive to high channel correlations, but it can be significantly improved by transmitting with just two antennas.

5. 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] Lucent. Further link level results for HSDPA using multiple antennas. TSG_R WG1 document TSGR1#17(00)1386, 21-24th, November 2000, Stockholm, Sweden.
[3] Siemens. Channel model for TX diversity simulations using correlated antennas. TSG_R WG1 document TSG1#15(00)1067, 22-25th, August 2000, Berlin, Germany.

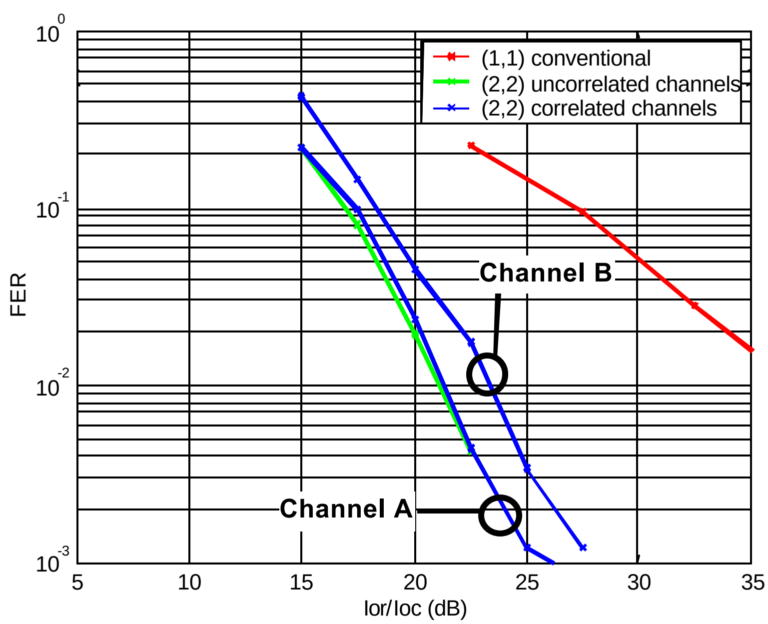

Figure 2. FER for (2,2) system, 10.8 Mbps

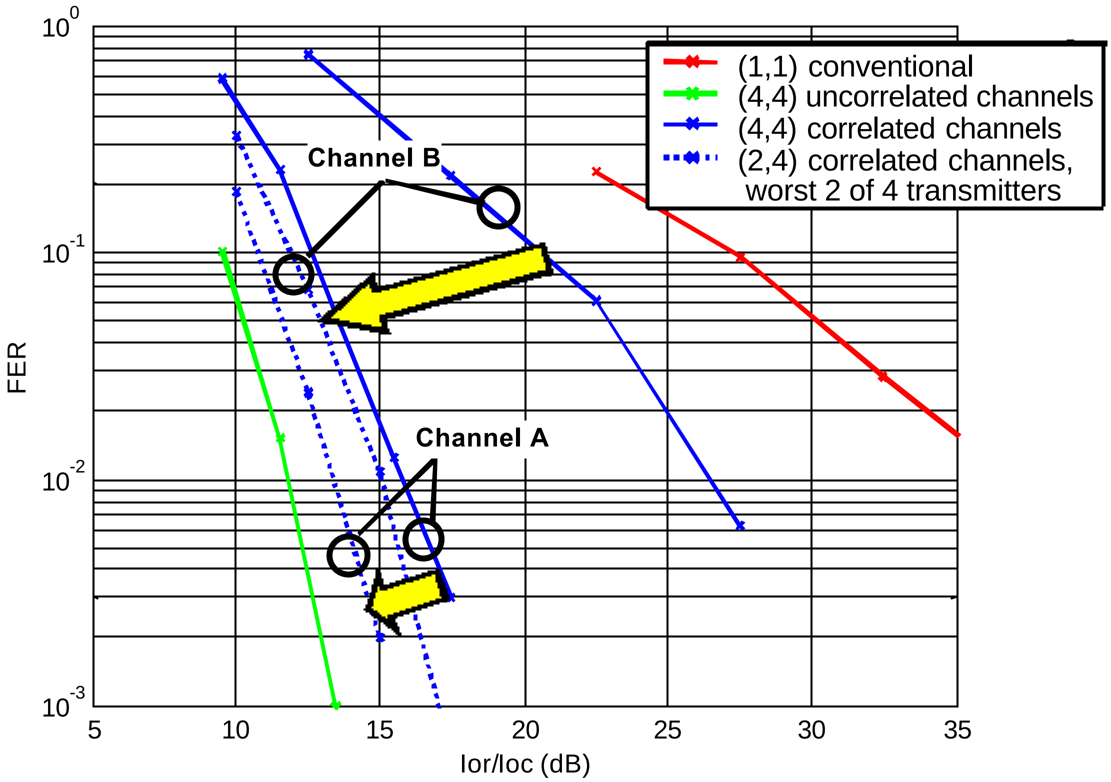

Figure 3. FER for (4,4) system, 10.8 Mbps

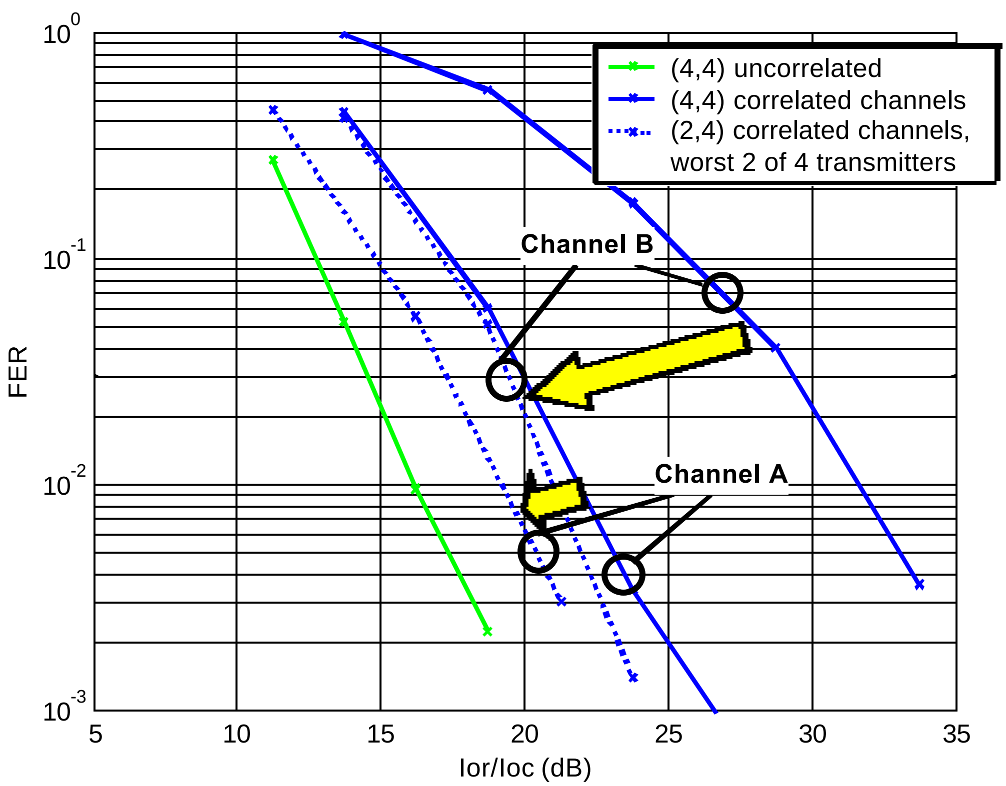

Figure 4. FER for (4,4) system, 14.4 Mbps