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Non-coherent Large Scale MIMO: massive but feasible

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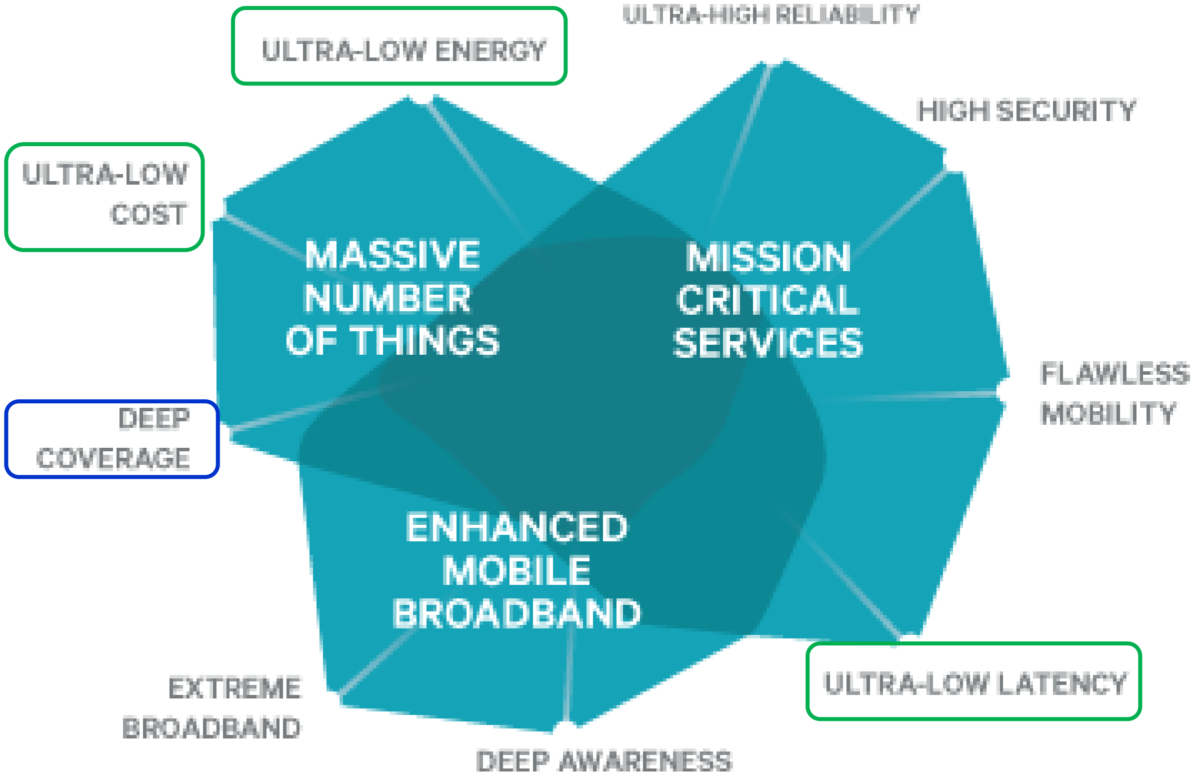
Agenda

- Introduction and overview
- Non-coherent transmission schemes for Massive MIMO
- Multi-user DMPSK-based massive MIMO
  - SINR and Error probability
  - Channel coding to reduce the number of antennas
- Conclusions

Introduction

- New requirements call for new technologies



Non coherent processing may be a good solution

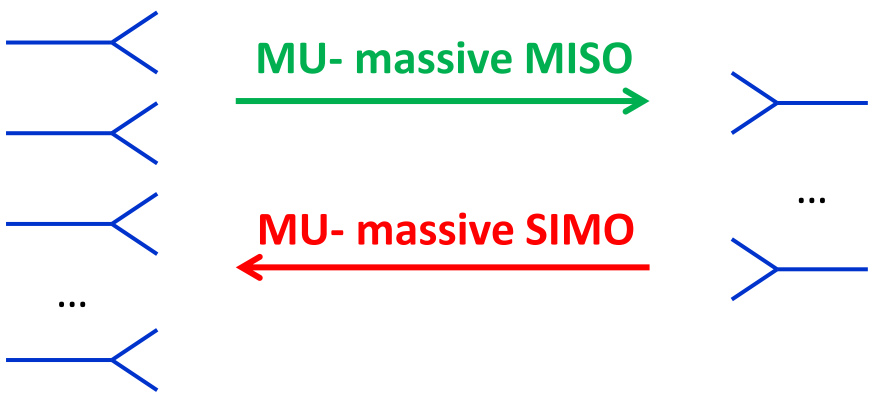
if combined with massive MIMO

Non coherent communications – why now?

- 3 dB loss of non-coherent (NC) vs coherent (C) processing
- When we consider the needs of channel state information (CSI) obtaining and sharing, this loss may become negligible
  - A. Goldsmith's work: To train or not to train? Channel estimation is wasteful in some circumstances (channels with low coherence time, low SNR)
- NC massive MIMO: the perfect match!
  - The "magic" of massive MIMO (self interference cancellation) may improve NC performance
  - CSI estimation and sharing is vey complex in massive MIMO (pilot contamination ...)

Massive MIMO

- Benefits of increasing (a lot) the number of antennas
  - Improve data rates and reliability (multiplexing and diversity gains)
  - Decrease required transmit power
  - Very simple precoders/decoders
- Most usual configuration is



R antennas at BS, *R* >>

K single antenna users, *K*<<*R*

Non-coherent massive MIMO

- [1] proposed an Uplink ASK (amplitude shift keying) energy-detector scheme
  - For a single user, they achieve rates which are not different from coherent schemes in a scaling law sense
  - 2-user system proposed in [2]
  - Too many antennas are required for reasonable performance with actual constellation design.
- [3] proposed decision-feedback differential detection of DMPSK. Relies on particular channel model and similarities to IR-UWB
  - Assumes the users to be randomly distributed in front of a large linear antenna array at the BS. Not general.

