Multi-rate Group-Wise Successive Interference Cancellation Structure in COST 259DCM Channels

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***Resumo* — Neste trabalho foi proposto um Cancelador de Interferência Sucessivo de Grupo (MC-GSIC) para sistemas CDMA adaptado a canais com desvanecimento multipercurso. Particularmente, foi analisado o desempenho do receptor sujeito a canais COST259DCM através de simulação Monte Carlo (MCS).**

***Abstract* — In this paper we have proposed a multi-code Group-Wise Successive Interference Cancellation (MC-GSIC) CDMA topology, adapted for multipath fading channels; particularly, we have analysed the performance under COST259DCM channels via Monte Carlo simulation (MCS).**

***Index Terms*—Multi-user, Interference Cancellation, SIC, PIC, GSIC, COST259, Monte Carlo.**

I. Introduction

Conventional Detectors (like Matched Filter or Rake Receiver) are inefficient because they treat the Multiple Access Interference (MAI) as AWGN and additionally are sensible to near far effect that imposes a strong power control necessity. The natural step is to consider some type of detector that uses all users' information for the desirable signal detection. S. Verdú first introduced this type of detector [1] and [2]. Unfortunately this detector requires an exhaustive search procedure so is not quite practical. So some sub-optimum variations need to be considered. Multi-user Detectors (MuD) can be classified as linear and non-linear. The non-linear approach or IC (Interference Cancellation) type MuD tries to subtract the influence of others users (or most of them) from the desired user signal and after this operation, ideally, we have a "cleaned" version of the input signal for subsequent detection. This interference cancellation can be done in a successive (SIC), parallel (PIC) or hybrid manner, combining users in groups and performing the cancellation in serial or parallel mode, following some criterion (GSIC or GPIC).

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Among various multi-rate transmission possibilities we have selected the multi-code scheme due its implementation and code selection simplicity.

II. MC-GSIC Structure

The basic idea behind the MC-GSIC structure is to group the users according its received powers in a form to use one receiver for each one of S groups. In this form we are detecting only those users that have similar received powers. It's very important to put all groups in a decreasing received power order. With this ordination we can guarantee that all users with smaller power will be detected in the last stage.

In MC-GSIC structure first we detect all users from the first group; after all signals reconstruction, this combined signal is subtracted from the delayed input and sent to the next group detector, and so on, until to reach the final detection group. Of course, with perfect estimation in one group the next group input signal is MAI (including delayed versions for multipath channels) free from users from previous group power.

In the MC-GSIC structure for the multipath channel version, the stages' number S (and accordingly the groups) and the power limits for group separation were defined based on all users received power histogram.

For three power groups existence (fixed as maximum in this work) we have to have groups with more than 10% of total users. We define the number S as the number that satisfies this condition. In general the power limits are re-calculated in order to guarantee that the bands are equally distributed between the maximum and minimum received power. When the difference between the power extremes is smaller than 4dB we fix S=1. In this stage of our investigation we are assuming perfect power estimations.

The proposed topology is presented in Fig. 1 and 2. Each of s=1, 2, … , S power groups is basically a RAKE receiver with MRC followed by a group MC-PIC stage and hard decision (HD) device. We adopted a PIC with 2 stages. Except for first group s=1, the cancelling of users from the superior group precedes the detection of users in each group. Therefore, when S=1 the structure is equivalent to an MC-PIC structure for multipath channels.

