TSG-RAN Working Group 1 Meeting #20~~18~~ ***TSGR1#20~~18~~(01)0529~~0~~102~~0XX~~***

Busan~~Boston~~, South Korea~~ USA~~
Ma~~Januar~~y 21~~5~~-25~~18~~, 2001

Source: **~~-~~Texas Instruments~~NTT DoCoMo~~**
Title: **Impact of Intracell Interference on the Performance of ~~Proposal of~~ Multipath Interference Canceller (MPIC) for HSDPA with~~and~~ ~~E~~16-QAM and ~~ffect of~~ 64-QAM Data Modulation**
Agenda Item: **AH24 (HSDPA)**
Document for: **Discussion**

---

1. Introduction

In this contribution we~~e~~ present simulation results for the uncoded bit error rate (U-BER) of a UE employing multipath interference canceller (MPIC) as suggested in [1]. Multicode HSDPA transmission with 16-QAM and 64-QAM for data modulation is considered. In particular, we evaluate the impact of intracell interference on the U-BER of MPIC. The only intracell interference considered by the simulation assumptions in [1] was that caused by the CPICH which was assigned 10% of the total transmitted power (I_{or}) while the remaining 90% was assigned to the multicodes of HSDPA. We show that the MPIC performance in multipath interference (MPI) environments quickly degrades as the intracell interference power increases and that the performance benefits of MPIC relative to a conventional Rake receiver vanish for intracell interference power levels as small as 20%-30% of the I_{or}.
~~show the link level simulation results for multi-level data modulation such as 16QAM and 64QAM in case that UE employs multipath interference canceller (MPIC) in multipath fading environment. The results show that propose a mutlipath interference canceller (MPIC) that achieves high throughput performance above 8Mbps with adaptive multi-level data modulation such as 64QAM in multipath fading environment. This contribution shows that~~

~~(1) Proposed MPIC can mitigate the severe multipath interference (MPI) and keep high-throughput in multipath environments.~~

~~(2) 64QAM data modulation~~ can be~~is effective in increasing maximum throughput since~~if ~~MPI (and MAI) is effectively eliminated with MPIC.~~

~~We also discuss the need of AMC selection that makes UE fairly benefit from high performance receiver like MPIC.~~

2. MPIC Performance in a~~Method of Improving Throughput~~ in Multipath Fading Channels~~ Environment~~

It is well understood that the degradation caused by MPI on the U-BER of multilevel QAM places severe limitations on the achievable throughput relative to its line-of-sight value and those limitations cannot be overcome by increasing the SIR since they are MPI inflicted. A receiver structure (MPIC) was suggested in [1] to largely remove the error floor exhibited by QAM modulations in MPI environments. Substantial performance gains were achieved relative to the conventional Rake receiver. However, those gains come at the expense of a considerable increase in the UE receiver complexity. The complexity increase is 3(8) times that of the conventional Rake for a 1(3) stage MPIC [2].

The performance gains suggested by the results in [1] are also susceptible to the corresponding simulation assumptions, particularly the ones regarding intracell interference power and number of codes used by HSDPA. In [1], only the CPICH was considered as an additional transmitted channel. This however will never be the case in practice. Channels dedicated to voice users and the remaining (other than CPICH) common forward link channels coexist with HSDPA. Those channels together with the CPICH will account for substantially more than 10% of the total cell transmitted power I_{or}. In [3], Vodafone Group suggested that the maximum power allocated to HSDPA transmission is 70% of I_{or}. In fact, accounting for the geometry of the distribution of low rate UEs and HSDPA UEs, the intracell interference experienced by HSDPA UEs will likely be considerably larger than 30% of I_{or} as HSDPA UEs are located closer to Node B. Moreover, [1] considered HSDPA transmission using the maximum 20 codes. This also produces the largest MPIC performance gains relative to the Rake receiver.

In this contribution we show that the MPIC performance becomes practically equivalent to that of the conventional Rake receiver for intracell interference power levels as low as 30%-40% of I_{or} in the case of 16-QAM and 20-30% of I_{or} in the case of 64-QAM. As a consequence, the MPIC cannot remove the error floor experienced by QAM modulation in MPI channels and cannot improve throughput performance and coverage area in non-line-of –sight environments.

~~By increasing the modulation level of the data modulation, the peak throughput of HSDPA can be increased in theoretically assuming no multipath channel. However, in an actual propagation channel, multipath (frequency-selective) fading appears in a 5-MHz W-CDMA bandwidth. Although the multipath interference (MPI) of high-speed packet channel is suppressed to 1/SF on average (SF denotes spreading factor), severe MPI degrades the SIR, and consequently the throughput performance since the equivalent SF must be nearly 1 to achieve throughput higher than 10 Mbps. Note that when multipath fading occurs even when the received signal power is sufficiently high, the throughput of a high-speed packet channel is degraded not by the background noise, but by its own severe MPI. Thus, efficient amplitude/phase data modulation such as 16QAM and 64QAM is ineffectual in multipath fading channel because the required SIR is higher than that with QPSK modulation. Thus, the area in which high-speed data services are provided using an equivalent low SF and high-level data modulation is very limited to the rare line-of-sight environment in the immediate vicinity of the base station.~~ One possible solution is implementing MPIC to the receiver. ~~Therefore, we propose MPIC associated OVSF codes usage for effectively making~~ can make ~~use of multi-level amplitude/phase modulation especially of~~ for ~~64QAM and for~~ can ~~improv~~e~~ing throughput performance of high-speed packets even in a multipath fading channel, thereby result~~s~~ing in extension of the coverage area of high-speed packet service.~~