[1] M. Chowdhury, A. Manolakos, A.J. Goldsmith, “Design and Performance of Noncoherent Massive SIMO Systems,” Proc. of 48th Annual Conference on Information Sciences and Systems, Princeton, 2014.
[2] M. Chowdhury, A. Manolakos, A.J. Goldsmith, “CSI is not needed for Optimal Scaling in Multiuser Massive SIMO Systems,” Proceedings of ISIT., Honolulu, July 2014.
[3] A. Schenk, R.F.H. Fischer, “Noncoherent Detection in Massive MIMO Systems,” Proc. of International ITG/IEEE Workshop on Smart Antennas, Stuttgart, March 2013.

Multi-user Large Scale single input-multiple output (SIMO) uplink [4]

- One base station (BS) with *R* receive antennas
- *K* Mobile Stations (MSs) with single antenna
- Data symbol sequences $s_j[n]$ (j=1,…K) are M-PSK:

$$\mathfrak{M}_j = \{s_{j,m}, m = 0, 1, \ldots, \mathrm{M}\} \qquad |s_{j,m}[n]| = 1$$

- Tx signal at time instant *n* comes from differentially encoding $s_j[n]$:

$$x_j[n] = x_j[n-1] s_j[n], n > 1$$

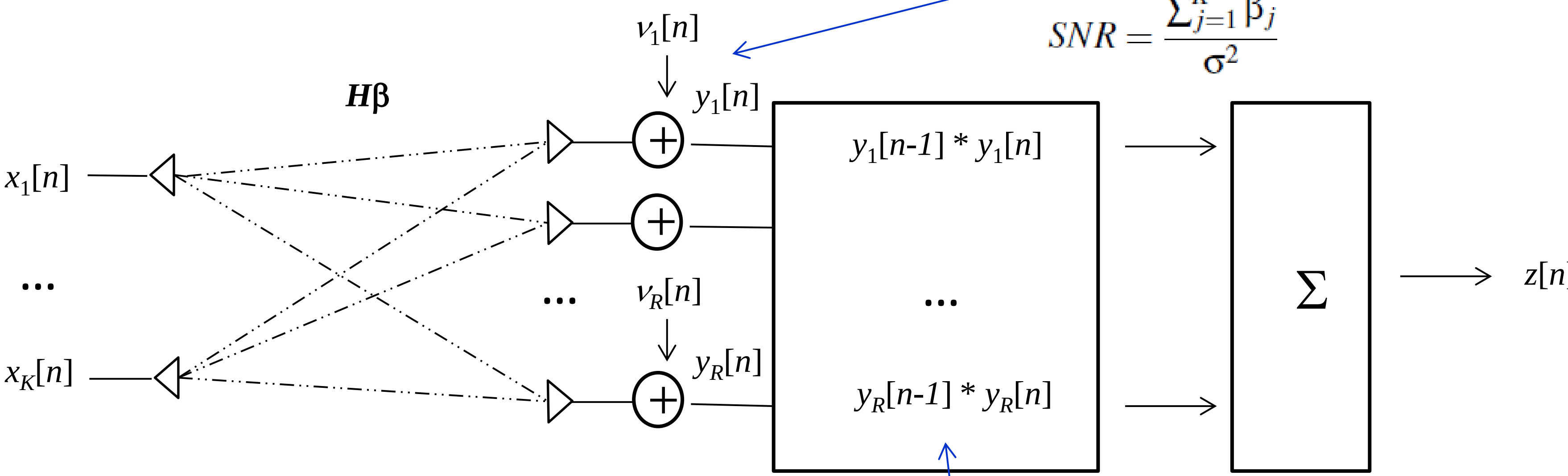
- No channel coding (by now)

[4] A. G. Armada and L. Hanzo, "A Non-Coherent Multi-User Large Scale SIMO System Relying on M-ary DPSK," IEEE ICC, Jun. 2015 pp 2517-2522.

System model

Reference SNR

$$SNR = \frac{\sum_{j=1}^{K} \beta_j}{\sigma^2}$$



$$\boldsymbol{y} = \boldsymbol{H}\boldsymbol{\beta}\boldsymbol{x} + \boldsymbol{\nu}$$

$$z[n] = \frac{1}{R}\sum_{i=1}^{R} y_i[n-1]^* y_i[n]$$

At the Rx: the phase difference of two consecutive symbols received at each antenna is non-coherently detected and they are all added to give the decision variable $z[n]$

Multiple users - detection

We define the **joint symbol** as $\varsigma[n] = \sum_{j=1}^{K} \beta_j s_j[n]$

- can be estimated from $z[n]$

Asymptotic behavior:

From the Law of Large Numbers we know that

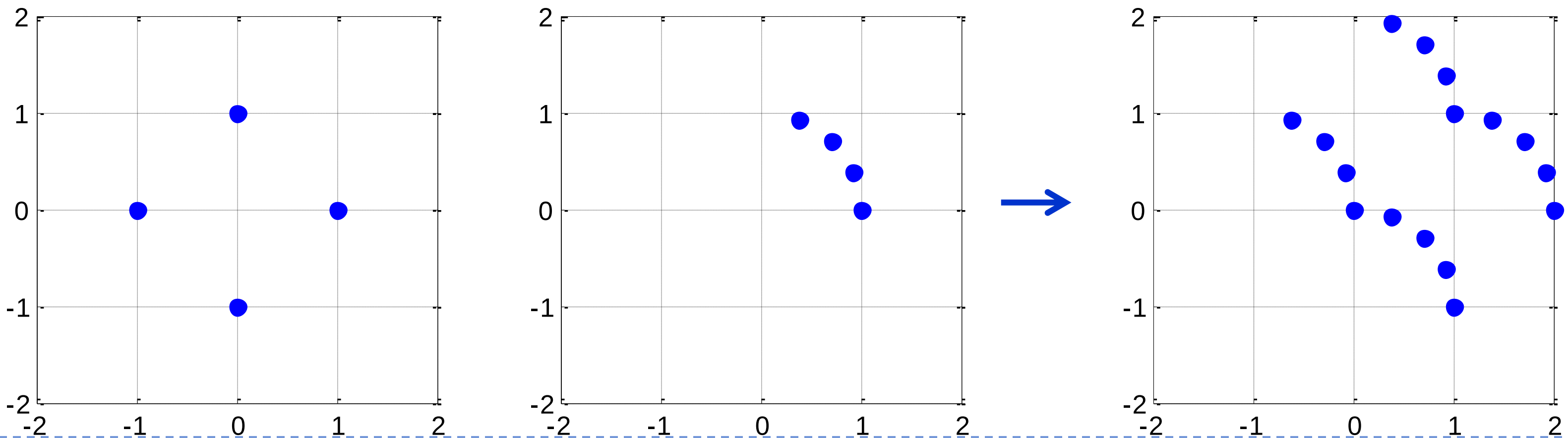
$$\frac{1}{R}\sum_{i=1}^{R} |h_{ij}|^2 \overset{R\to\infty}{=} 1$$

So we have

$$z[n] \overset{R\to\infty}{=} \varsigma[n] + noise\ terms$$

Joint constellation:

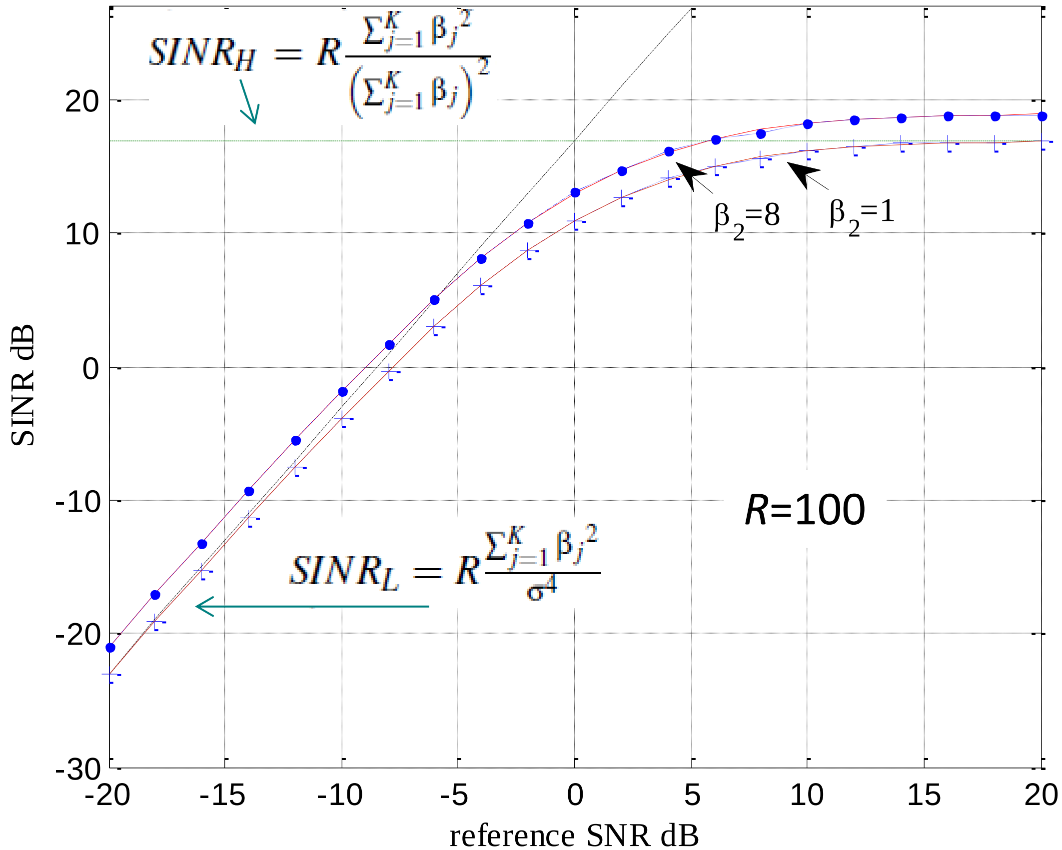
$$\mathfrak{M} = \{\varsigma_m, m = 0, 1, \ldots, \mathfrak{K}\} \quad \mathfrak{K} = \mathrm{M}^K$$



