Multistage Interference Cancellation with Diversity Reception for QPSK Asynchronous DS/CDMA System over Multipath Fading Channels: Comparison of QPSK and BPSK Spreading Schemes [1]

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Abstract

In this report, we compare the performance of the multistage interference cancellation (MIC) using QPSK spreading with that using BPSK spreading. In QPSK spreading, the in-phase and quadrature branches are with two different signature waveforms, while in BPSK spreading, the in-phase and quadrature signature waveforms are the same. Simulation results indicate that the detector with QPSK spreading can alleviate the power of multiple-access interference and the resulting performance is generally better than that with BPSK spreading.

1 Introduction

In our previous report [1], we presented the multistage interference cancellation (MIC) with diversity reception for QPSK asynchronous DS/CDMA system over multipath fading channels. The spreading scheme considered there was QPSK, for which the in-phase and quadrature branches were with two different signature waveforms. Although QPSK spreading is a popular approach not only in theory [2, 3] but also in practical IS-95 CDMA digital cellular systems [4, 5], BPSK spreading is also of interest due to its simplicity [6]. In BPSK spreading, the in-phase and quadrature signature waveforms are the same. Thus, we may assign each user one signature waveform rather than a pair of signature waveforms in QPSK spreading. In a single-user direct sequence system, there is no performance difference between these two spreading schemes. In multiuser system, however, the use of QPSK may effectively randomize the phase of transmitted signals and thereby it alleviates to some extent the power of interference from other users' signals [4]. Since the MIC scheme can effectively suppress the multiple-access interference (MAI) and the self-interference (SI) as shown in our previous report [1], one may have interest on the MIC with BPSK spreading. Therefore, in this report, we would like to compare the MIC performance using QPSK spreading with that using BPSK spreading.

The MIC with BPSK spreading can be regarded as a special case of the MIC with QPSK spreading by setting the same in-phase and quadrature signature waveforms. Therefore, the details of the MIC can be found in the previous report [1] and thus will be omitted in this report. The results show that the MIC with QPSK spreading can provide better performance than that with BPSK spreading. This report is organized as follows. In Section 2, the MIC with BPSK spreading is briefly described. The experimental comparison of QPSK and BPSK spreading is shown in Section 3. In Section 4, we draw our conclusions.

2 Multistage Interference Cancellation with BPSK Spreading

In BPSK spreading, the in-phase and quadrature signature waveforms are the same. Therefore, BPSK spreading can be regarded as a special case of QPSK spreading. Specifically, the transmitted signal for user k by employing BPSK spreading can still be written as

$$s_k(t) = \sqrt{\frac{2\rho_k}{N}} b_k(t - T^{(k)}) a_k(t - T^{(k)}) e^{j\theta_k} \tag{1}$$

where k is the user index, $\rho_k := E_k/N_o$ is the normalized signal power, where E_k is the symbol energy for user k and N_o is the noise power spectral density. $T^{(k)}$ and θ_k are the time delay and the phase shift associated with user k. The information bearing waveform $b_k(t)$ is given by

$$b_k(t) = \sum_{n=-\infty}^{\infty} e^{-j\phi_n^{(k)}} P_{T_b}(t - nT_b) \tag{2}$$

where $\phi_n^{(k)}$ is the data bearing phase and is taken from the set $\{2\pi(m-1)/4, m = 1, 2, ..., 4\}$ for QPSK phase modulation.

In (1), $a_k(t)$ is the signature waveform assigned to user k. Note that in BPSK spreading, the in-phase and quadrature branches are with the same signature waveform. Thus, $a_k(t)$ is given by

$$\begin{aligned} a_k(t) &= \sum_{i=-\infty}^{\infty} \frac{1}{\sqrt{2}} \left[a_i^{(k)} + j a_i^{(k)} \right] P_{T_c}(t - iT_c) \\ &= \sum_{i=-\infty}^{\infty} a_i^{(k)} e^{j\pi/4} P_{T_c}(t - iT_c) \end{aligned} \tag{3}$$

where $a_i^{(k)} = a_{N+i}^{(k)}$ are PN codes assigned to user k, and are taken from the set $\{-1, 1\}$. $\frac{1}{\sqrt{2}}$ is a normalization factor.

