Recent advances in non-coherent massive MIMO

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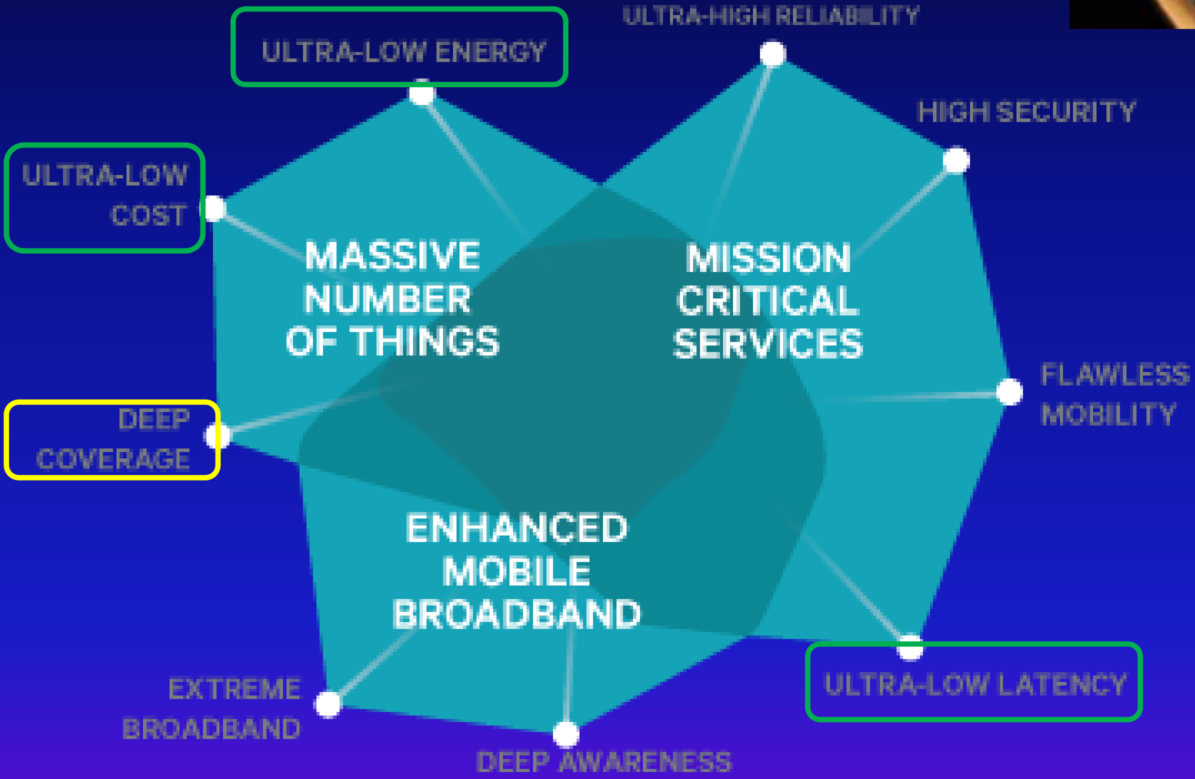
New requirements call for new technologies



Non coherent processing may be a good solution

if combined with massive MIMO

Non coherent communications – why now?

- In non-coherent (NC) communications, there is no channel estimation, even at the receiver
- Traditionally not used: 3 dB loss with respect to coherent
- When we consider the needs of channel state information (CSI) obtaining and sharing, this loss may become negligible
  - Channel estimation is wasteful in some circumstances (channels with low coherence time, low SNR)
  - CSI estimation and sharing is vey complex in massive MIMO (TDD required, pilot contamination, insufficient pilots for high time variability)
- NC massive MIMO: the perfect match!
  - NC may solve some of these problems for massive MIMO
  - The “magic” of massive MIMO (self interference cancellation) may improve NC performance

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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 MU-MISO(MIMO)

Non-coherent massive MIMO

- ASK (amplitude shift keying) energy-detector schemes
  - They achieve rates which are not different from coherent schemes in a scaling law sense
  - Too many antennas are required for reasonable performance with actual constellation designs
- Differential PSK schemes
  - Single user with improved performance (wrt req. number of antennas)
  - Multi-user through constellation design

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.

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.

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.

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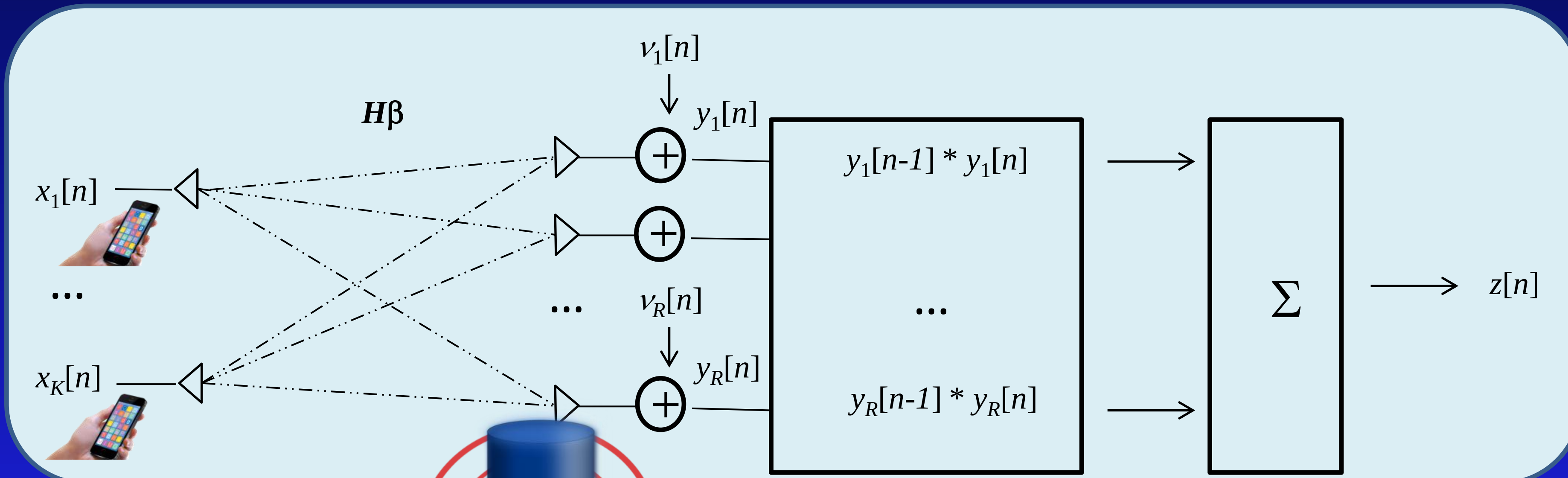
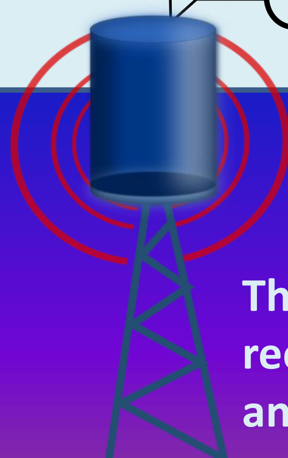
Multi-user uplink with M-DPSK

