DTMB Non-Uniform Constellations design through PSO algorithm

Authors:
Eng. Ernesto Fontes Pupo.
MSc. Reinier Diaz Hernández.
Eng. Yoania Acosta Cintado.

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Outline

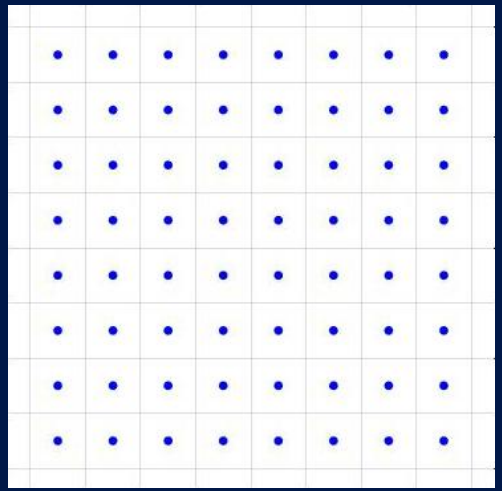
- Introduction
- Brief description of the Uniform Constellations, Non-Uniform Constellations and Capacity equation.
- Description of the Particle Swarm Optimization algorithm.
- Results of the optimization process.
- Conclusions

Introducción

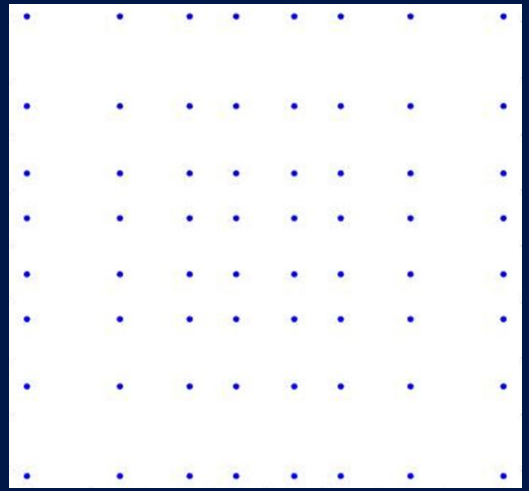
- In 1974, Foschini proposed Non-Uniform Constellations, which minimize symbol error rates over an AWGN channel.
- March 2016, Non-Uniform Constellations for ATSC 3.0.
- **November 2017, Proposal of Non-Uniform Constellations for DTMB.**