The phase shift in (3) can be absorbed into θ_k in (1) such that $a_k(t) = \sum_{i=-\infty}^{\infty} a_i^{(k)} P_{T_c}(t - iT_c)$. Using this $a_k(t)$, the procedure of the MIC schemes for BPSK spreading can be followed exactly as for QPSK spreading in this report. Therefore, we will not repeat it here but focus on the performance comparison shown in next section.

3 Simulation results

In this section, several simulation results are presented to compare the MIC performance using QPSK spreading with that using BPSK spreading.

In the simulation, we use the same simultion model as in this report. In addition, Gold sequences with N=31 are still considered as PN codes. It is noteworthy to mention that for QPSK spreading, a pair of Gold sequences is assigned to each user while for BPSK spreading, only one Gold sequence with N=31 is assigned. In the notation, the MIC (new) still refers to the new MIC scheme, in which the MAI and the partial SI are reconstructed and subtracted in the canceller. The MIC (old) denotes the conventional MIC scheme [7, 8], in which the MAI and the total SI are reconstructed and subtracted in the canceller. Besides, MIC-0 denotes the initial stage decision of the MIC. Since there is no interference cancellation used in MIC-0, its performance is thereby equivalent to that of the conventional Rake receiver.

All bit error rates (BER) presented are estimated from 3×10^{-6} Monte Carlo trials.

In Fig.1, the BER of the MIC with QPSK or BPSK spreading in 3-user system with N=31 over 2-path Rayleigh fading channels is plotted versus SNR. All users are with equal power and perfect channel knowledge is assumed. It can be seen that all MICs with QPSK spreading can provide lower bit error rates than the corresponding ones with BPSK spreading. In particular, significant performance achievement of QPSK spreading over BPSK spreading is observed in the MIC-0 and the MIC-1 (old). In the MIC-1 (new), however, the performance difference is very small. Such phenomenon is due to the fact that the MAI and the SI can be well suppressed in the new MIC such that the interference alleviation provided by QPSK spreading over BPSK spreading is not salient.

In Fig.2, we plot the BER of the MIC with QPSK or BPSK spreading versus the power of interfering users, i.e., SNR$\#3$-SNR$\#1$ (dB), in 3-user system with SNR$\#1$=20dB and N=31 over 2-path Rayleigh fading channels. We still consider perfect channel knowledge. Similar observation to that in Fig.1 is obtained.

Now, we study the performance versus the number of diversities L. The results in 3-user system with SNR=20dB and N=31 are shown in Fig.3. It can be seen that the the MIC with QPSK spreading still outperforms that with BPSK spreading except for a particular point of the MIC (new) at L=4. This may be due to the accuracy of the BER estimated from 3×10^{-6} simulation trials.

Further study on the performance versus the number of active users is conducted and the results are shown in Fig.4 and Fig.5 for the old MIC and the new MIC, respectively, where the MIC-0 is the same. From Fig.4, we can see that even in the case of multiple active users, the performance of the MIC with QPSK spreading still outperforms that with BPSK spreading. In Fig.5, it is also shown that the performance of the new MIC with QPSK spreading is generally better than that with BPSK spreading although at the testing point of K=9 users, the performance of the new MIC-1 with QPSK spreading is slightly worse than that with BPSK spreading. A possible explanation is that in the new MIC, due to the good suppression of the MAI and the SI, the performance of QPSK spreading and that of BPSK one are comparable while in the old MIC or the MIC-0 (no interference cancellation), the use of QPSK spreading is preferable.

Next, we consider the performance in the presence of imperfect channel knowledge. The BER in 3-user system with SNR=20dB over 2-path Rayleigh fading channels versus the variance of channel estimation error is plotted in Fig.6. Good performance of the MIC with QPSK spreading over that with BPSK spreading is observed.

Finally, the BERs of the old MIC and the new MIC versus the number of active users when the variance of the channel estimation noise is set to 10^{-2} are plotted in Fig.7 and Fig.8, respectively. The results are similar to those in Fig.4 and Fig.5, and they still indicate that the performance of the MIC with QPSK spreading is generally better than that with BPSK spreading especially in the MIC-0 and the old MIC-1,2.