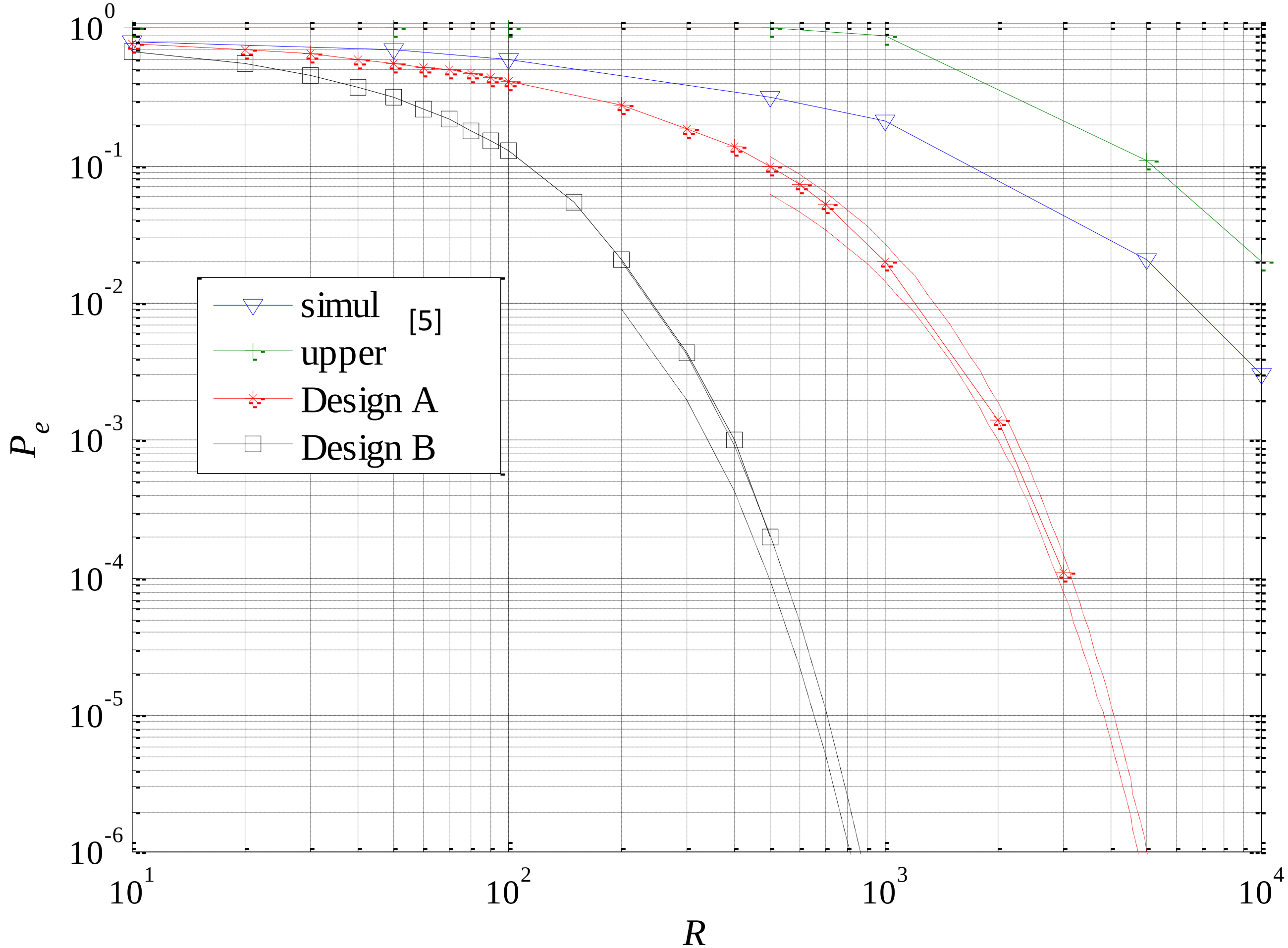
Signal to Interference plus Noise Ratio (SINR)

$$SINR = \frac{E\{|\varsigma|^2\}}{I} = \frac{R\sum_{j=1}^{K}\beta_j^2}{\left(\sum_{j=1}^{K}\beta_j\right)^2 + 2\sigma^2\sum_{j=1}^{K}\beta_j + \sigma^4}$$