~~3.MPIC~~

~~Figure 1 shows the structure of the proposed MPIC~~ that we employed in this evaluation. We ~~assum~~ed~~ing two-branch antenna diversity reception. MPIC comprises several channel estimation and interference replica generation units (CEIGUs), the number of which corresponds to the number of stages. On and after the second stage, the MPI replica estimated in the previous stage is removed from the received signal for the input signal of CEIGU. The structure of the CEIGU is illustrated in Fig. 2. In each CEIGU, the input sample sequence of each antenna is despread by a matched filter. The channel variation due to fading of each resolved path is estimated by coherently averaging the despread in-phase and quadrature component of the common pilot symbols over one-slot length. Then, the phase variation of each path is compensated and coherently Rake-combined. The tentative hard-decision of data sequence of the Rake combiner output is performed to estimate the data modulation. The MPIC replica is generated using the decision data sequence, channel estimate, and received power of each path.~~

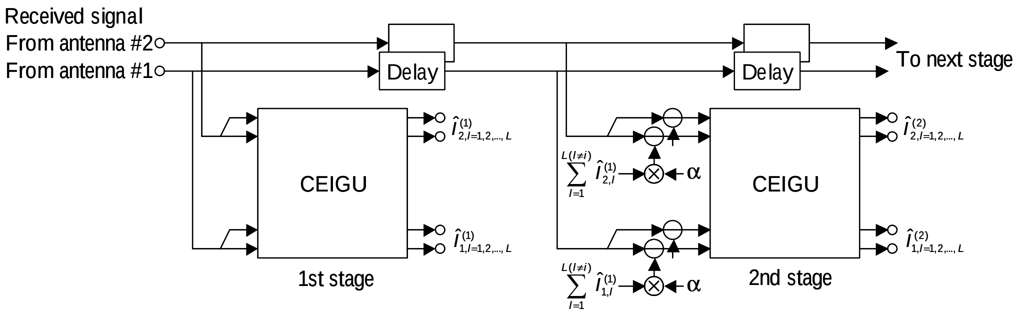
~~Let $\tilde{\xi}_{b,l}^{(p)}(t)$ be the estimated complex channel variation and $\tilde{d}_k^{(p)}(t)$ be the estimated data modulation for the *l*-th path ($1 \le l \le L$) of the b-th antenna ($1 \le b \le 2$) of the k-th code channel ($1 \le k \le 20$) at the p-th stage ($1 \le p \le 4$). Then MPI replica $\hat{I}_{b,l}^{(p)}(t)$ of the p-th stage is expressed as~~

~~$\hat{I}^{(p)}_{b,l}(t-\hat{\tau}_l)=\sum_{l=1}^{L}\tilde{\xi}^{(p)}_{b,l}(t)\left(\sum_{k=1}^{K}\tilde{d}^{(p)}_k(t-\hat{\tau}_l)\cdot c_k(t-\hat{\tau}_l)+d_{cpich}(t-\hat{\tau}_l)\cdot c_{cpich}(t-\hat{\tau}_l)\right)$ (1)~~

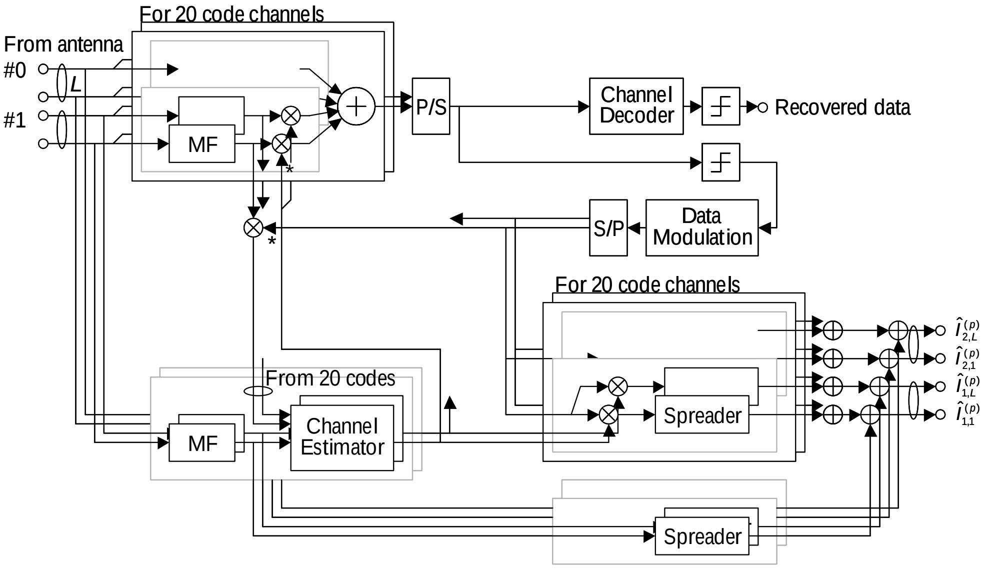
~~where $c_k(t)$ and $c_{cpich}(t)$ are the spreading modulation for the k-th code channel and common pilot channel, respectively. Term $d_{cpich}(t)$ is the known pilot channel modulation and $\hat{\tau}_l$ is the estimated delay time of the *l*-th path. By using $\hat{I}^{(p)}_{b,l}(t)$ and received signal $r_b(t)$, the input signal, $r^{(p+1)}_{b,l}(t)$, of MF in the CEIGU for the *l*-th path of the b-th antenna at the (p+1)-th stage is represented as~~