- Data symbol sequences M-PSK
- Tx signal comes from differentially encoding the data symbols: D-MPSK





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

K users
R antennas at BS
Frequency-fat fading

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 $z[n]$

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Multiple users

- **Can we obtain the users information from this decision variable?**

- We define the **joint symbol** as a (weighted) combination of the original users constellations
- The massive number of antennas will help us get rid of the channel effects and interference

$$
\begin{aligned}
z[n] = {} & \frac{1}{R}\sum_{j=1}^{K}\sum_{i=1}^{R}|h_{ij}|^2\beta_j s_j[n] \\
& + \frac{1}{R}\sum_{j=1}^{K}\sum_{\substack{k=1 \\ k\neq j}}^{K}\sum_{i=1}^{R} h_{ij}^* h_{ik} x_j^*[n-1]\sqrt{\beta_j\beta_k}\, x_k[n] \\
& + \frac{1}{R}\sum_{i=1}^{R}\nu_i^*[n-1]\sum_{j=1}^{K} h_{ij}\sqrt{\beta_j}\, x_j[n] \\
& + \frac{1}{R}\sum_{i=1}^{R}\nu_i[n]\sum_{j=1}^{K} h_{ij}^*\sqrt{\beta_j}\, x_j^*[n-1] + \frac{1}{R}\sum_{i=1}^{R}\nu_i^*[n-1]\nu_i[n]
\end{aligned}
$$

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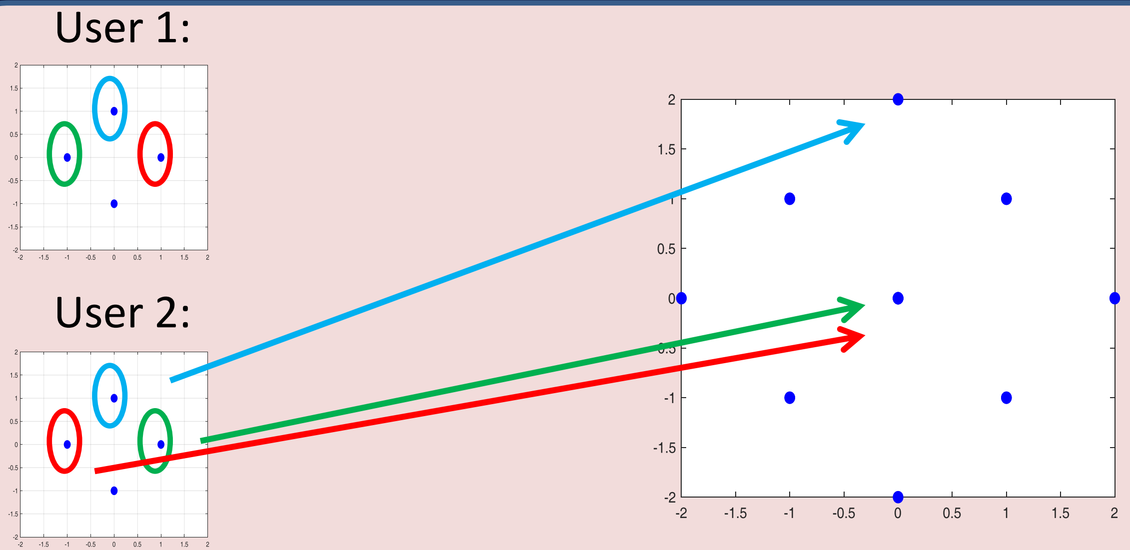
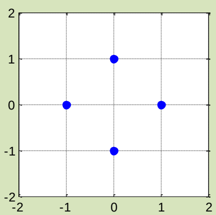
Joint constellation

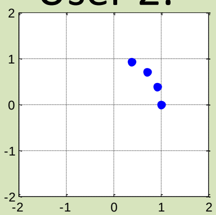


Not a good choice ..
Cannot decode unambiguously all points of individual users

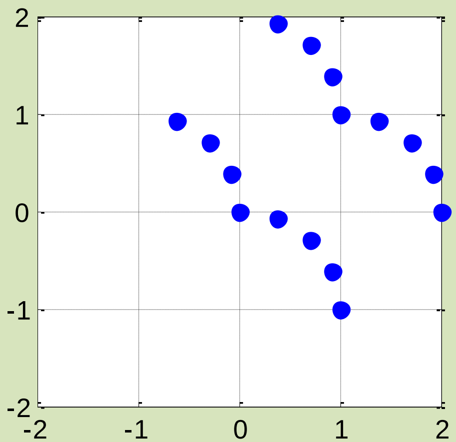
User 1:



User 2:



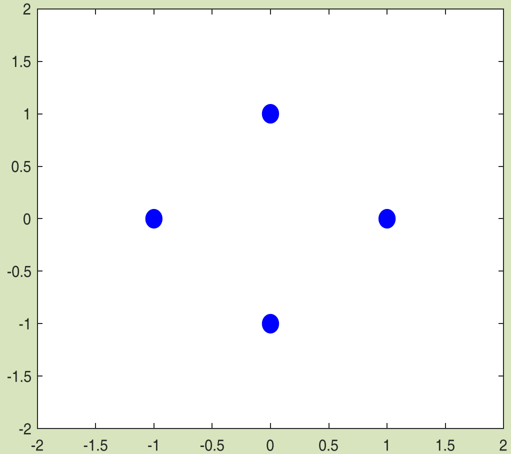
(Design A)



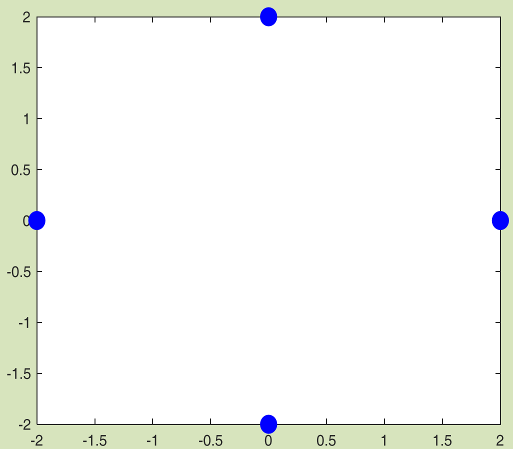
16 distinct points
Good choice!