By the results, the MIC with QPSK spreading is shown to provide better performance than that with BPSK spreading. The performance improvement is significant in the conventional detectors and not salient in the new MIC when the MAI and the SI in the received signals are well suppressed.

4 Conclusions

This technical report compares the performance of the MIC using QPSK with that using BPSK spreading. The results indicate that the use of QPSK spreading can alleviate, to some extent, the power of interference from multiple users' signals and multipath signals and the resulting performance is generally better than the use of BPSK spreading. However, the gain is very slight for the new MIC due to the subtraction of the interference.

Bibliography

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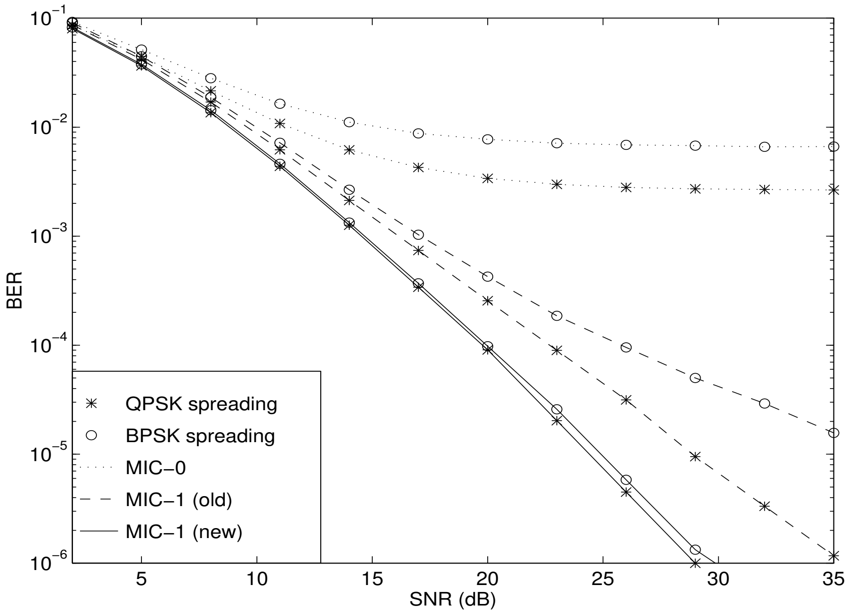

Fig. 1: Simulated BERs of the MIC with QPSK or BPSK spreading versus SNR in 3-user system with N=31 over 2-path Rayleigh fading channels. All users are with equal power. Perfect channel knowledge. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC.

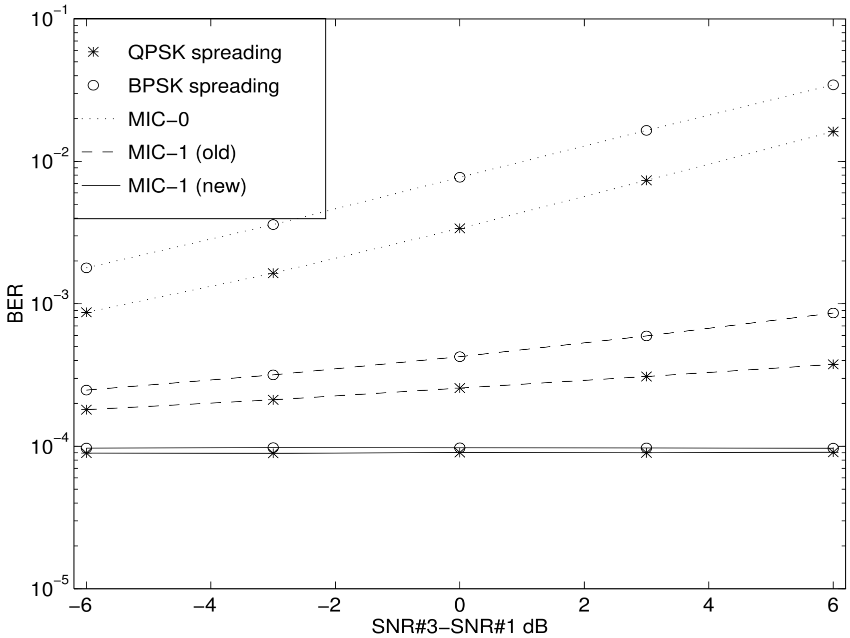

Fig. 2: Simulated BERs of the MIC with QPSK or BPSK spreading versus SNR#3-SNR#1 in 3-user system with SNR#1=20dB and N=31 over 2-path Rayleigh fading channels. SNR#2=(SNR#1+SNR#3)/2dB. Perfect channel knowledge. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC.