~~$r^{(p+1)}_{b,l}(t)=r_b(t)-\alpha\sum_{\substack{j=1\\ j\neq l}}^{L}\hat{I}^{(p)}_{b,j}(t-\hat{\tau}_j)$ (2)~~

~~where α is the real-valued interference rejection weight ($0<\alpha\leq 1$), which alleviates the impact of generation error of the MPI replica. Since the updated MPI is removed from the received signal, and the channel estimation and tentative data decision are repeatedly performed in each canceling stage, the accuracy of the regenerated MPI replica is improved as the number of stages increases. Since the MPIC removes MPI of one high-speed packet channel, the increase of signal processing complexity from conventional Rake receiver is not so large.~~



~~**Fig. 1 MPIC structure**~~



~~**Fig. 2 CEIGU structure**~~

4.3. Simulation Assumptions

The main simulation assumptions are listed in Table 1~~Table 1Table. 1Table. 1Table. 1Table. 1Table. 1~~.

Table~~.~~ 1~~1~~ Simulation assumptions

Chip rate		3.84 Mcps
Spreading factor (SF)		32
Number of multicodes for HS-DSCH		16
Modulation	Data	16-QAM, 64-QAM
	Spreading	QPSK
CPICH Ec/Ior		-10.0 dB (10% of Ior)
DSCH Ec/Ior		90%, 80%, 70%, 60%, 50% of Ior
Channel coding / decoding		Turbo coding (R = 3/4, k = 4) / Max-Log-MAP decoding (8 iterations)
Intracell interference		QPSK, 8 codes, SF=32,64
Channel estimation		CPICH-assisted (4-6 slots averaging)
Antenna diversity reception		1-branch, 2-branch
Channel model		2-path Rayleigh UE Speed: 3 Km/h, 30 Km/h
Number of stages of MPIC		4
Number of stages of MPIC		1,2,3
TPC		Off
TPC		Off
MPIC Operation		Only HSDPA Multicodes

The power of the intracell interference was evenly distributed among the corresponding channels. This setup minimizes the impact of intracell interference on the Rake/MPIC performance. Moreover, perfect timing was assumed. The MPIC is more sensitive to timing errors than the Rake and this assumption also produces an upper bound for the MPIC performance relative to that of the Rake.

The MPIC performance was similar when the intracell interference comprised of codes with spreading factors of 32 and 64. The scaling weights on the regenerated signal for the different cancelling stages were chosen at their optimum values.

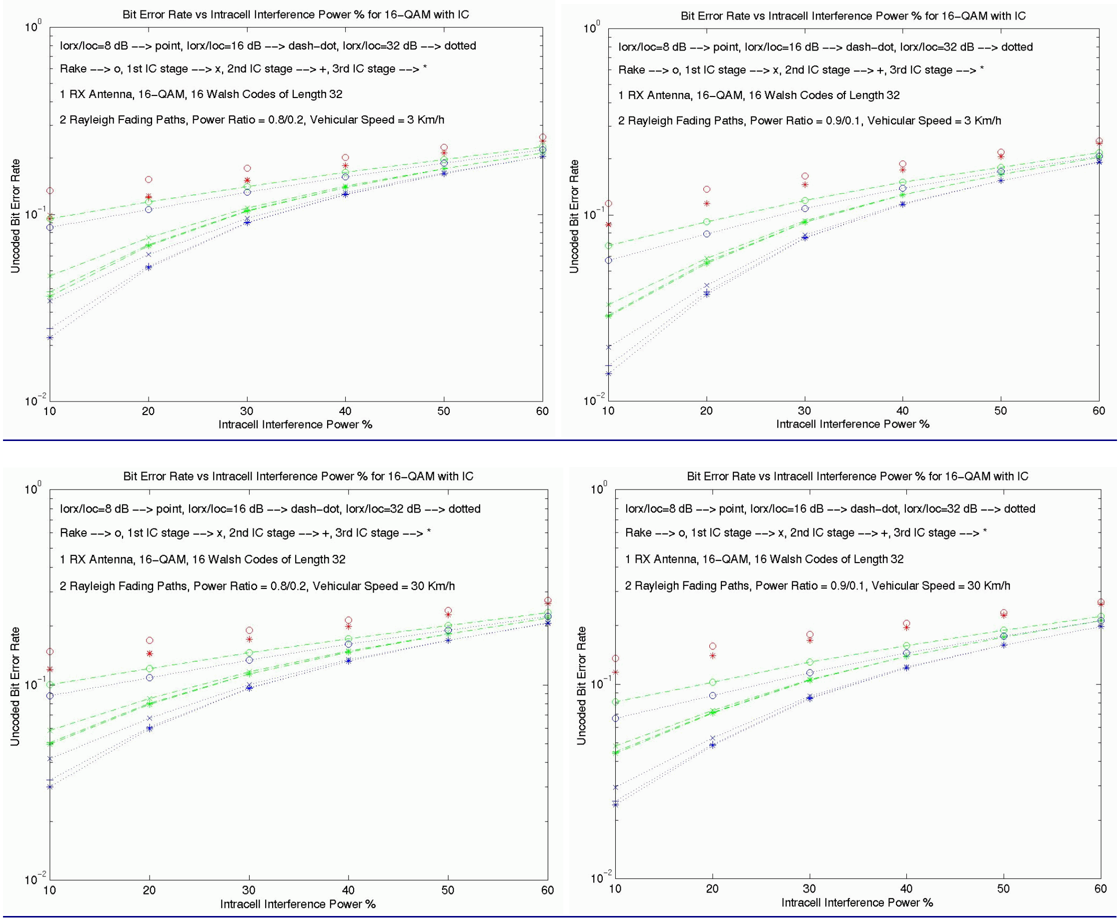
~~MCSs used in the simulation are shown in Table. 2Table. 2Table. 2 Table 2. .~~