Uniform Constellations & Non-Uniform Constellations

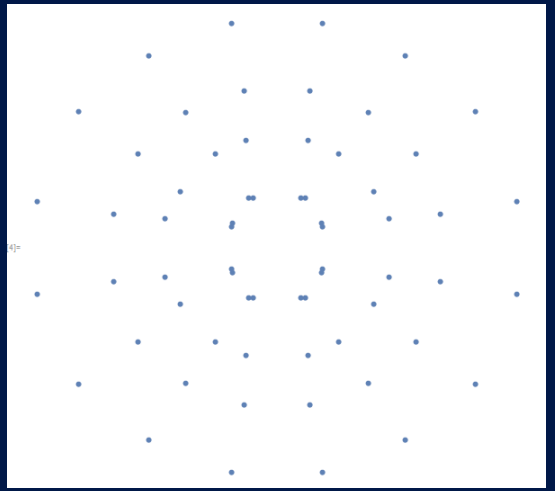
UC



1D-NUC

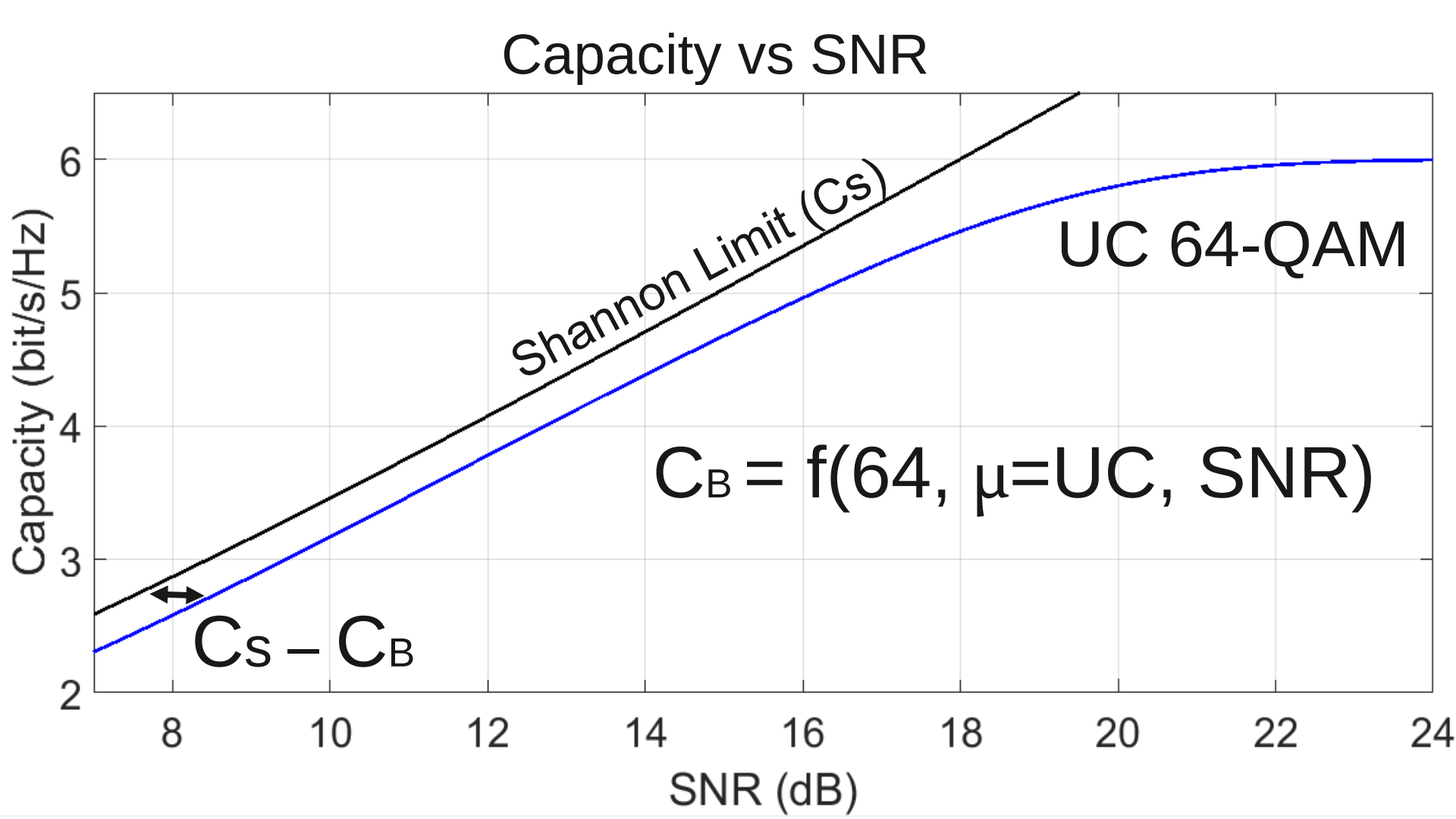