Another feasible joint constellation

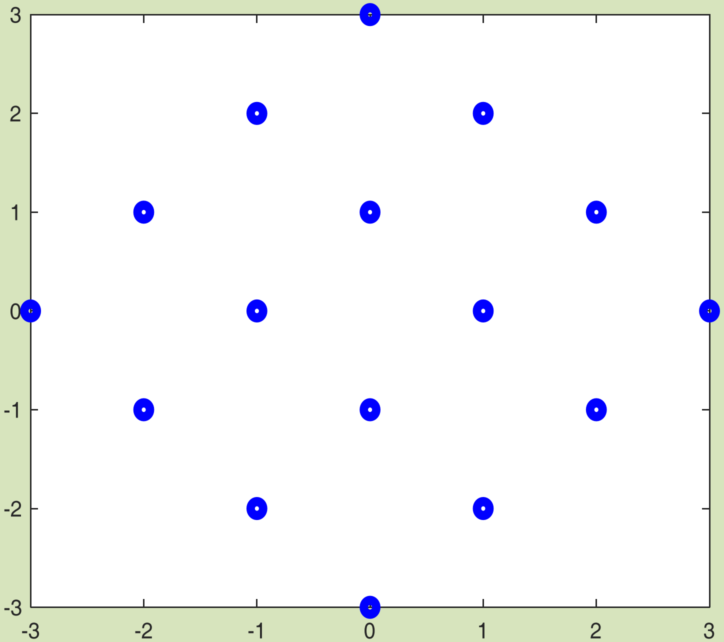
User 1:



User 2:



(Design B)



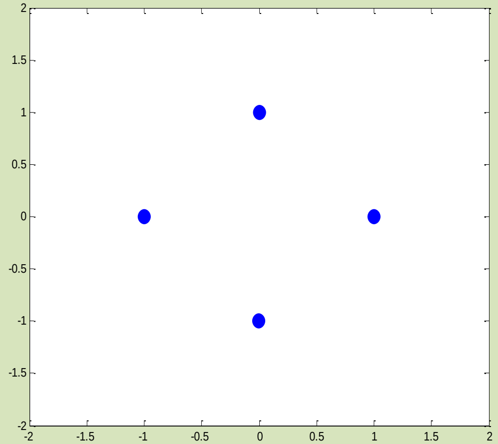
16 distinct points

Good distance between them

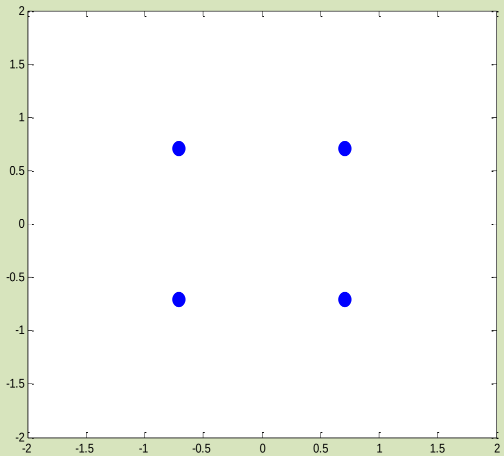
Good choice!

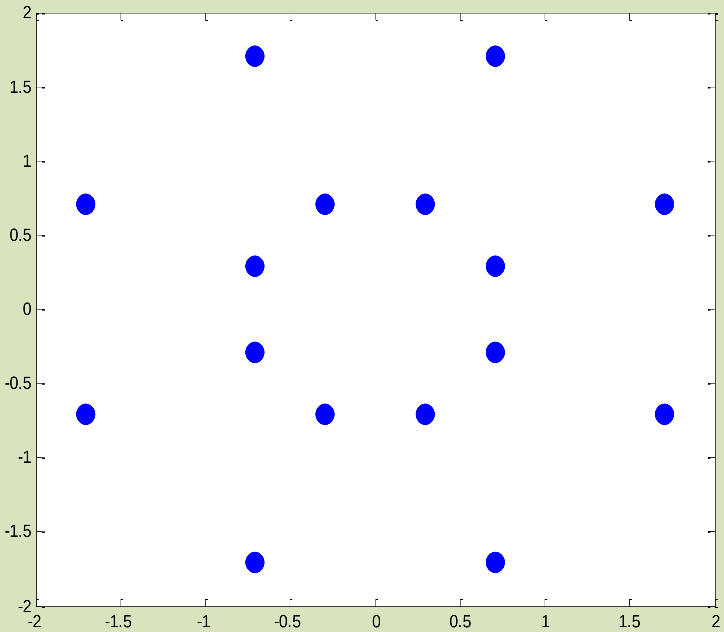
Equal error protection constellation

User 1:



User 2:





16 distinct points

Same performance for both users

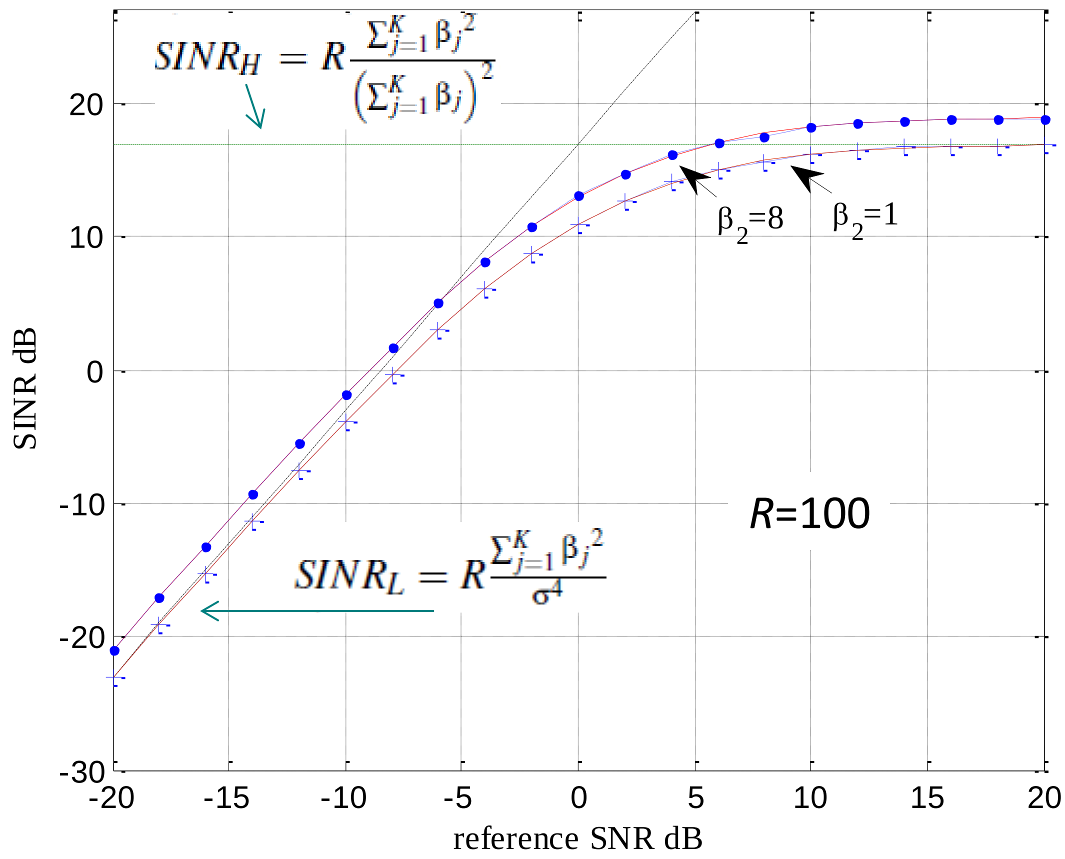
Good choice!