~~Table. 2222 MCS used in the simulation~~

MCS	Info. Rate (Mbps)	Number of Info. Bits in Packet	Modulation	Coding Rate
1	7.2	4800	16QAM	3/4
2	10.8	7200	64QAM	3/4

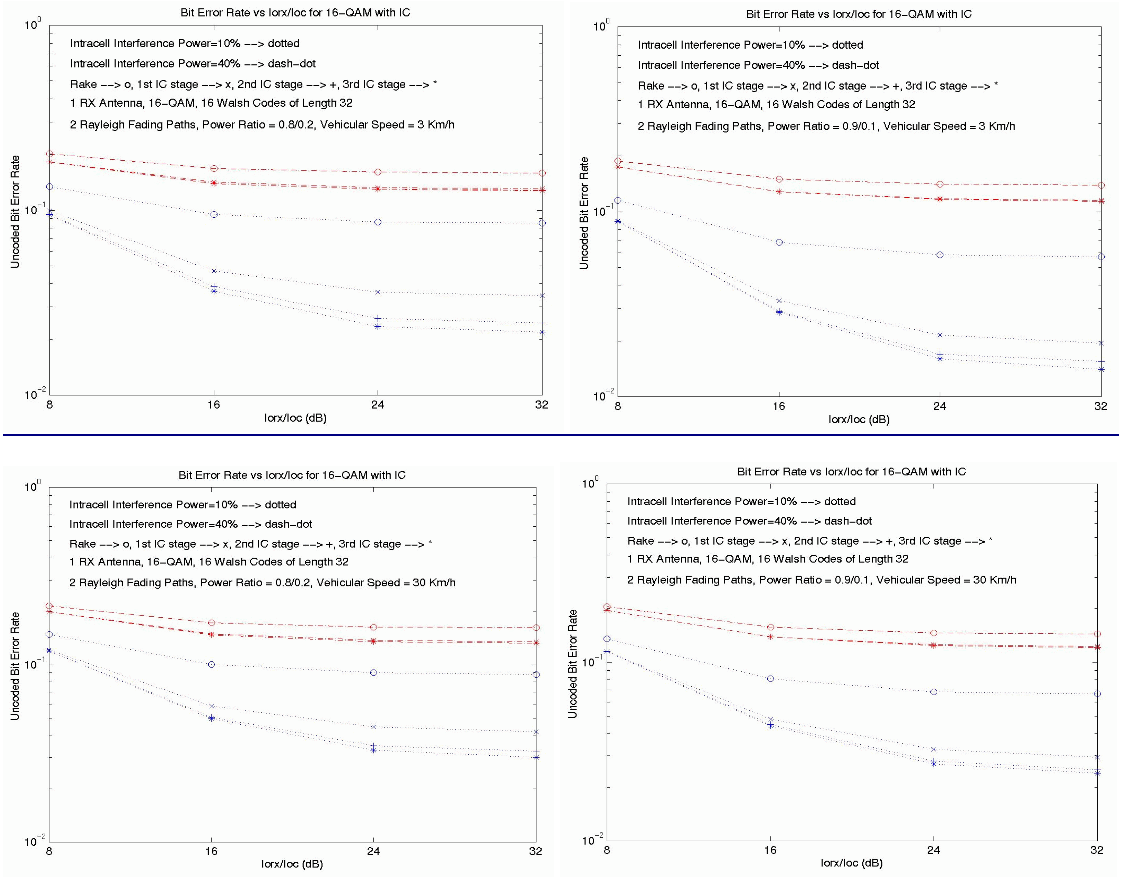
~~5.~~4. Simulation results

The U-BER evaluation was obtained for 2-path Rayleigh fading channels. Two combinations for relative path powers (path1/path2=0.8/0.2 and 0.9/0.1), and two UE speeds (3 Km/h, 30 Km/h) were considered. The MPIC performs cancellation only for the MPI caused by the HSDPA multicodes. –Figures 1a-1d~~3~~ show~~s~~ the U-BER~~ throughput~~ performance for the MPIC and Rake receivers as a function of the I_{or} percentage of intracell interference for 16-QAM modulation, 3 values of I_{orx}/~~(~~I_{oc} (8 dB, 16 dB, 32 dB), and 1 receive antenna. I_{orx} denotes the received power from the desired cell and I_{oc} denotes the power of intercell interference. ~~$+N_0$)~~