energy efficiency scaling with *R*, same as with perfect CSI

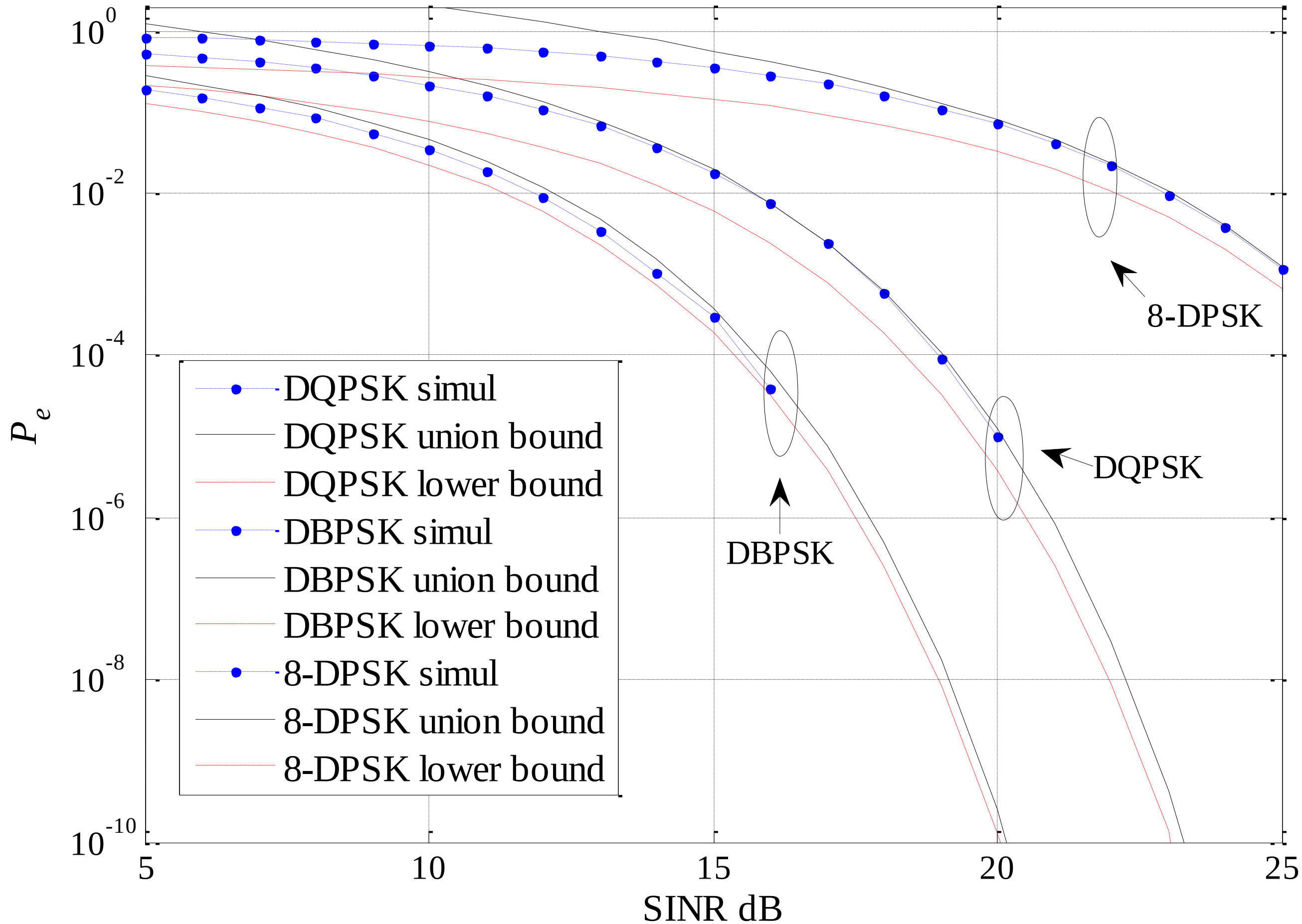


Performance – 2 users, DQPSK, SNR=0 dB

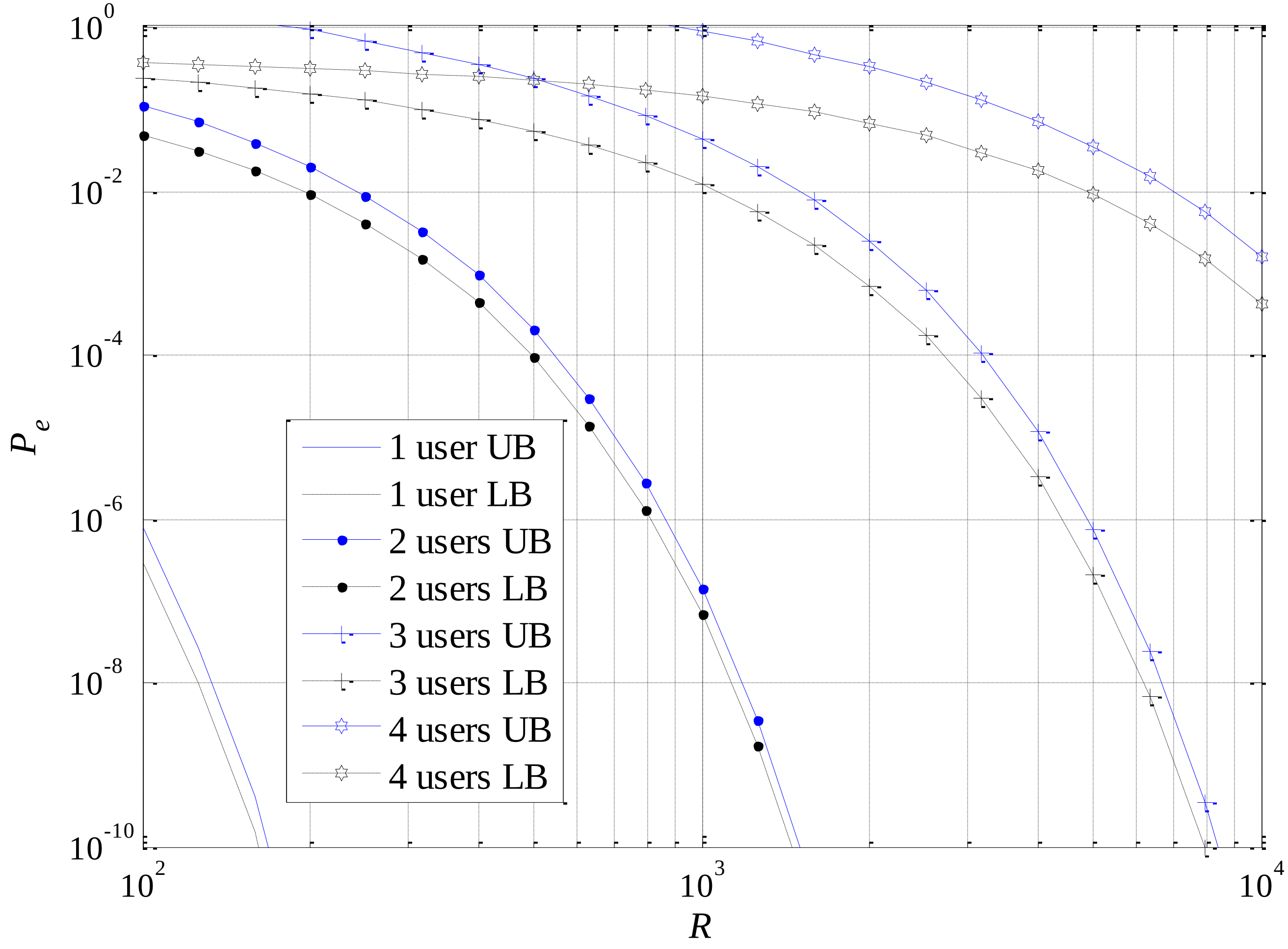


[5] M. Chowdhury, A. Manolakos, A.J. Goldsmith, “CSI is not needed for Optimal Scaling in Multiuser Massive SIMO Systems,” Proceedings of ISIT., Honolulu, July 2014.