(EEP)

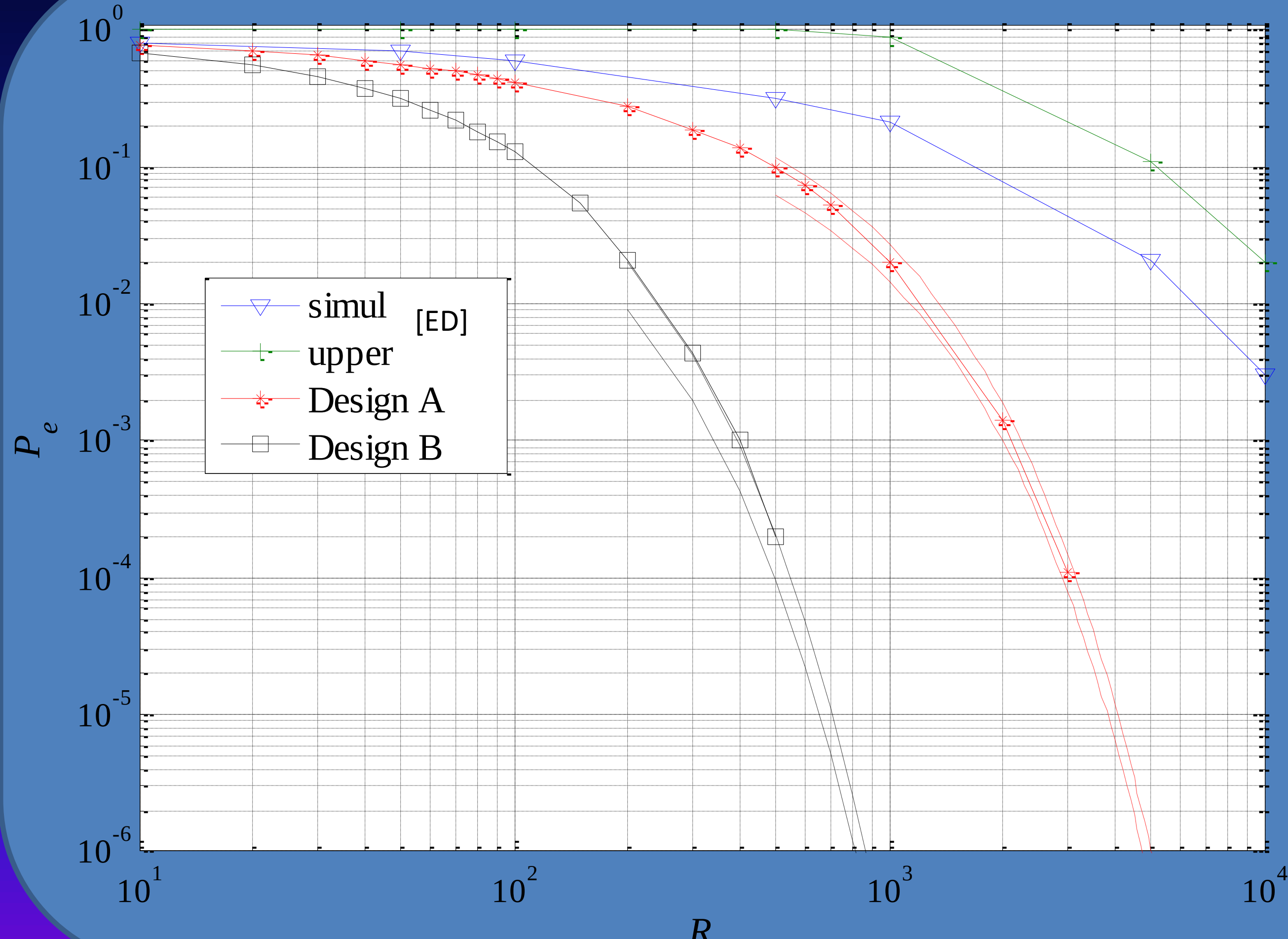
Getting rid of the interference

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

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



Two users and low SNR (0 dB)



[ED] 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.