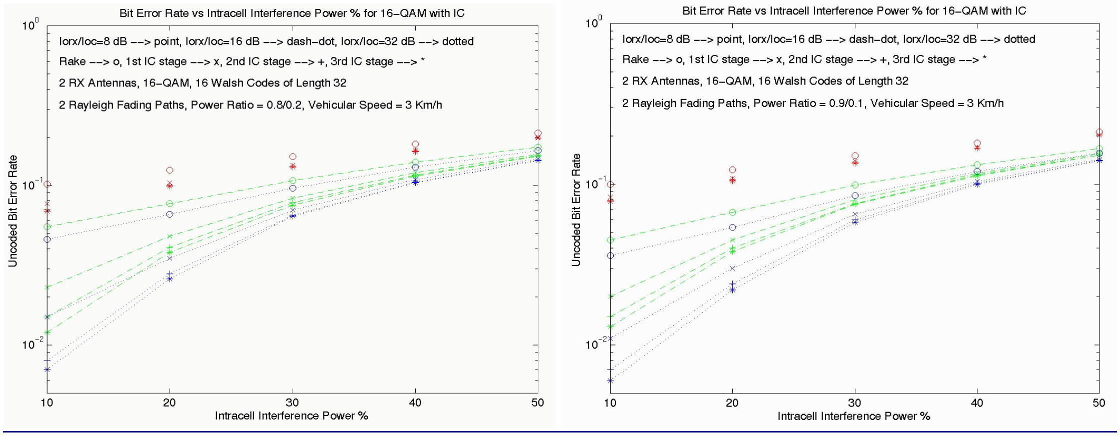
Figs 1a-1d: MPIC and Rake U-BER versus intracell interference power for 16-QAM modulation in 2-path Rayleigh fading channels and 1 Rx antenna.

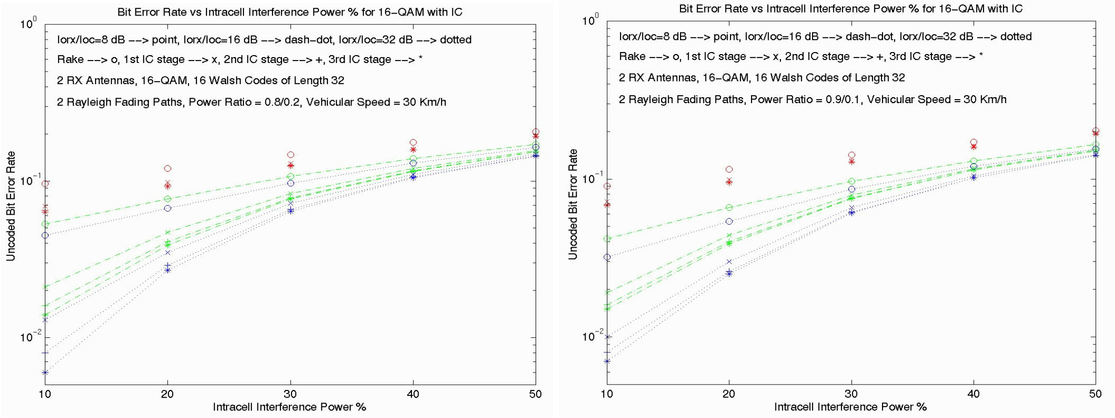
Figures 2a-2d present the MPIC and Rake U-BER as a function of I_{orx}/I_{oc} for 2 values of intracell interference and 1 receive antenna.