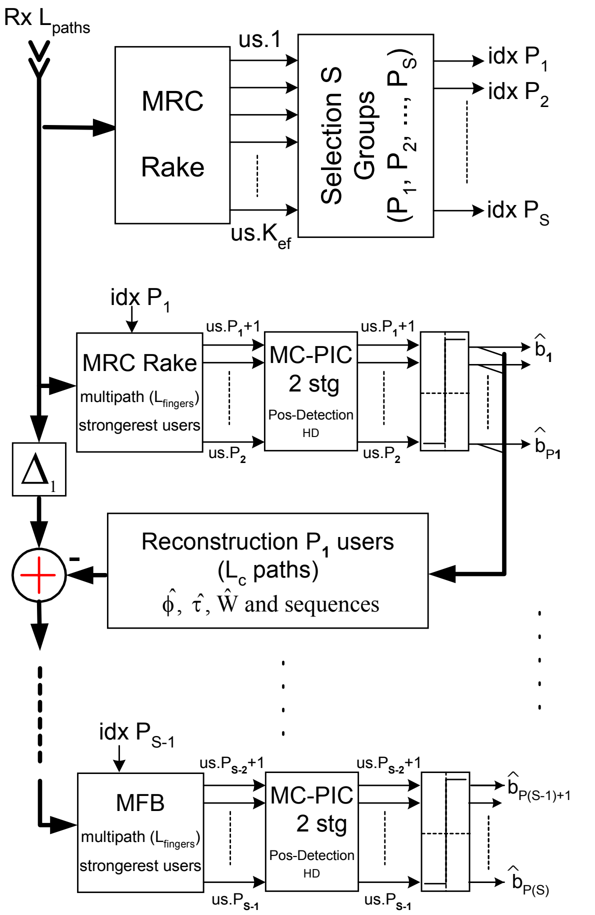


Fig. 1 - MC-GSIC Pre-Detection structure for multipath channel with Lpaths paths, S successive stages and with MC-PIC groups of 2 stages.

III. Multipath Channel Simulation

In our simulations we have considered the three data rate case (rates R, 2R and 4R), Gold spreading sequences with length 31 and an auto-interference cancellation scheme which considers only adjacent symbols energy, *SiI* [3]. Since the multipath channel self-interference (*SI*) can be decomposed in two parts:

$$SI = SiI + ScI \quad (1)$$

where: *SiI* denotes the self-interference component considering only the inter-symbolic part and *ScI* denotes the self-interference component considering only the current symbol part, we have considered MAI reconstruction and the self-interference reconstruction only in the case of partial self-interference when: *SI* = *SiI*. In this case, the current symbol part of self-interference, *ScI,* will aid in the bit decision, reducing the BER.

We have considered the filtered COST259DCM channel simulator [4], filtered with an ideal low pass filter with BW=1/T_c. Adopting system conditions compatible with the 3G patterns:

a) Carrier frequency: $f_c = 1.9GHz$;
b) Multi-rate Multi-code (MC) scheme, the symbol rate in each channel will be the same: $T_b^{Max} = T_b^{Basic}$, for any symbol rate;
c) W-CDMA bandwidth, resulting in a chip duration given by: $T_c \simeq BW^{-1} = 260.4ns$.

Additionally, assuming short code: T_b= (GP)T_c and processing gain GP = 31 the information symbol duration of $T_b = 8.072\mu s$ (i.e. a basic symbol rate $R = 120Kb/s$). The resulted normalised Doppler displacements, D_{dpl}, are very small. We have obtained simulations results for three possible scenarios in a typical urban (TU) environment (Table I).

TABLE I
PARAMETERS FOR THREE TU ENVIRONMENT

TU Scenario	Relative Velocity [Km/h]	f_m [Hz]	D_{dpl}
Fast Vehicular	110	194	1.61×10^{-3}
Slow Vehicular	50	88	0.73×10^{-3}
Pedestrian	5	8.8	73.33×10^{-6}

where the normalised Doppler displacement is given by:

$$D_{dpl} = T_b f_m \quad (2)$$

where f_m is the maximum Doppler frequency due to transmitter (and or receiver) mobility. But due to the space limitation in this paper we just presents results for fast vehicular macrocell TU scenario.