2D-NUC

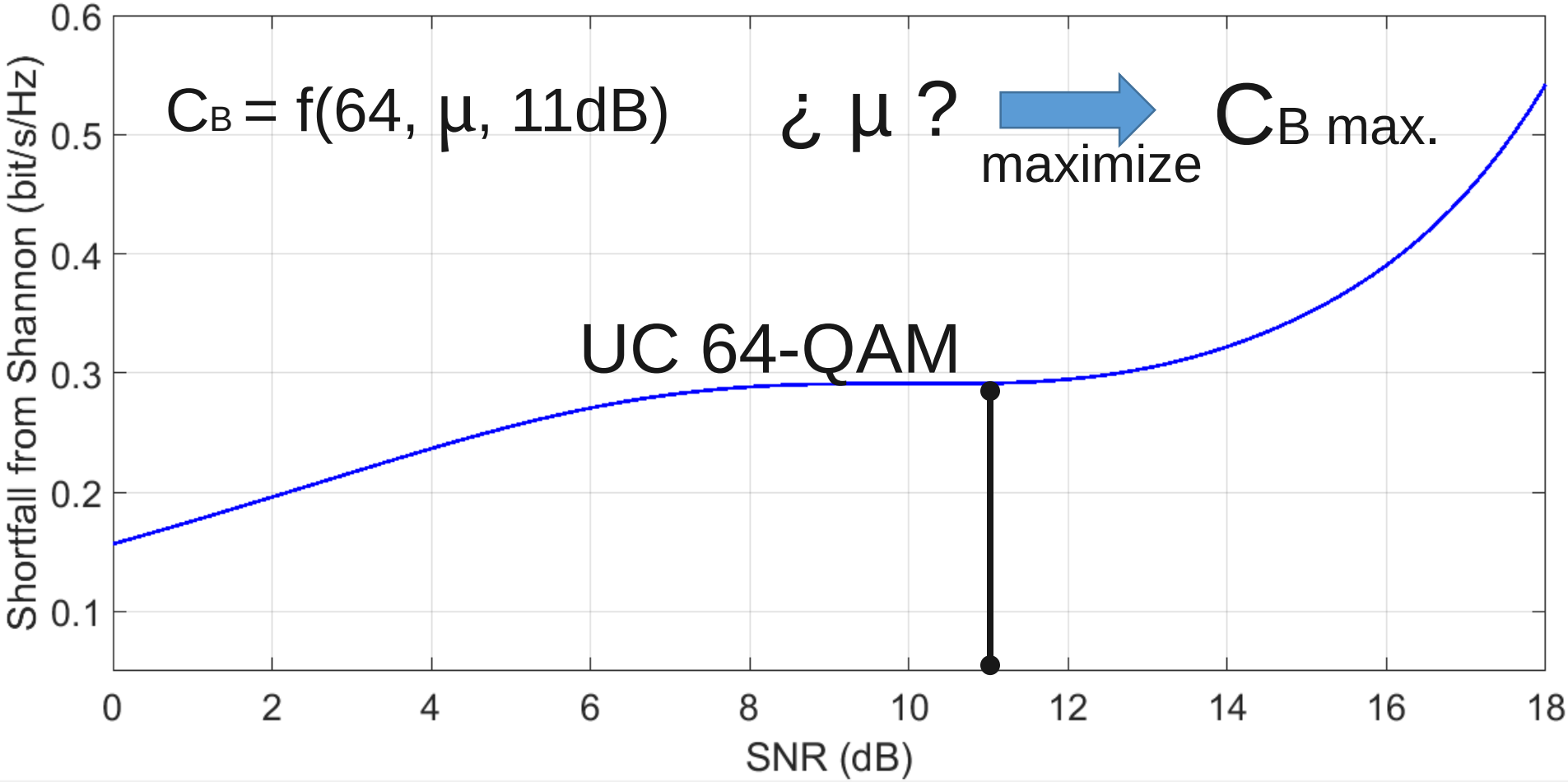


$\mathbb{X}$: Symbol alphabet. μ: Constellation shape. C_B: Capacity.