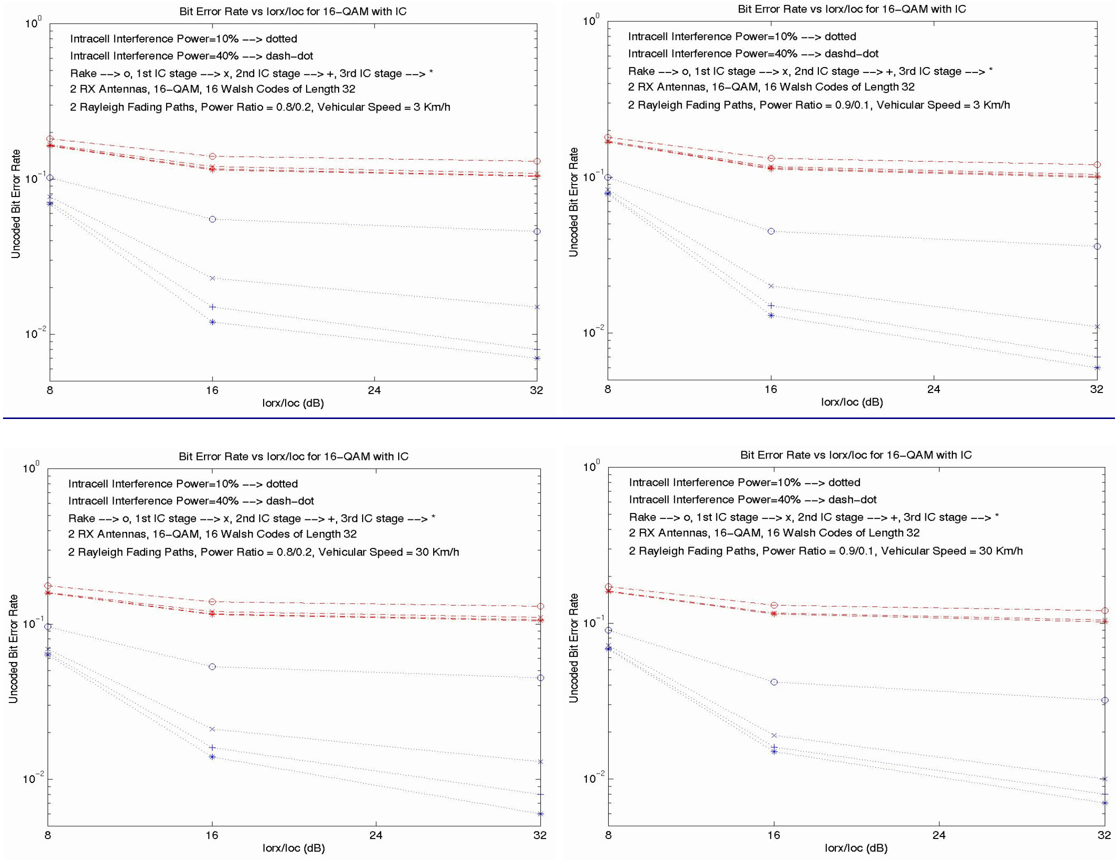
Figs 2a-2d: MPIC and Rake U-BER versus I_{orx}/I_{oc} for 16-QAM modulation in 2-path Rayleigh fading channels and 1 Rx antenna.

The U-BER evaluation presented in Figures 1a-1d and Figures 2a-2d is repeated in Figures 3a-3d and Figures 4a-4d, correspondingly, for diversity reception with 2 antennas.





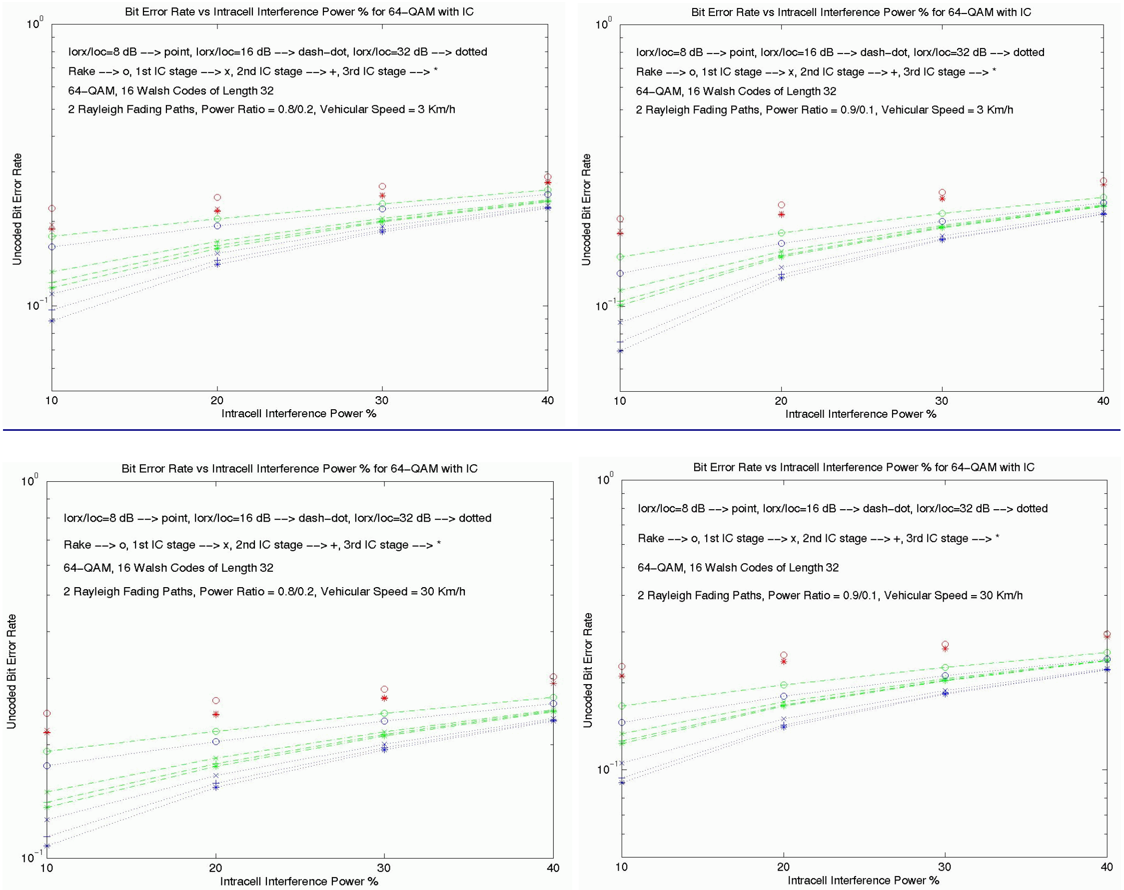
Figs 3a-3d: MPIC and Rake U-BER versus intracell interference power for 16-QAM modulation in 2-path Rayleigh fading channels and 2 Rx antennas.