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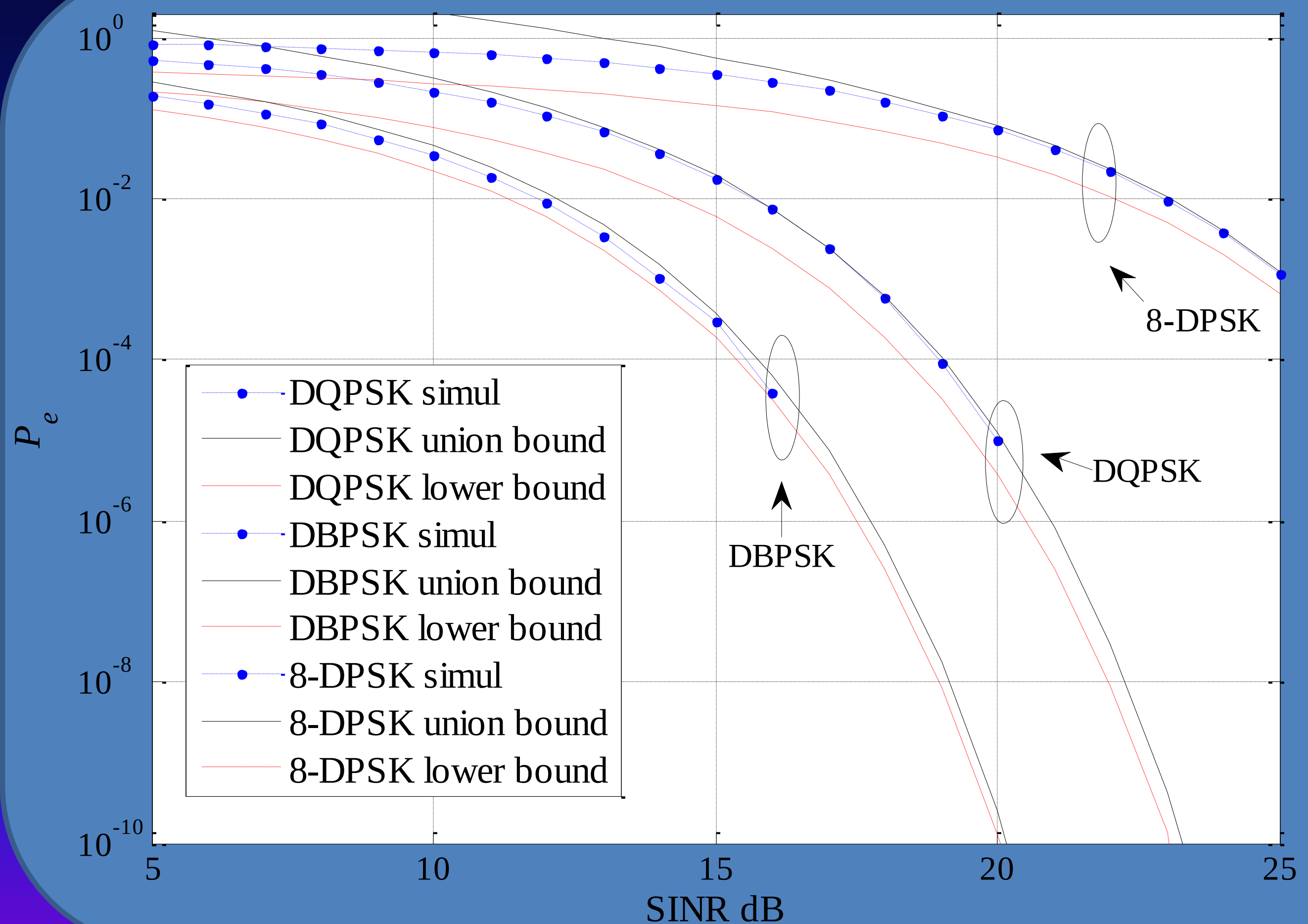
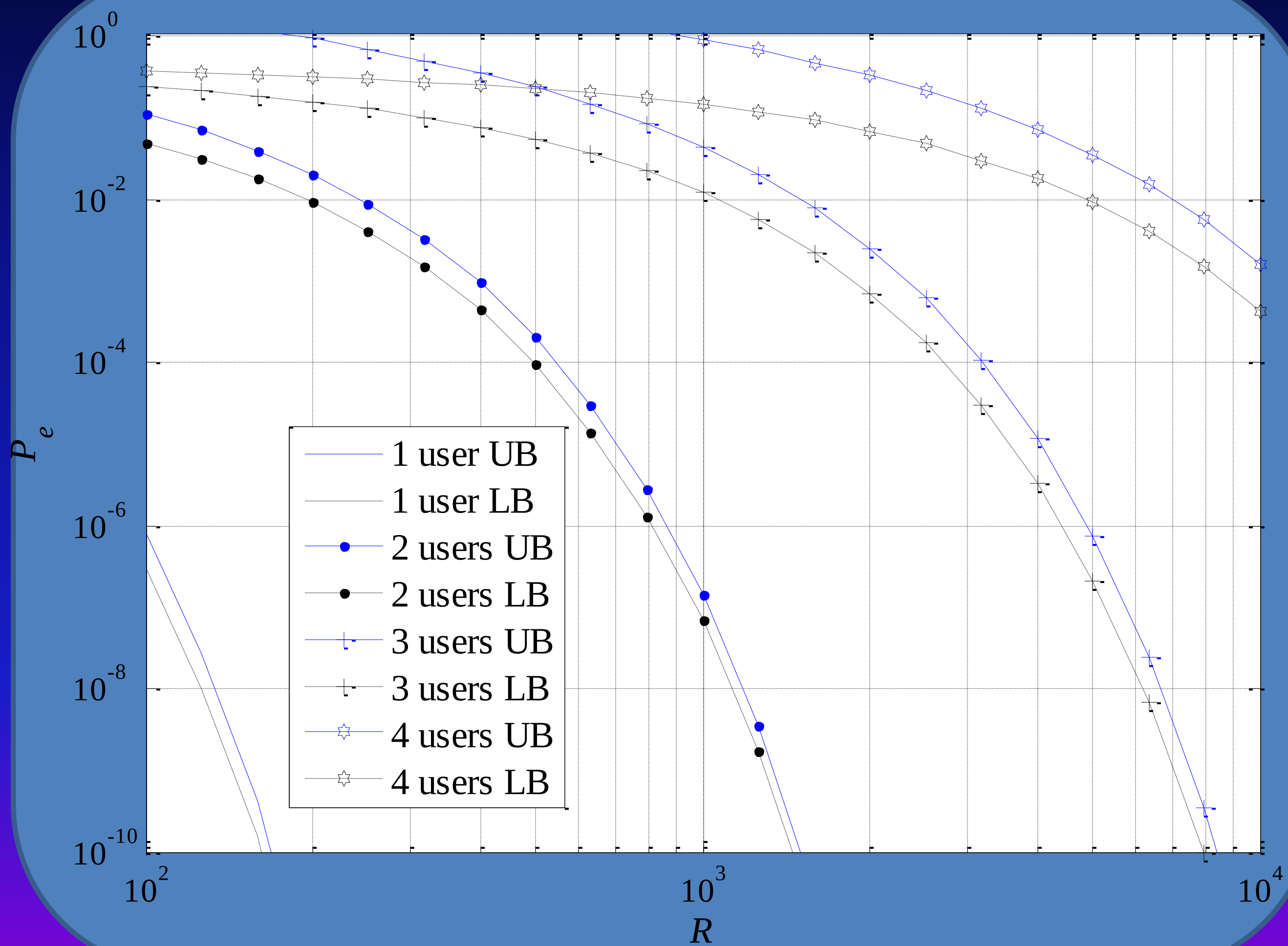
Higher order constellations



(Design B)

Multiplexing more users in the constellation (SNR=0 dB)



(Design B)