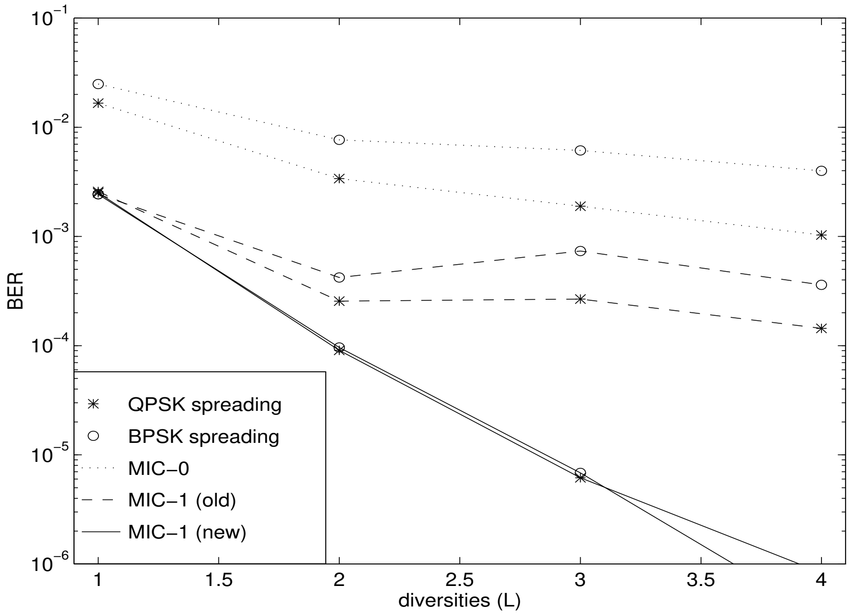

Fig. 3: Simulated BERs of the MIC with QPSK or BPSK spreading versus the number of diversities (L) in 3-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. Perfect channel knowledge. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC.

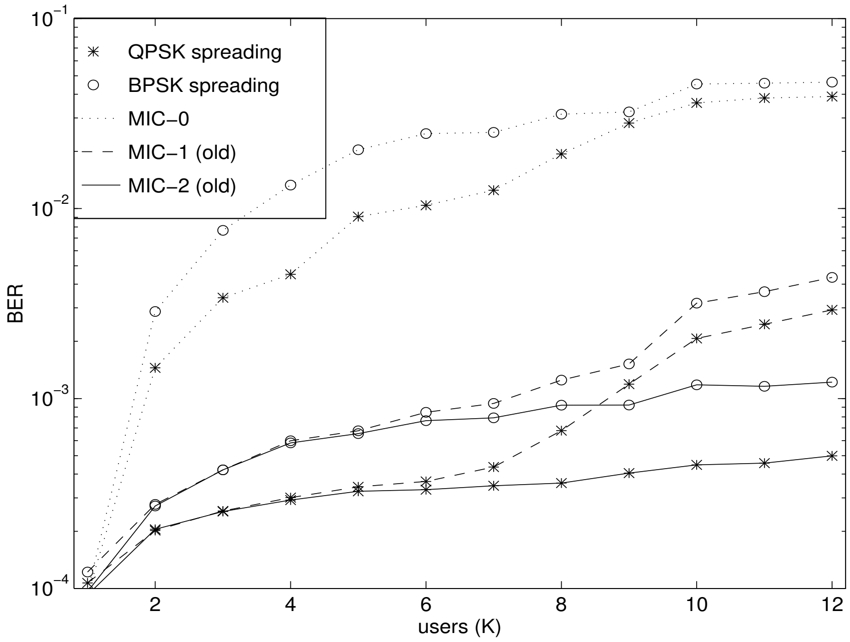

Fig. 4: Simulated BERs of the MIC (old) with QPSK or BPSK spreading versus the number of users (K) in multi-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. Perfect channel knowledge. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC; MIC-2: 2-stage MIC.