Figs 4a-4d: MPIC and Rake U-BER versus I_{orx}/I_{oc} for 16-QAM modulation in 2-path Rayleigh fading channels and 2 Rx antennas.

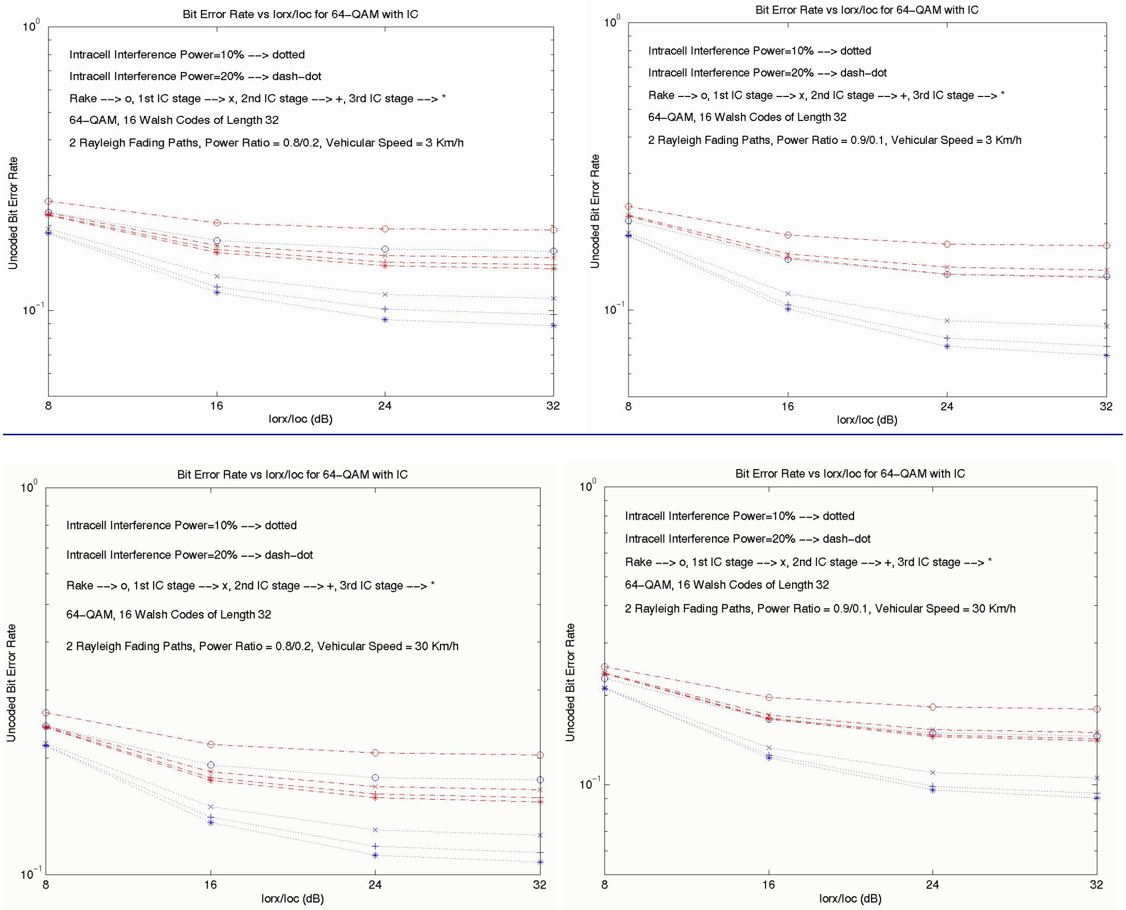
From the previous figures it becomes apparent that MPIC offers significant U-BER improvements over the conventional Rake when the intracell interference power is only 20% or less of I_{or}, particularly for large values of I_{orx}/I_{oc}. However, those improvements vanish as the power of intracell interference increases relative to the power allocated to HSDPA. For intracell interference power levels above 20% of I_{or}, MPIC offers most of the U-BER gains after only one cancellation stage. Figures 1a-1d and Figures 3a-3d suggest that for any realistic value of the intracell interference power (>30% of I_{or}), the MPIC performance gains are minimal and do not justify the considerable increase in the UE receiver complexity. Moreover, as expected, the number of receive antennas does not change the previous conclusions. The UE speed and relative path power also have no noticeable effect on the previous conclusions.