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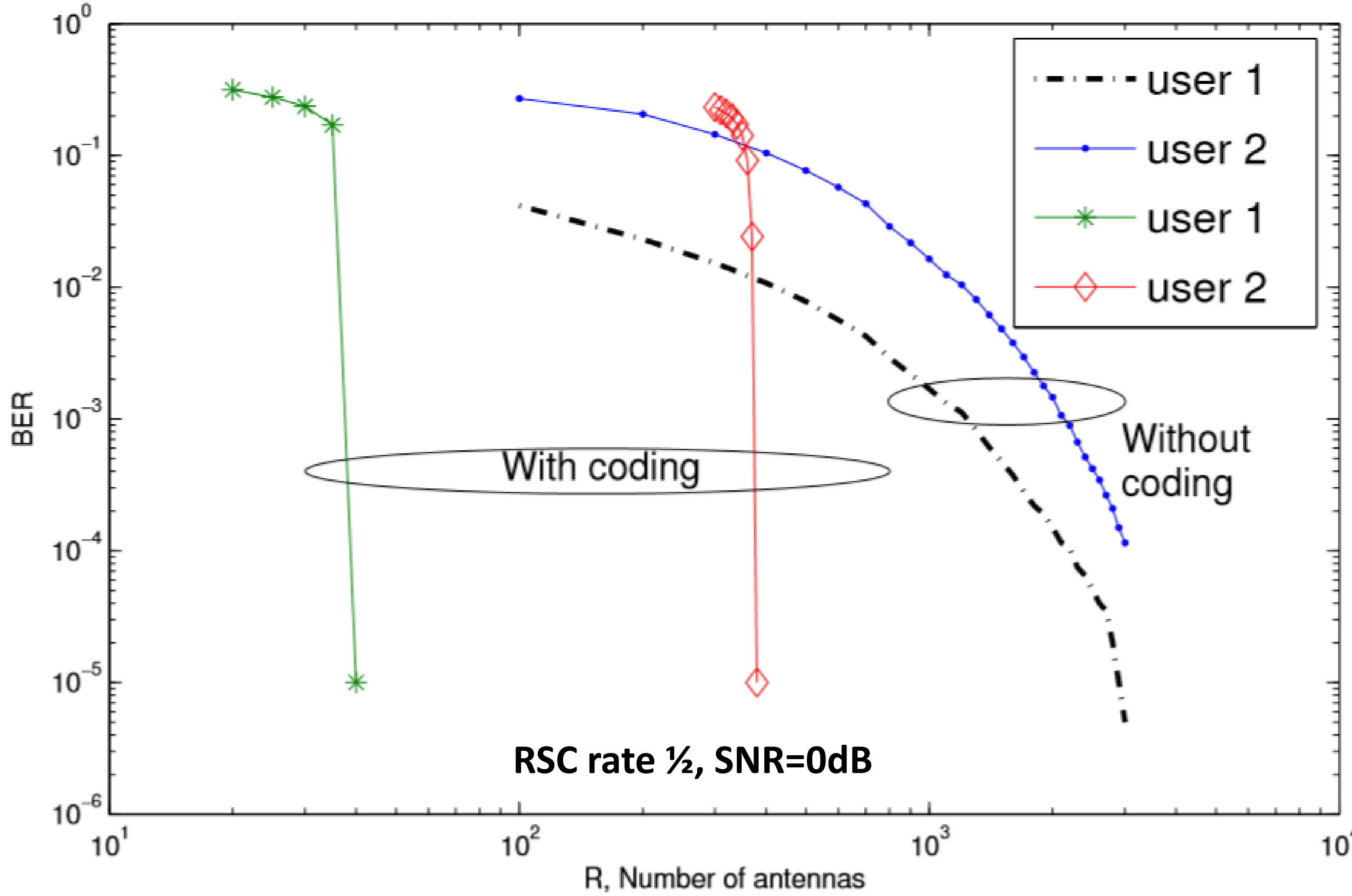
Reducing the number of antennas with channel coding



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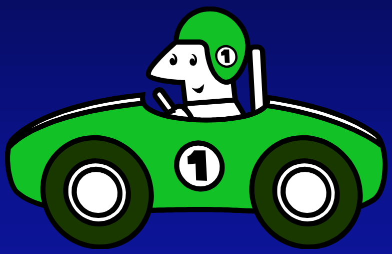
Number of antennas vs coding rate

	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

V. Monzon Baeza, A. Garcia Armada, W. Zhang, M. El-Hajjar, L. Hanzo, "A Non-Coherent Multi-User Large Scale SIMO System Relying on M-ary DPSK and BICM-ID", IEEE Trans. on Vehicular Technology, Vol. 67, no. 2, pp. 1809-1814, Feb. 2018.

What about channel variability?

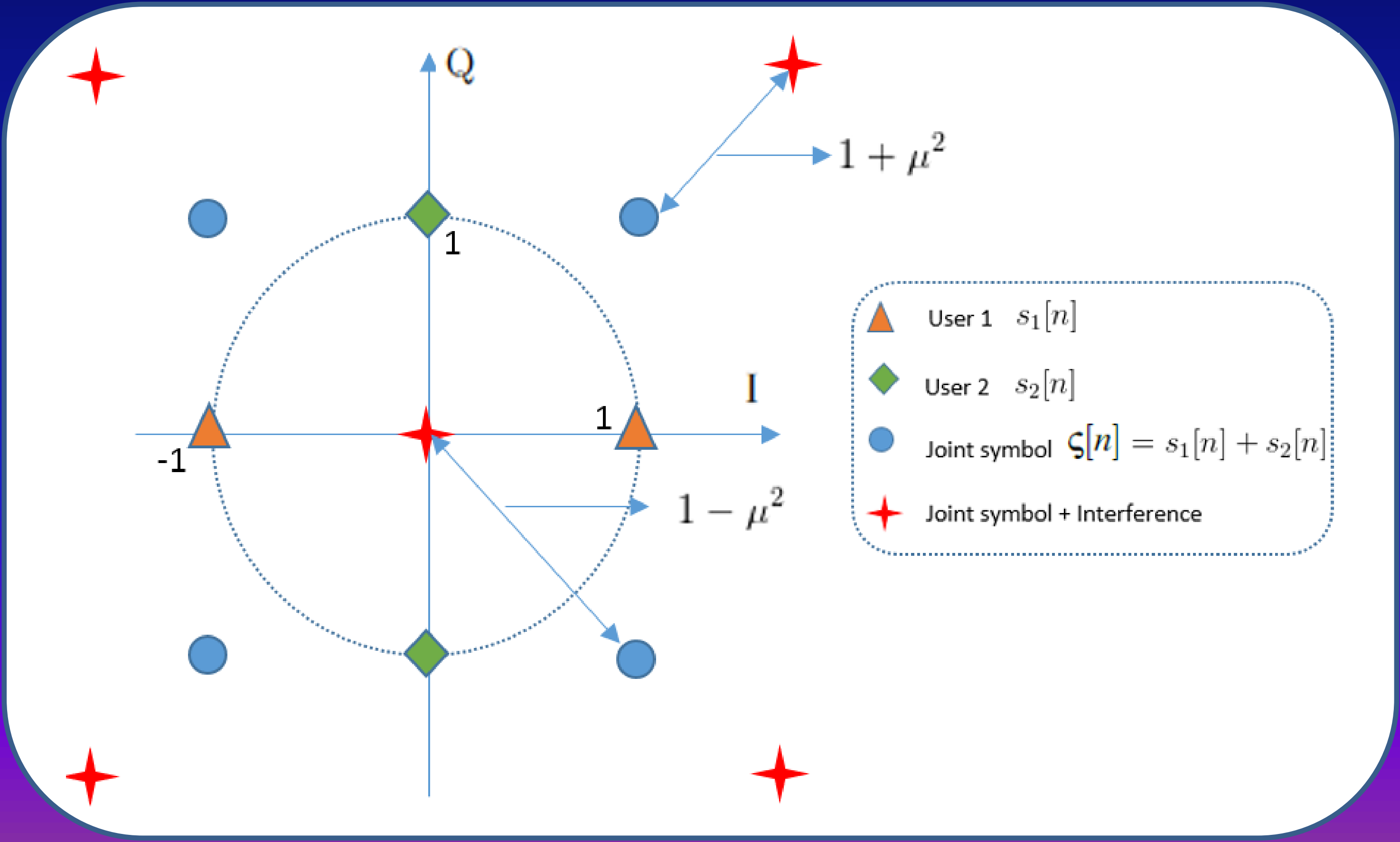
- For BW/f_D > 10 the performance is the same as with constant channel. That is, for any realistic channel we can envisage
- Examples
  - fc=2.6 GHz, BW= 20 MHz and a mobile velocity of 120 km/h, we have BW/f_D =70,000
  - fc=2.6 GHz, BW= 20 MHz and a mobile velocity of 500 km/h , we have BW/f_D = 16,600
  - fc=60 GHz, BW= 100 MHz and a mobile velocity of 120 km/h, we have BW/f_D = 15,000



V. Monzón, A. García Armada, M. El-Hajjar, L. Hanzo, "Performance of a Non-Coherent Massive SIMO M-DPSK System", IEEE Vehicular Technology Conference, Sept. 2017.