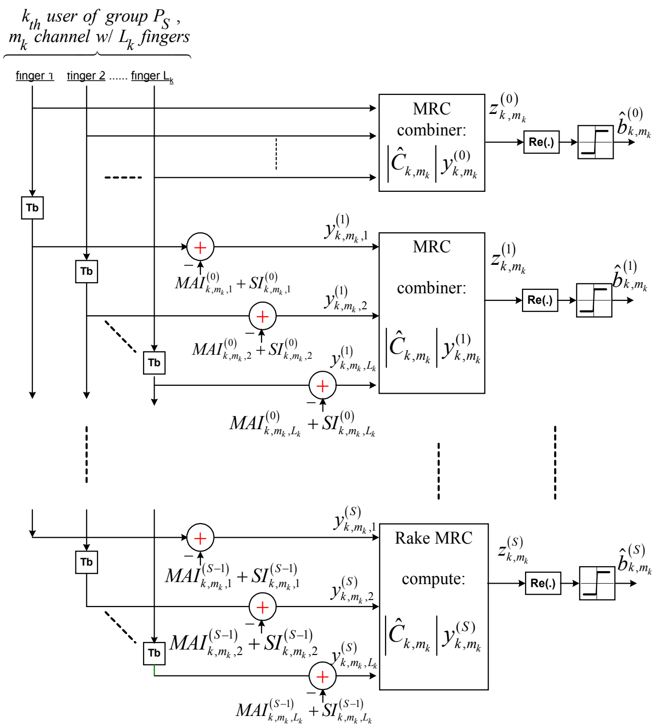


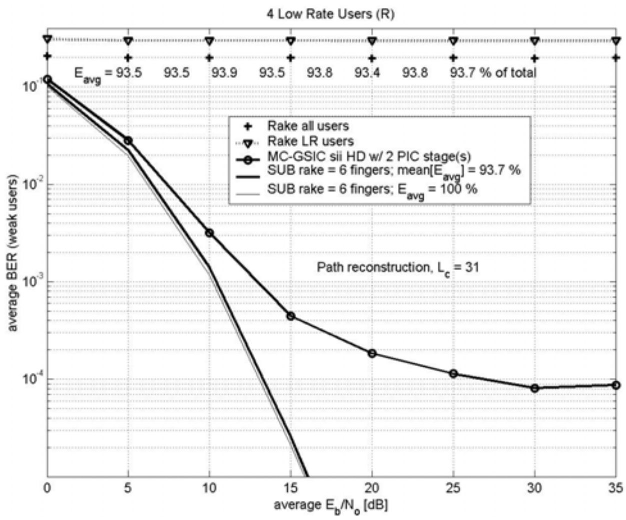
Fig. 2 - Details of the MC-PIC block used in the MC-GSIC Pre-Detection: K us. with m_k parallels channels in a Multi-rate Multi-code and Rayleigh Multipath channel.

The next sections describe in details the simulation conditions and performance results in average bit error rate ("average BER") terms for the simulated MC-GSIC-SiI structure in channel with multipath fading.

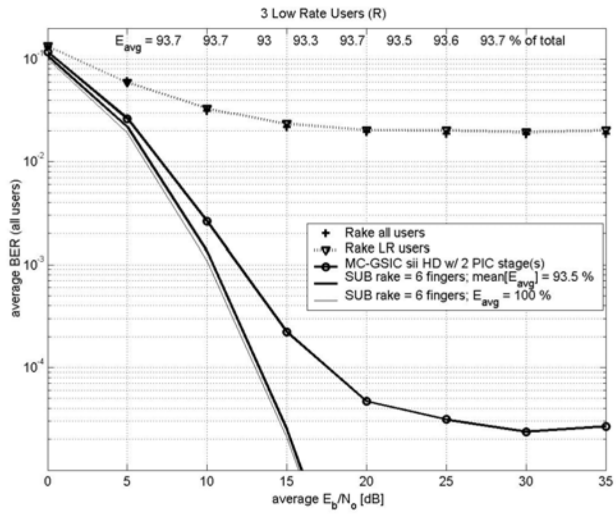
IV. MC-GSIC-SII PERFORMANCE IN FAST VEHICULAR TU SCENARIO COST259DCM

This section presents MCS simulation results for the MC-GSIC-SiI with 6 fingers in a Rayleigh fading channel (filtered COST259DCM with 31 paths spaced by T_c). These simulations were carried out with Gold spreading sequences of length 31. Table II shows the main simulation parameters.