Figures 5a-5d show the U-BER performance for the MPIC and Rake receivers as a function of the I_{or} percentage of intracell interference for 64-QAM modulation, 3 values of I_{orx}/I_{oc} (8, 16, 32), and 1 receive antenna.



Figs 5a-5d: MPIC and Rake U-BER versus intracell interference power for 64-QAM modulation in 2-path Rayleigh fading channels and 1 Rx antenna.

Figures 6a-6d present the MPIC and Rake U-BER for 64-QAM modulation as a function of I_{orx}/I_{oc} for 2 values of intracell interference.



Figs 6a-6d: MPIC and Rake U-BER versus I_{orx}/I_{oc} for 64-QAM modulation in 2-path Rayleigh fading channels and 1 Rx antenna.

Similar observations as for 16-QAM apply in the 64-QAM case. The impact of larger intracell interference on the MPIC performance for 64-QAM is even more severe than for 16-QAM. The U-BER performance improvements of MPIC relative to the conventional Rake receiver are considerably diminished for intracell interference power as low as 20% of I_{or}.

~~in 1- and 2-path fading channel. In 2-path fading channel, throughput performance with and without proposed 4-stage MPIC were plotted. In single-path channel, MCS2 which employs 64QAM can achieve higher maximum throughput compared with MCS1 with 16QAM in enough high $I_{or}/(I_{oc}+N_0)$ region. However in 2-path fading channel, throughput with MCS2 were severely degraded due to the severe MPI of its own channel without MPIC. As a result, MCS2 cannot improve throughput compared to that with MCS1 in any $I_{or}/(I_{oc}+N_0)$ region without MPIC in 2-path fading channel. On the other hand, when MPIC was applied, almost the same or higher throughput can be obtained in 2-path fading channel compared to that in single-path channel owing to accurate MPI cancelling and Rake diversity effect. Therefore 64QAM data modulation combined with MPIC can increase the maximum throughput even in multipath fading channels.~~

~~**Fig. 3 Throughput performance**~~

~~Selection of AMCS by Node-B~~

~~As indicated in above section, there is a significant difference in performances between UE with MPIC and that without MPIC. If HSDPA system allows the case that each UE has difference receiver performance (for example, some has MPIC and others doesn't have MPIC), it is desirable that Node-B selects AMC level according to not only quality of channel but also the receiver ability. Straightforward way is employing explicit rate information as proposed in [3]. However, some contributions described disadvantages of the method [4,5]. Anyway, we should apply the method that makes UE fairly benefit from high performance receiver.~~

~~6.~~5. Conclusions

We showed physical layer simulation results for the uncoded bit error rate (U-BER) of 16-QAM and 64-QAM in multipath interference (MPI) channels and compared the performance of a conventional Rake UE receiver with the performance of a UE receiver ~~the link level simulation results for multi-level data modulation such as 16QAM and 64QAM in case that UE~~ employings multipath interference canceller (MPIC). ~~in multipath fading environment.~~ ~~We proposed a mutlipath interference canceller (MPIC) that achieves high throughput with adaptive high-level data modulation such as 64QAM in multipath fading channel. This contribution~~The results show~~s~~ that even under the most optimistic intracell interference levels expected in realistic cell environments, the MPIC cannot alleviate the significant degradation caused by MPI on the U-BER of 16-QAM and 64-QAM. The performance benefits of MPIC relative to the conventional Rake receiver are minimal and do not justify the 3x-8x increase in complexity.

~~t~~

- ~~(1)Proposed MPIC can mitigate the severe MPI and keep high-throughput in multipath environment.~~
- ~~(2)64QAM data modulation is can be effective in increasing maximum throughput if MPI (and MAI) is effectively eliminated with MPIC.~~

~~According to these results, we propose that~~

- ~~MPIC should be considered in AH24.~~
- ~~64QAM data modulation should not be excluded from AMC.~~

~~We also discuss the need of AMC selection that makes UE fairly benefit from high performance receiver like MPIC.~~

~~(In this contribution, MPIC removed MPI of one high-speed packet channel within a cell. Further, we can extend the application of MPIC to remove MPIs of high-speed packet channels from several contiguous cells in addition to own cell, thereby increasing throughput performance further the by suppressing dominant interference from other cells.)~~

References

~~[1]Motorola: "High Speed Packet Access", TSGR1#13(00)0727, May. 2000~~

~~[2]Ericsson, Motorola, Nokia: "Common HSDPA System Simulation Assumptions" TSGR1#15(00)1094, Aug. 2000~~

[1] NTT DoCoMo, "Multipath Interference Canceller (MPIC) for HSDPA and Effect of 64 QAM Data Modulation," TSGR1#18(01)0102, Boston, USA, January 15-18, 2001.

[2] NTT DoCoMo, "Complexity Analysis on MPIC for HSDPA," TSGR1#19(01)0329, Las Vegas, USA, February 27-March 2, 2001.

[3] Vodafone Group, "Refinement of Simulation Assumptions for HSDPA Capacity Evaluation", Tdoc 12A(01)0016, Sophia Antipolis, France, April 5-6, 2001.