This is all very nice, but the channel is not always Rayleigh …

- **When the fading is Rice (LOS component) there are new interference terms that do not gp away with increasing number of antennas**



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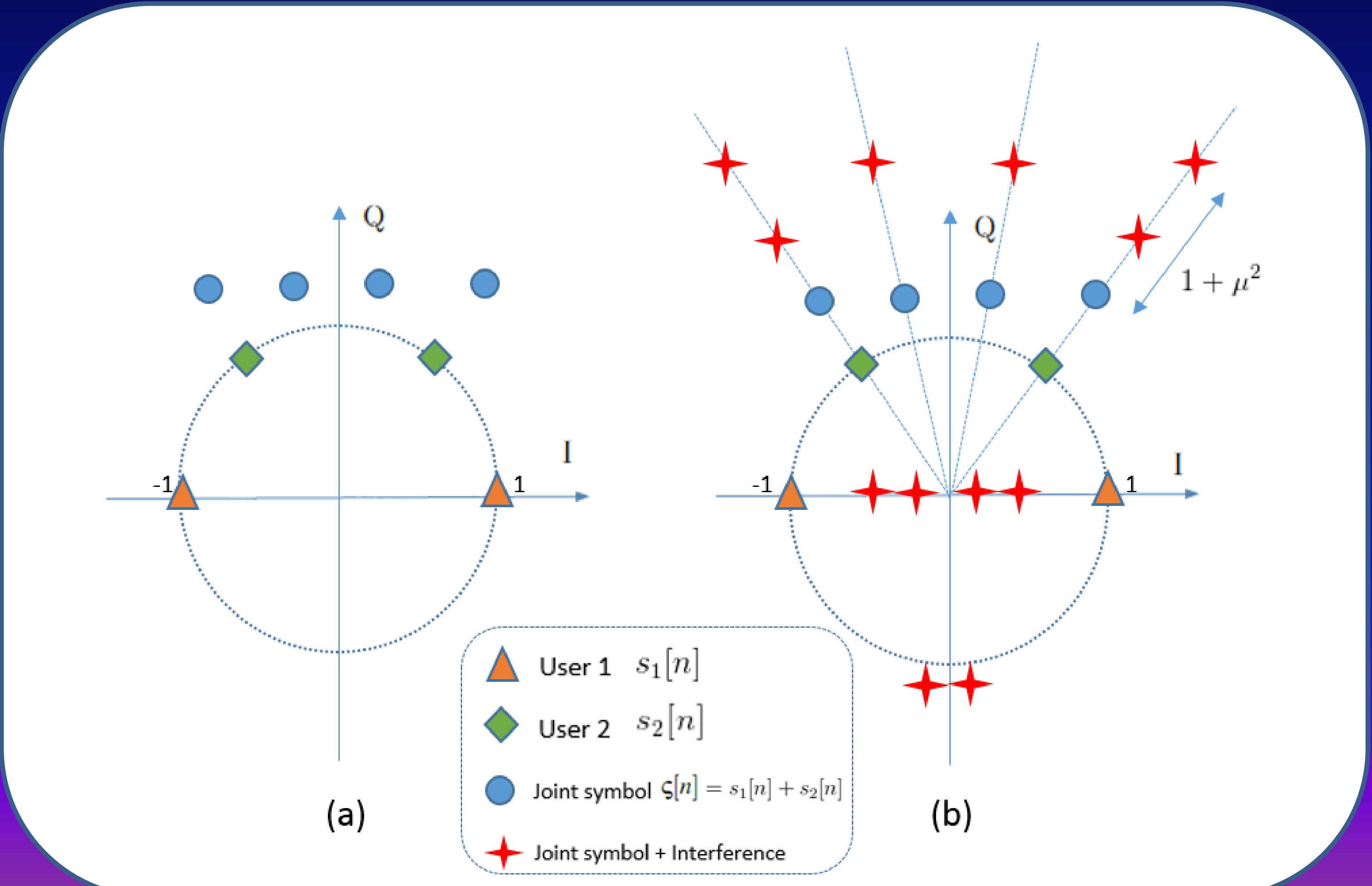
So we need to re-design the constellations