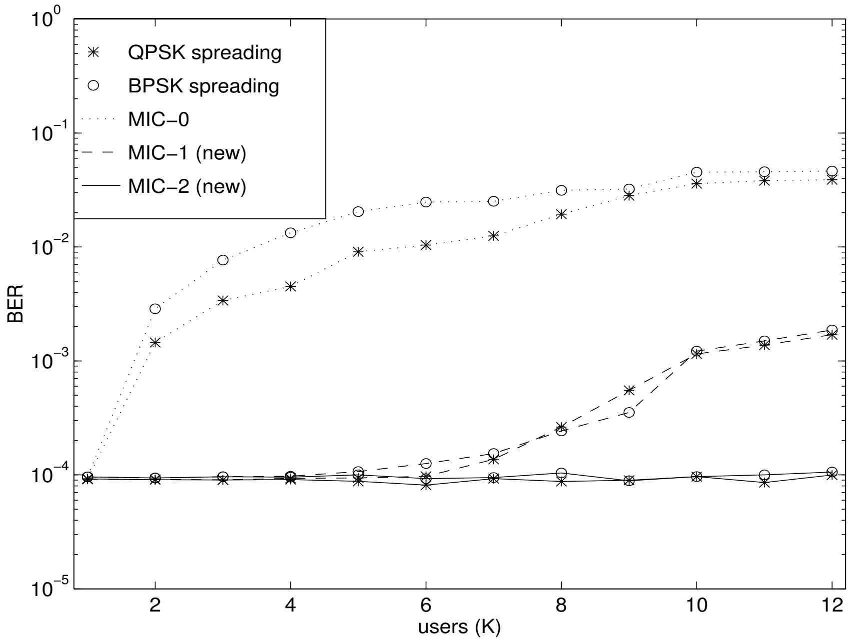

Fig. 5: Simulated BERs of the MIC (new) with QPSK or BPSK spreading versus the number of users (K) in multi-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. Perfect channel knowledge. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC; MIC-2: 2-stage MIC.

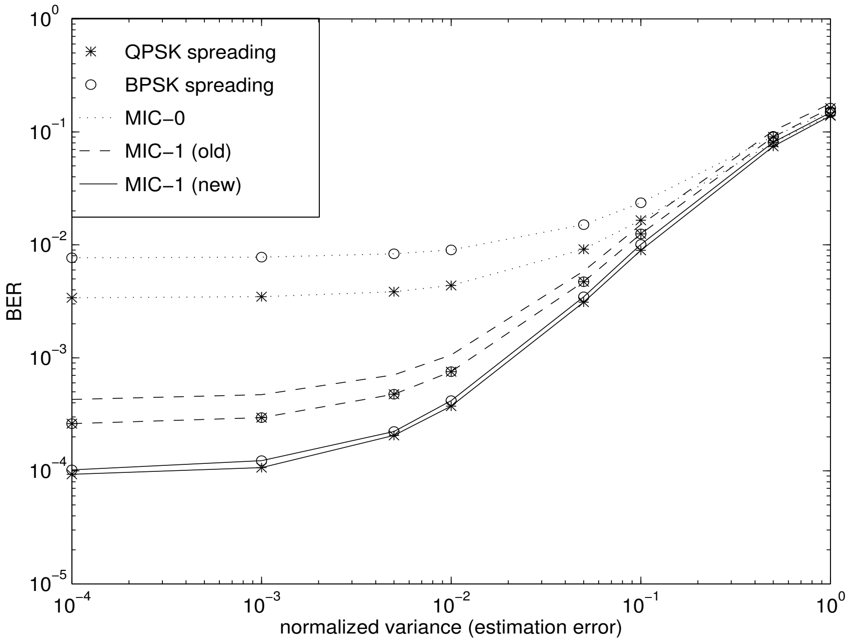

Fig. 6: Simulated BERs of the MIC with QPSK or BPSK spreading versus the normalized variance of channel estimation error in 3-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC.