Fig. 3, 4, 5 compare the average performance considering multi-rate users in a perfect power control scenario and the scenario where there is only 1 user from each group rate with NFR=+15dB (average performance of weak users only); the number of reconstruction paths in the groupwise interference canceller is $L_c = L_{path} = 31$.



(a) Power disparities: 1 of 4 LR user with NFR=+15dB



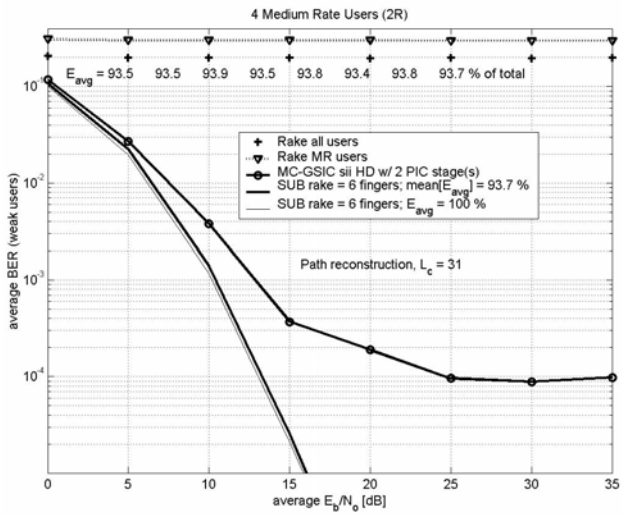
(b) 3 LR users with NFR=0dB

Fig.3: MC-GSIC-SiI low rate users performance

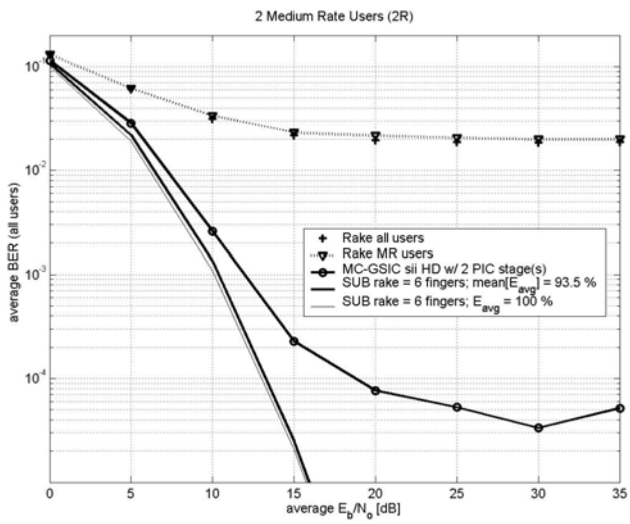
Note that the two scenarios also differ in loading: [4 4 2] users with power disparity and [3 2 1] users for perfect power control condition. For comparison purpose the Rake analytical performance with MRC (maximal ratio combining) and 6 fingers was considered ("SUB rake") [5]. Note that, in all presented results the 6 strongest rays represent more than 93% of total energy from the set generated by filtered COST259 with 31 multipath. We also show the (marginal) improvement obtained with the Rake receiver and 100% of energy contained in 6 rays (E_{avg}).