- Avoid symmetries



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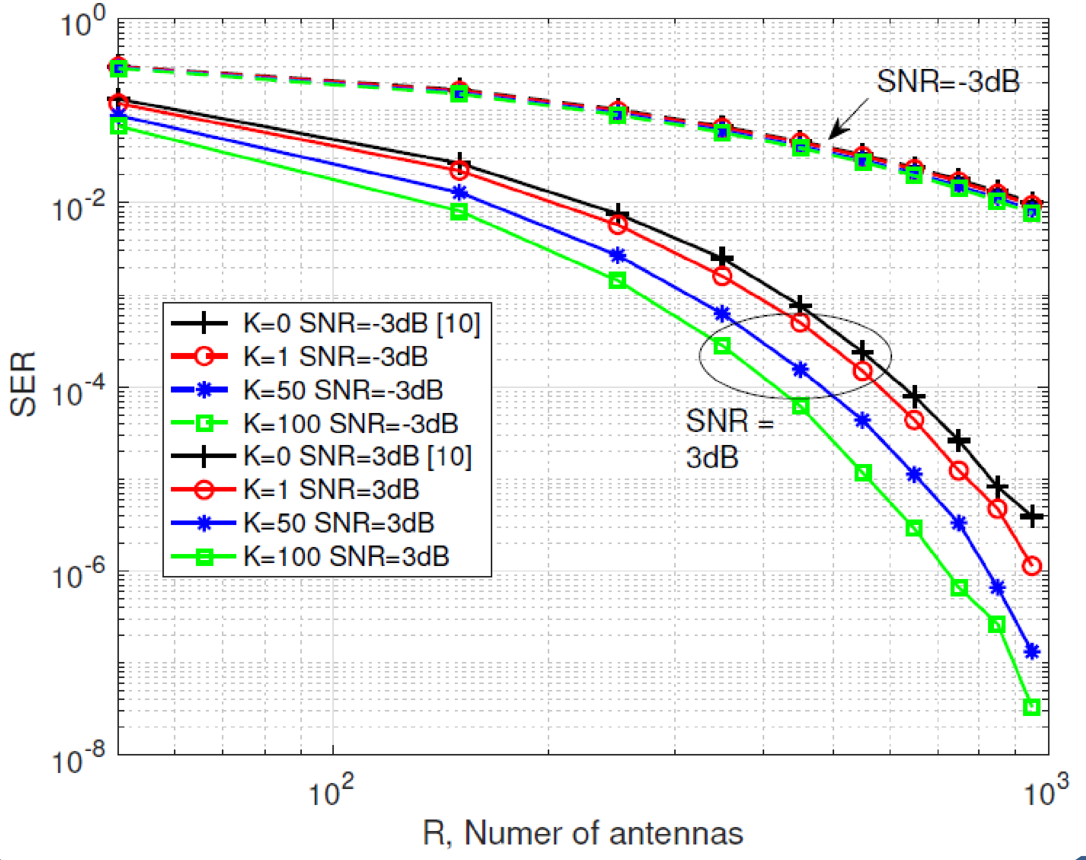
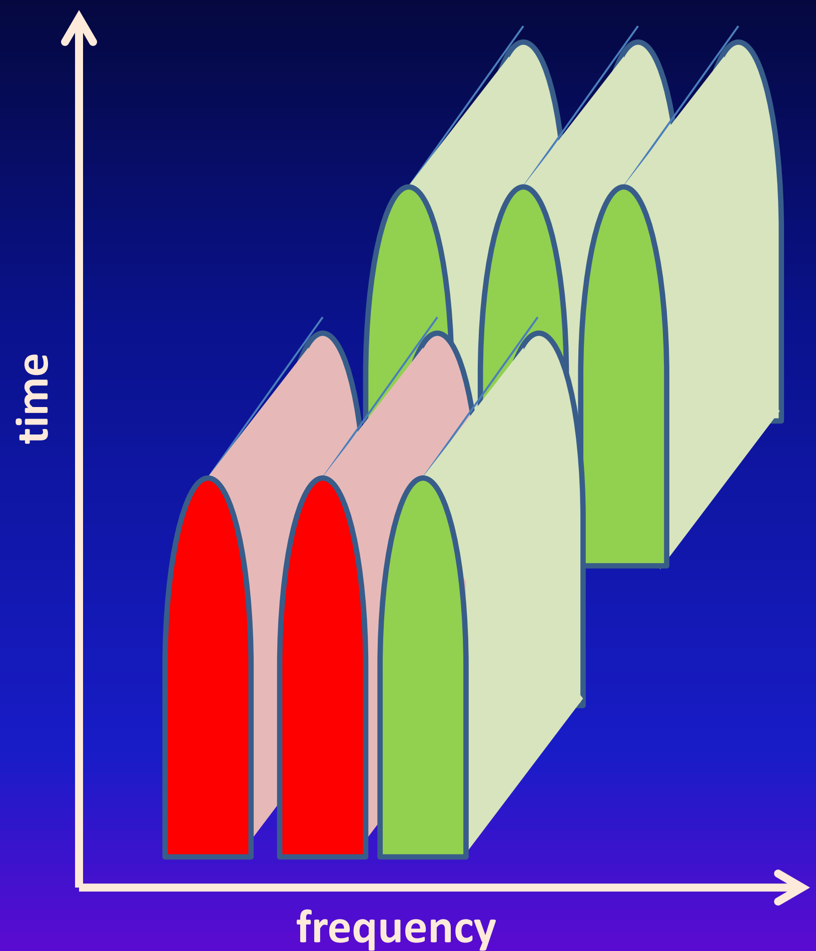
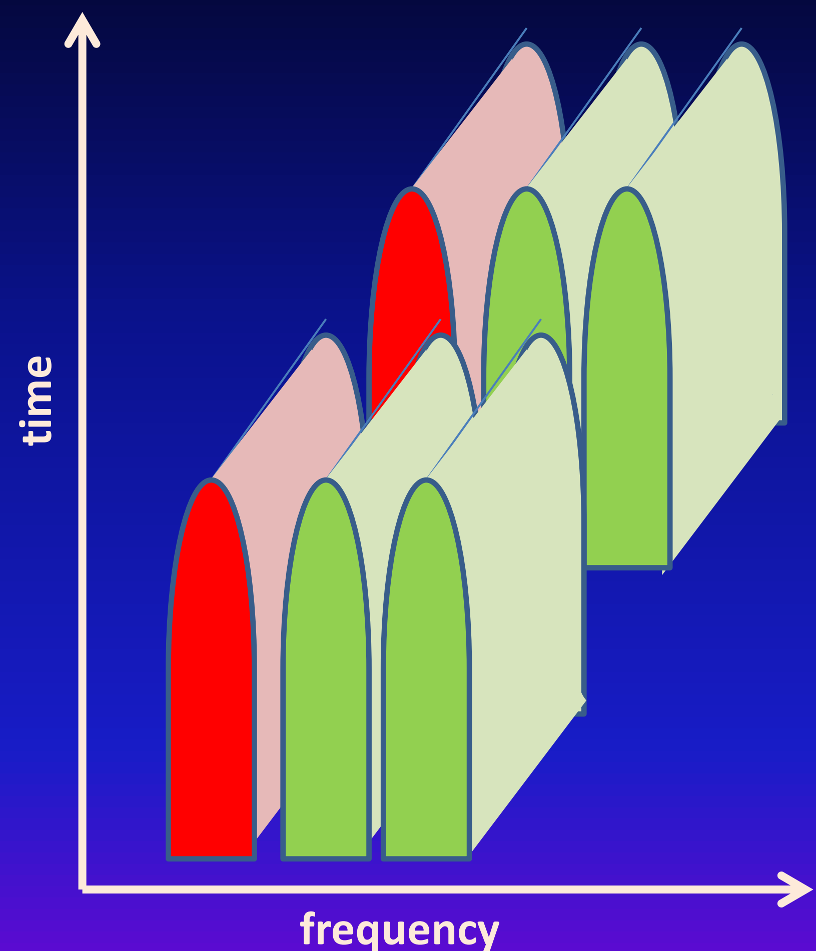
Improved decoding process that considers this new interference

- Rice and Rayleigh are the same for very low SNR and Rice is better for moderate-high SNR



And the channel is for sure not always frequency-flat …





Combined with OFDM, differential modulation across frequency or time

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Kun Chen-Hu, Ana Garcia Armada, “Non-Coherent Multiuser Massive MIMO-OFDM with Differential Modulation”, submitted to ICC 2019.

It is time for non coherent massive MIMO!

- DMPSK for massive MIMO does not need CSI
- Coding reduces the number of antennas to feasible values
- New constellations and detection process needed when the channel is Rice
- Not far from coherent systems when CSI is noisy and pilot overhead is taken into account

Thank you !

Please check our new MSC ITN with open PhD positions!
"New RAN TEchniques for 5G UltrA-dense Mobile networks"
http://teamup5g.webs.tsc.uc3m.es/

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ACK: joint work with Victor Monzon Baeza, Kun Chen Hu, Wenbo Zhang, Mohammed El-Hajjar, and Lajos Hanzo

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