Performance – 2 users (M-ary PSK)



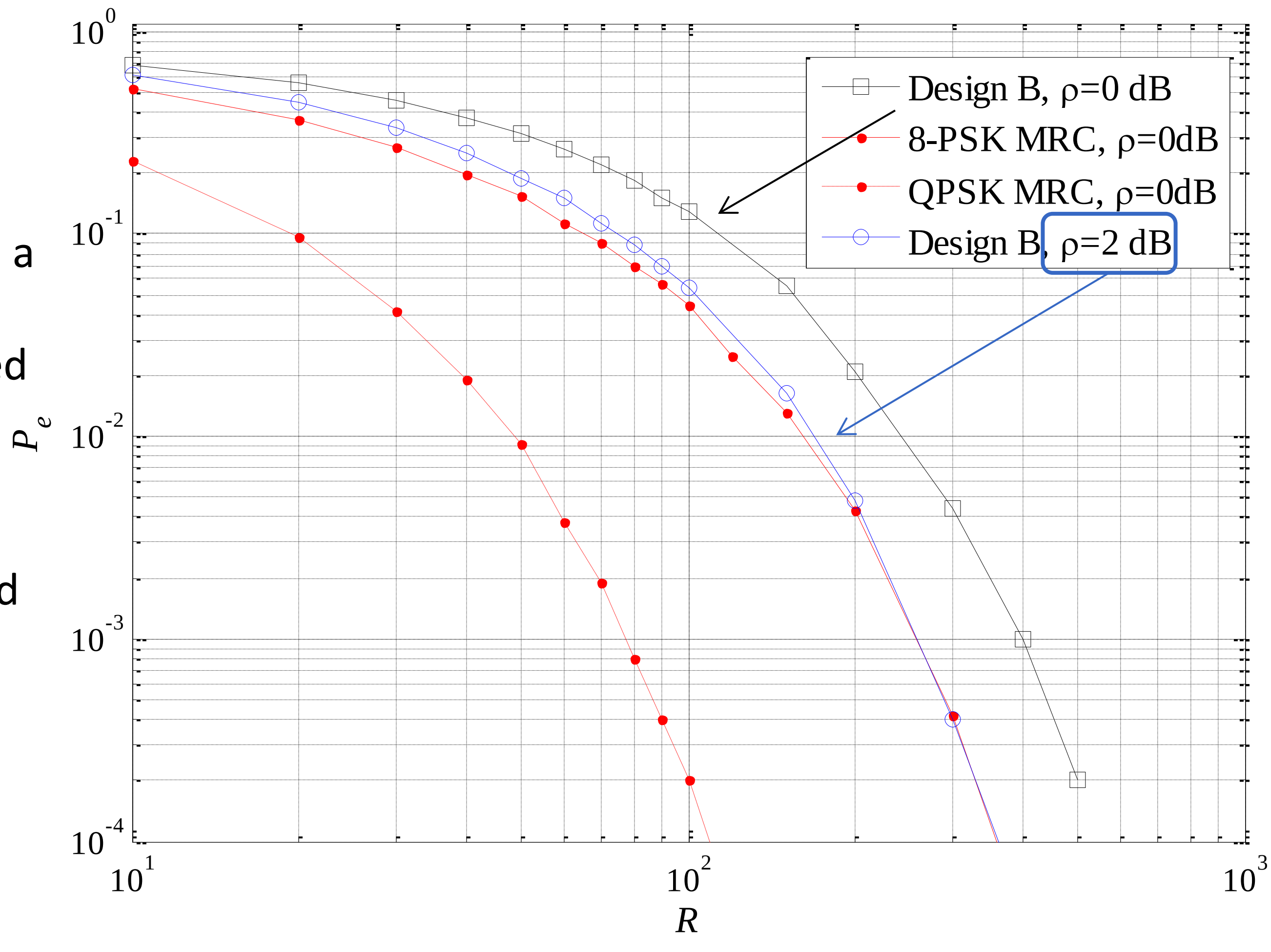
Design B – multiuser, M=4, SNR=0 dB



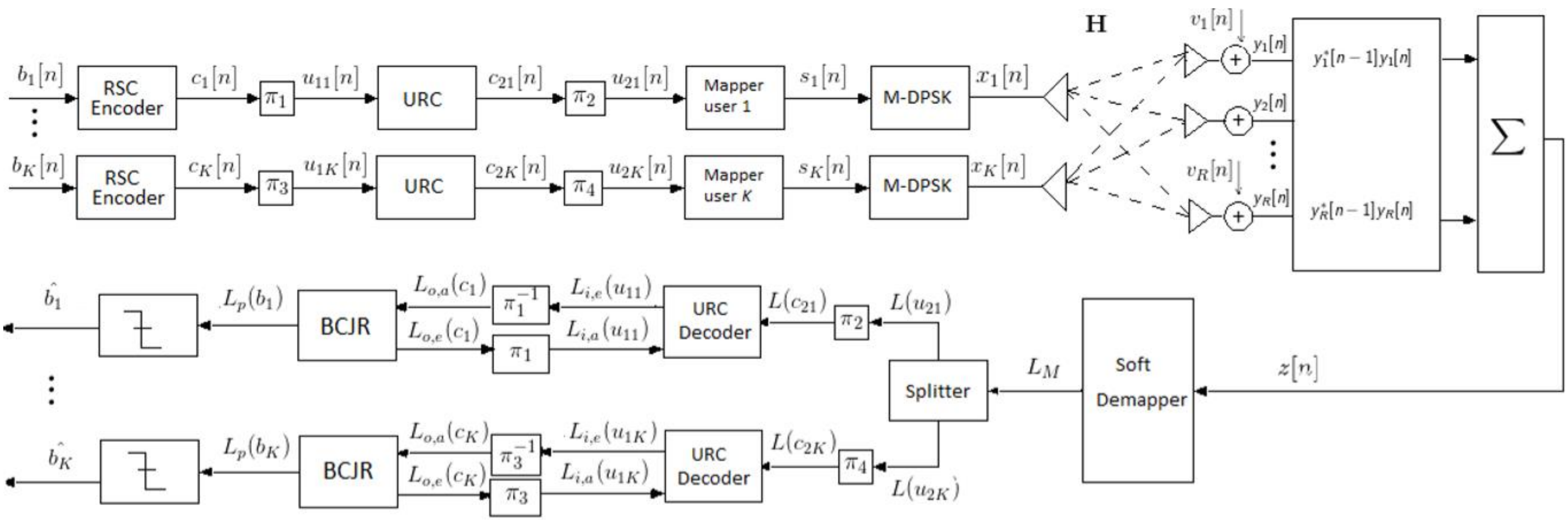
Comparison with coherent MRC – 2 dB loss