TABLE II
MCS SIMULATION PARAMETERS

E_b/N_0	0:5:35 [dB]
Multi-Rate Users	1R 2R 4R
Load	[4 4 2] or [3 2 1] MC users
Effective Load	20 or 11 users
Processing Gain	31
NFR	. 0 (Perfect Control Power) . +15 dB, 1 user of each rate . half users pop. with +10dB
Spreading Sequence	GOLD
Performance (weak users)	$\overline{BER}$ x EbNo and $\overline{BER}$ x K
Channel	Filtered COST259 TU – veh.
D_{dpl}	0.00156226
Fingers	6
PIC stages	2 or 3
L_c reconstruction paths	6 (> 93% of total Energy); 31 (total Energy)



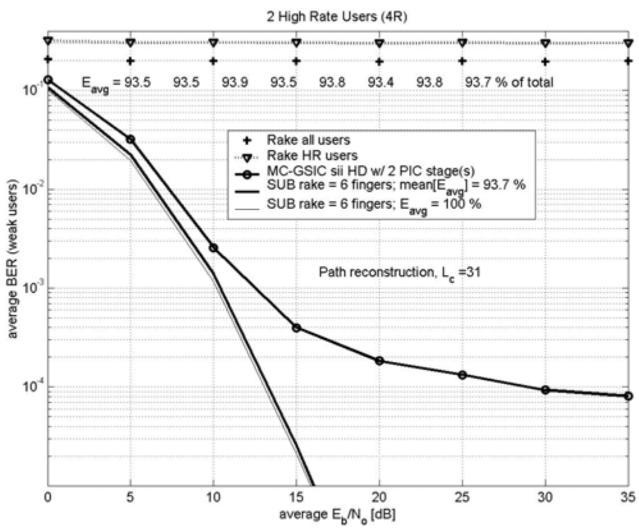
(a) power disparities: 1of 4 MR users with NFR=+15dB



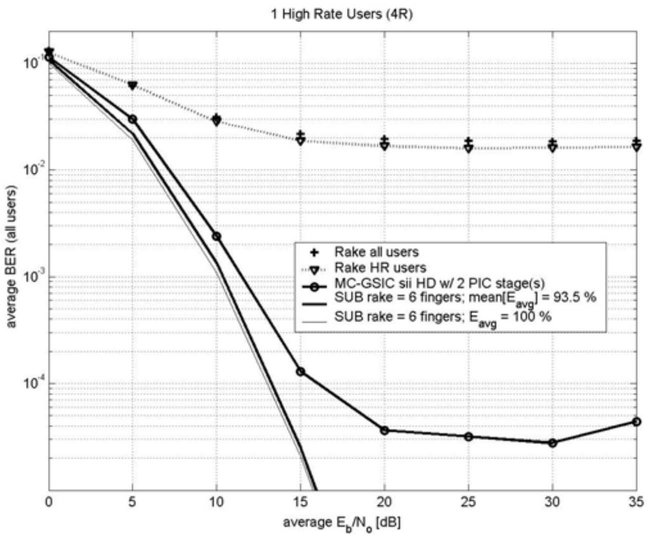
(b) 2 MR users with NFR=0dB

Fig. 4: MC-GSIC-SiI medium rate users performance

In the NFR=0dB condition, the MC-GSIC-SiI trends to MC-PIC SiI. The performance results for users with different rates are similar. In this scenario, the floor BER for the second stage is around $2x10^{-5}$ to $4x10^{-5}$ (this small fluctuation is caused by the insufficient trials in the simulation). In the power disparity scenario, there is a small degradation resulting that the floor BER for the second stage is around $2x10^{-5}$ to $4x10^{-5}$. This degradation can be justified because even that a power increase for strong users implies a benefice for weak users detection in a groupwise structure, for the simulated condition the degradation due to a largest load overcame this improvement. Nevertheless the final degradation shows to be insignificant.