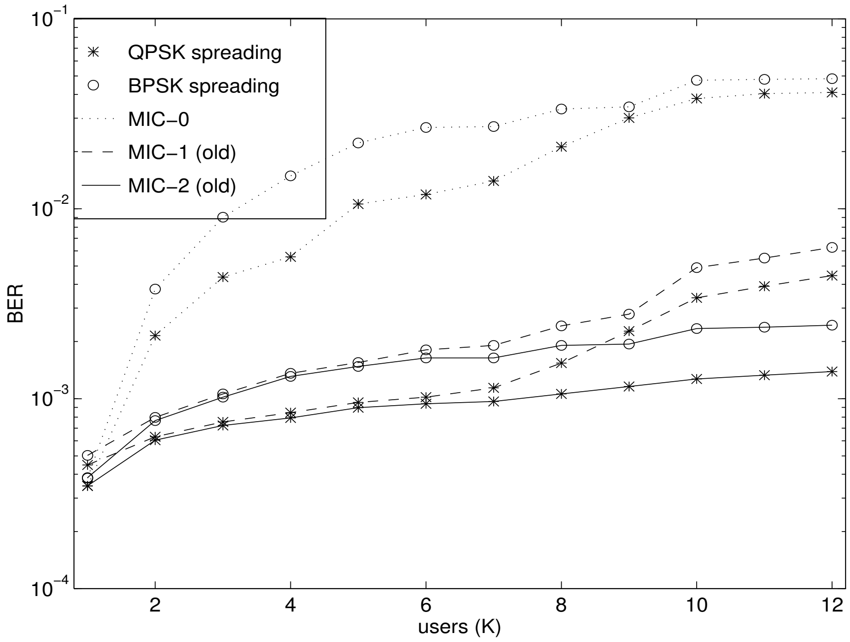

Fig. 7: Simulated BERs of the MIC (new) with QPSK or BPSK spreading versus the number of users (K) in multi-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. Imperfect channel knowledge with $\sigma_w^2 = 10^{-2}$. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC; MIC-2: 2-stage MIC.

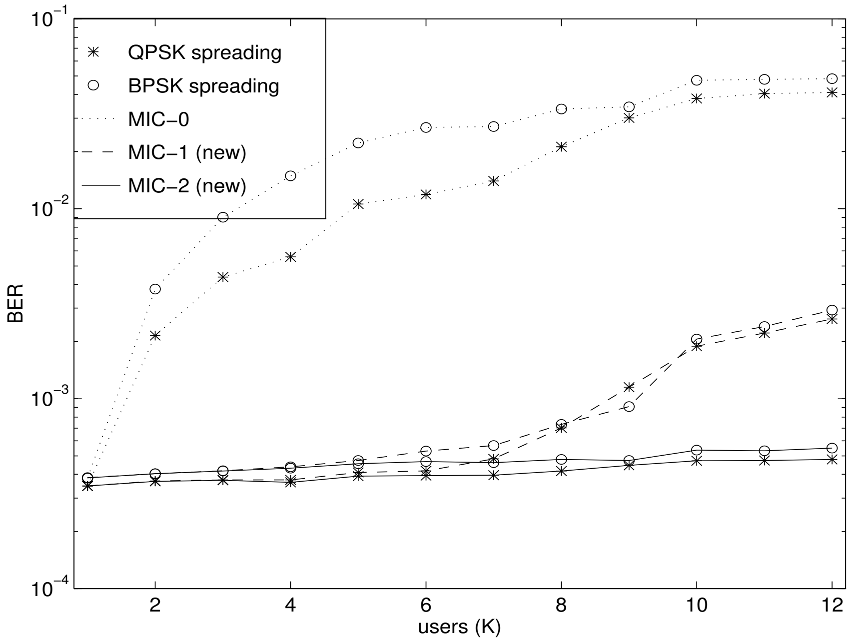

Fig. 8: Simulated BERs of the MIC (new) with QPSK or BPSK spreading versus the number of users (K) in multi-user system with SNR=20dB and N=31 over 2-path Rayleigh fading channels. All users are with equal power. Imperfect channel knowledge with $\sigma_w^2 = 10^{-2}$. MIC-0: 0-stage MIC; MIC-1: 1-stage MIC; MIC-2: 2-stage MIC.