CSI is estimated with a realistic error, which is also assumed to be Gaussian

rate-loss of 33% due to pilot overhead -> 8-PSK vs QPSK

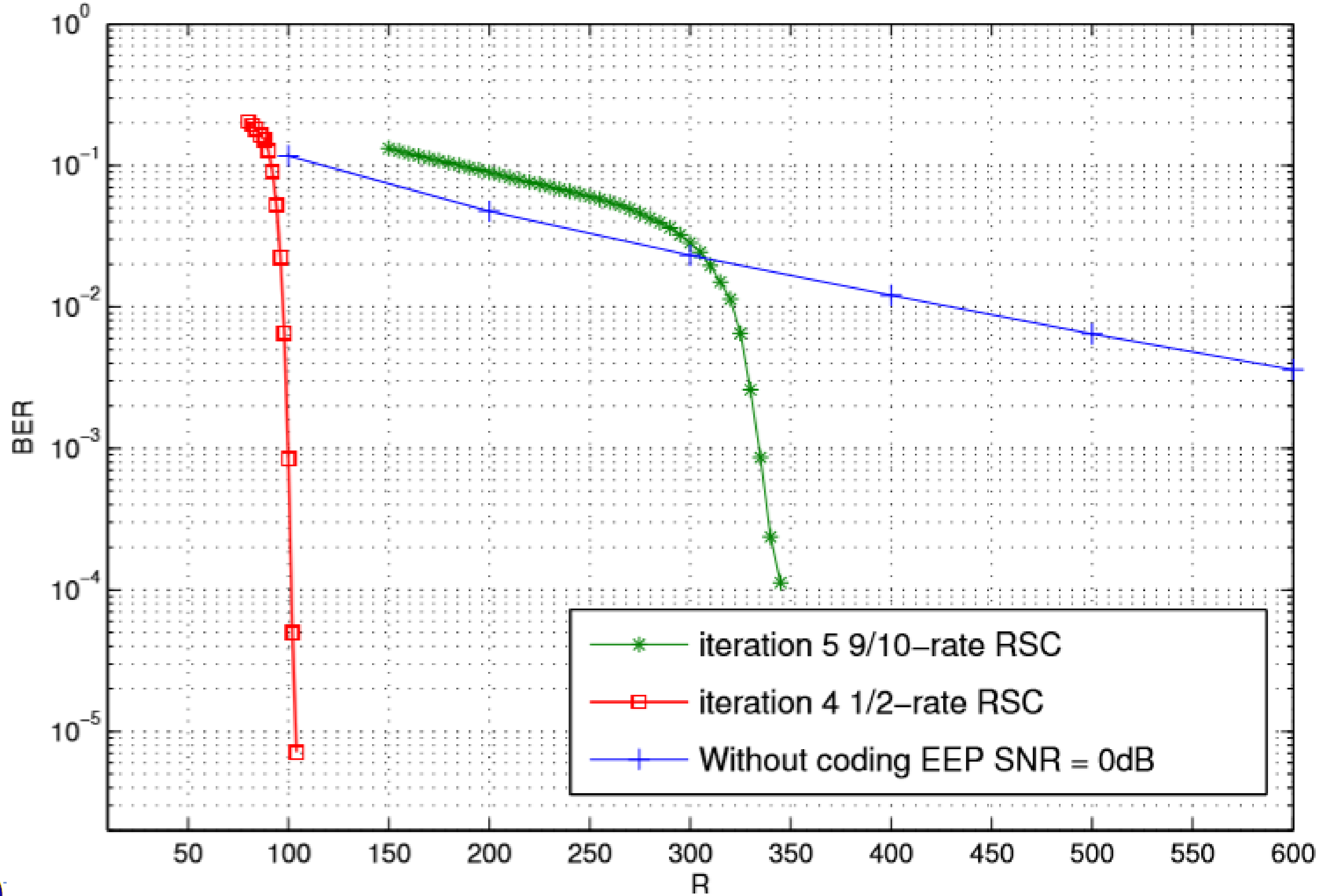


Channel coding and iterative decoding

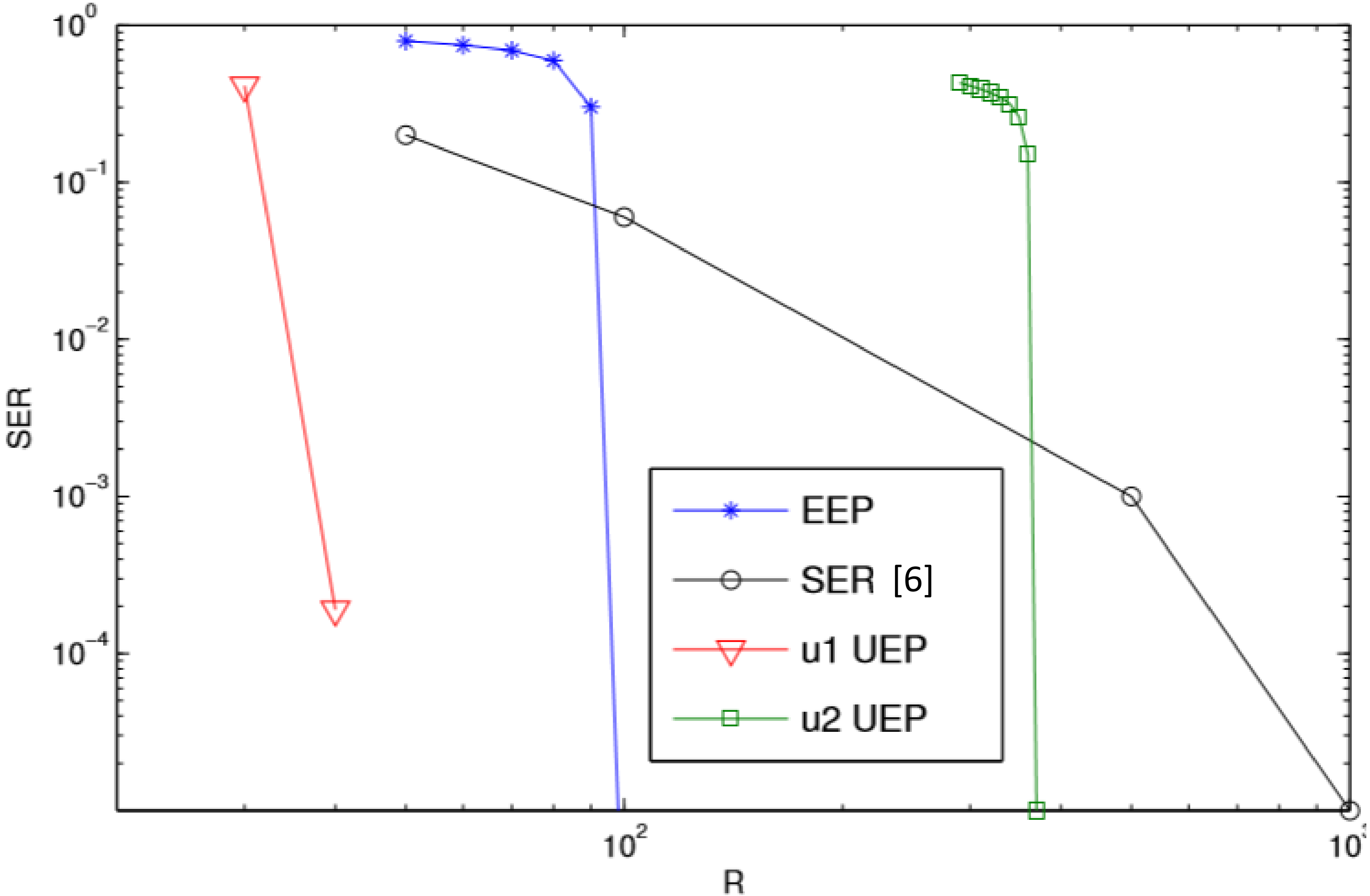


RSC: recursive systematic convolutional
URC: unity-rate code
BCJR: Bahl-Cocke-Jelinek-Raviv algorithm

BER improvement SNR=0dB



Comparison with [6], SNR=0dB



[6] M. Chowdhury, A. Manolakos and Andrea Goldsmith,"Scaling Laws for Noncoherent Energy-Based Communications in the SIMO MAC," IEEE Transaction on Information Theory, vol. 62, no. 4, Apr. 2016

Number of antennas vs coding rate

	Outer RSC	Required number of antennas R for each SNR: users 1,2 EEP				
		0 dB	3 dB	6 dB	-3 dB	-6 dB
Coding rate	1/10	20	20	20	50	120
	3/20	30	20	20	70	180
	1/5	40	20	20	90	230
	1/4	50	25	20	110	280
	3/10	55	30	20	125	310
	7/20	60	35	25	140	370
	2/5	70	40	30	110	440
	9/20	80	45	30	170	500
	1/2	90	50	35	200	550
	11/20	100	60	40	250	650
	3/5	120	65	45	270	750
	13/20	130	75	55	300	850
	7/10	150	90	60	350	1000
	3/4	180	100	70	400	1150
	4/5	210	120	85	500	1300
	17/20	260	150	100	600	1600
	9/10	350	180	130	750	1900

Conclusions

- DMPSK for massive MIMO does not need CSI
- Improved performance wrt previous work
- Not far from coherent systems when CSI is noisy and pilot overhead is taken into account
- Coding reduces the number of antennas to feasible values

Thank you!

This is joint work with Victor Monzon Baeza, Wenbo Zhang, Mohammed El-Hajjar, and Lajos Hanzo

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