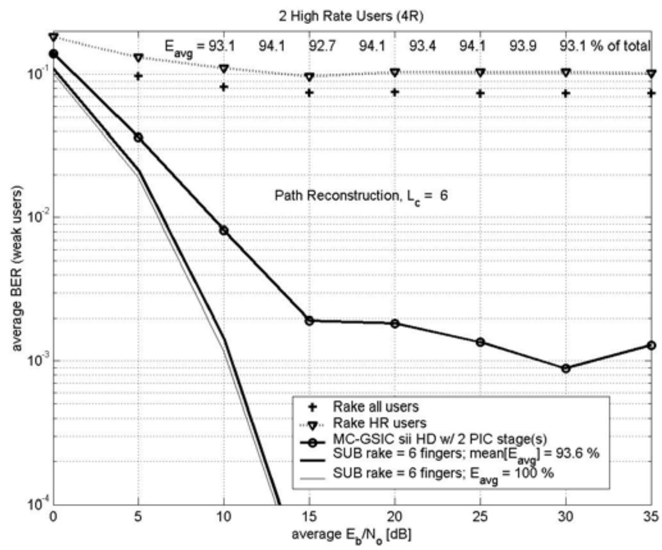
(a) power disparities: 1 of 2 HR user with NFR=+15dB



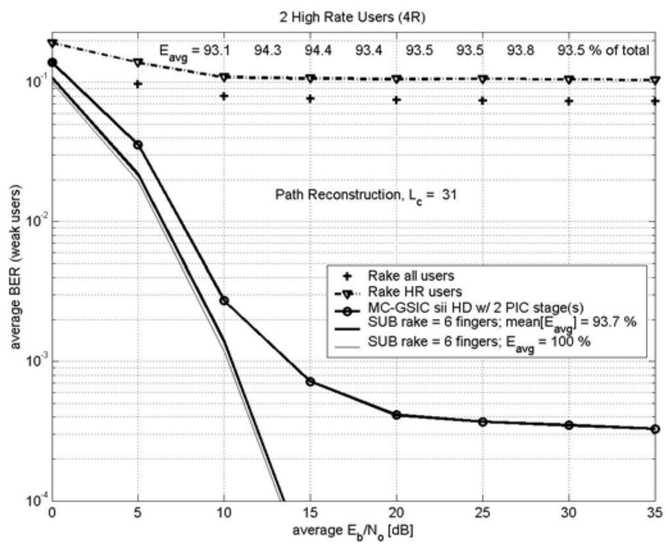
(b) 1 HR users with NFR=0dB

Fig. 5: MC-GSIC-SiI high rate users performance

Fig. 6 shows the MAI reconstruction (L_c) paths number effect in the MC-GSIC-SiI structure performance. The Rake receiver with 6 fingers captures 93% of total energy from the 31 paths filtered COST259 channel. It is assumed a PIC structure with 2 stages, load of 65%, i.e. [4 4 2] users, and a power disparity condition: 1 user from each group with NFR=+5dB. The weak users' performance, for users from low and medium rate group, follows the same performance pattern. The figure shows us that considering all paths for the MAI reconstruction we have a performance improvement: in our simulation conditions the floor BER was reduced from $1x10^{-3}$. (@L_c = 6) to $3x10^{-4}$ (@L_c = 31). In a GSIC-SiI scheme a small loss in the reconstruction process, mainly for the strongest users, degrades the weak users' performance. This fact shows that the maximum energy capture is important but not sufficient, mainly in a strong NFR condition. So in a strong NFR condition the perfect, and complete, reconstruction is vital. Obviously, in a perfect power control scenario (or almost) the fact is unimportant.



(a) number of reconstructed paths L_C=6.



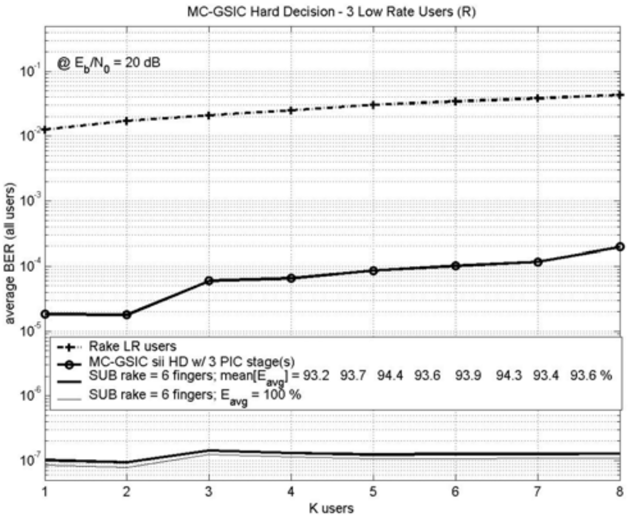
(b) number of reconstructed paths L_C=31.

Fig.6: MC-GSIC-SiI structure performance for high rate weak users and two reconstructed paths numbers *(L_C)*.

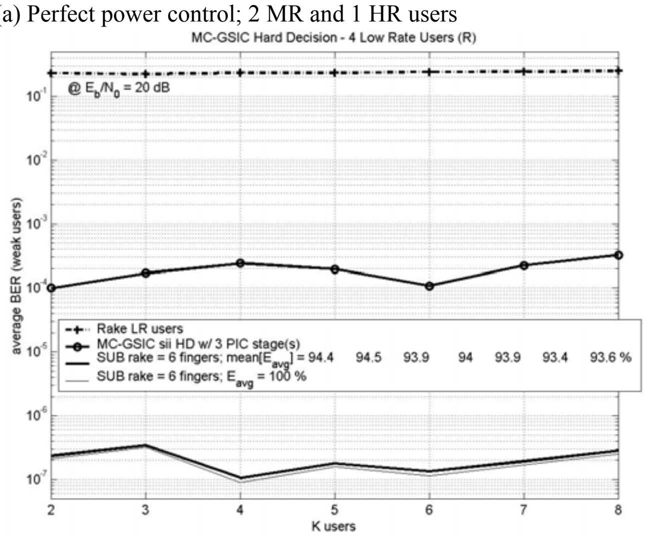
Fig. 7 summarises the MC-GSIC-SiI structure behaviour growing the multi-rate users' number, considering a perfect power control scenario and also a power disparity scenario.

The number of low rate users was increased maintaining constant the number of medium and high rate users. The number of reconstructed path was considered as L_C=31 and three parallel cancelling group stages was used. The scenarios with growing of medium and high rate users follow the same performance pattern.

Note the relative NFR robustness when perfect power control condition is changed to a NFR condition, with half of users 10 dB above others, Figs. 7.a and 7.b. Note also great immunity for load increasing: [1 2 1] to [8 2 1], i. e., 29% to 52%, in perfect power control condition (Fig. 7.a) and [2 4 2] to [8 4 2], i. e., 47% to 65%, in a NFR condition, Fig. 7.b.



(a) Perfect power control; 2 MR and 1 HR users



(b) ½ LR, MR and HR users with NFR=10dB; 4 MR and 2 HR users.

Fig. 7: MC-GSIC-SiI performance increasing LR users population; L_C=31; $\overline{E_b/N_0} = 20dB$.

V. CONCLUSIONS

On the presented simulations we have obtained and analysed performance results for the MC-GSIC-SiI multi-rate multi-user structure considering realistic fading channels as COS259DCM.

We have privileged the comparative analysis between the MC-GSIC-SiI and Conventional (Rake) algorithms, taking in account the power disparity, different loads, the number of reconstructed paths, two performance figures (increasing user population and variable E_b/N_0) and multipath channel effects.

In a power disparity scenario we have obtained very good results for the MC-GSIC-SiI structure. Despite the performance degradation we can infer from the MCS that the structure is robust with a strong power disparities among users in a severe and realistic channel COST259DCM.

So the MC-GSIC-SiI structure is attractive for scenarios where some users have a very small power or even when we can classify the users in sub-groups with a large power deviation.

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