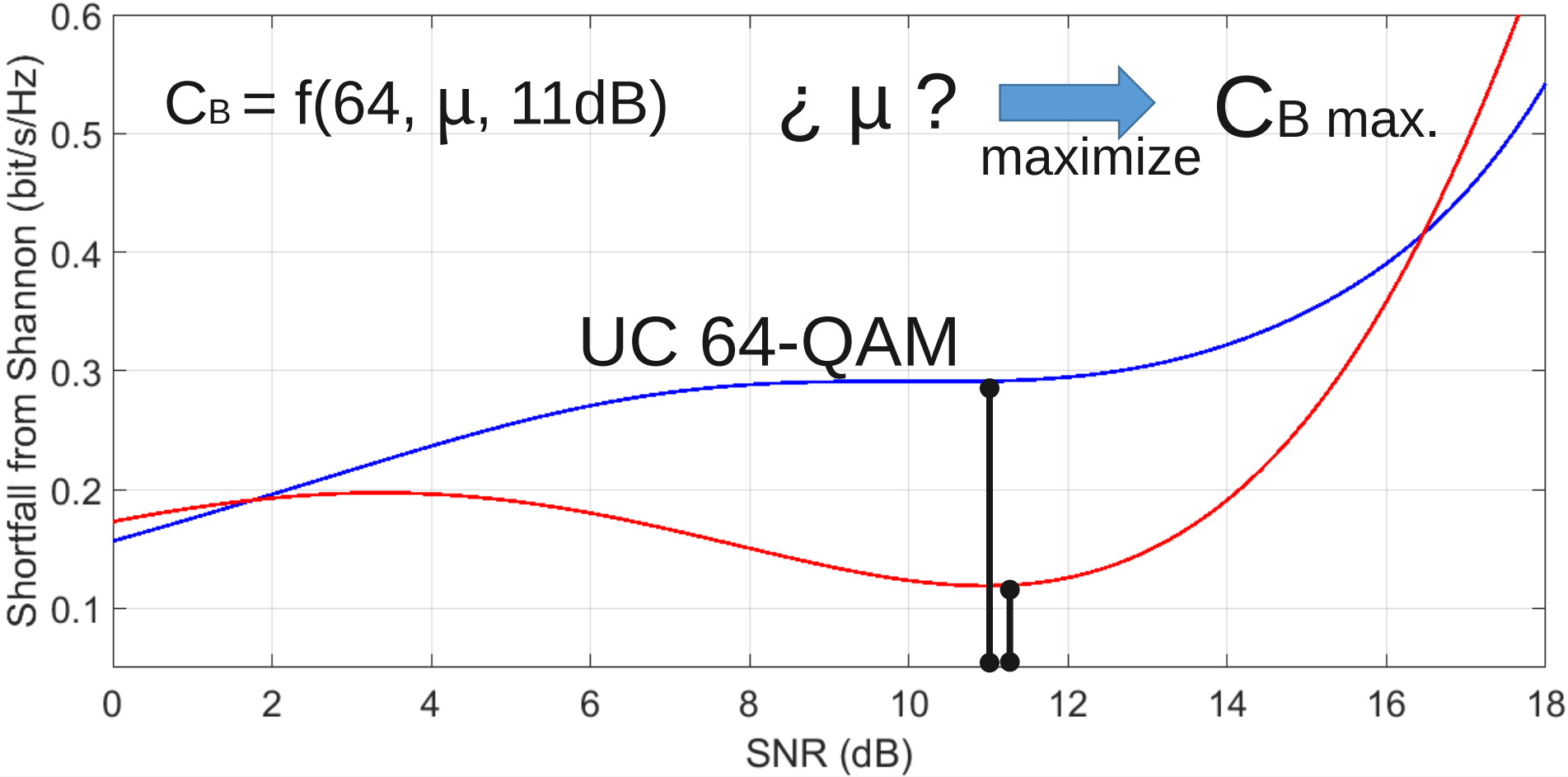
$$C_B = f(\mathbb{X}, \mu, SNR)$$


Capacity vs SNR
Capacity (bit/s/Hz)
SNR (dB)
Shannon Limit (Cs)
UC 64-QAM
$C_B = f(64, \mu=UC, SNR)$
$C_S - C_B$
2
3
4
5
6
8
10
12
14
16
18
20
22
24

Gap from Shannon of the UC



Gap from Shannon of the UC



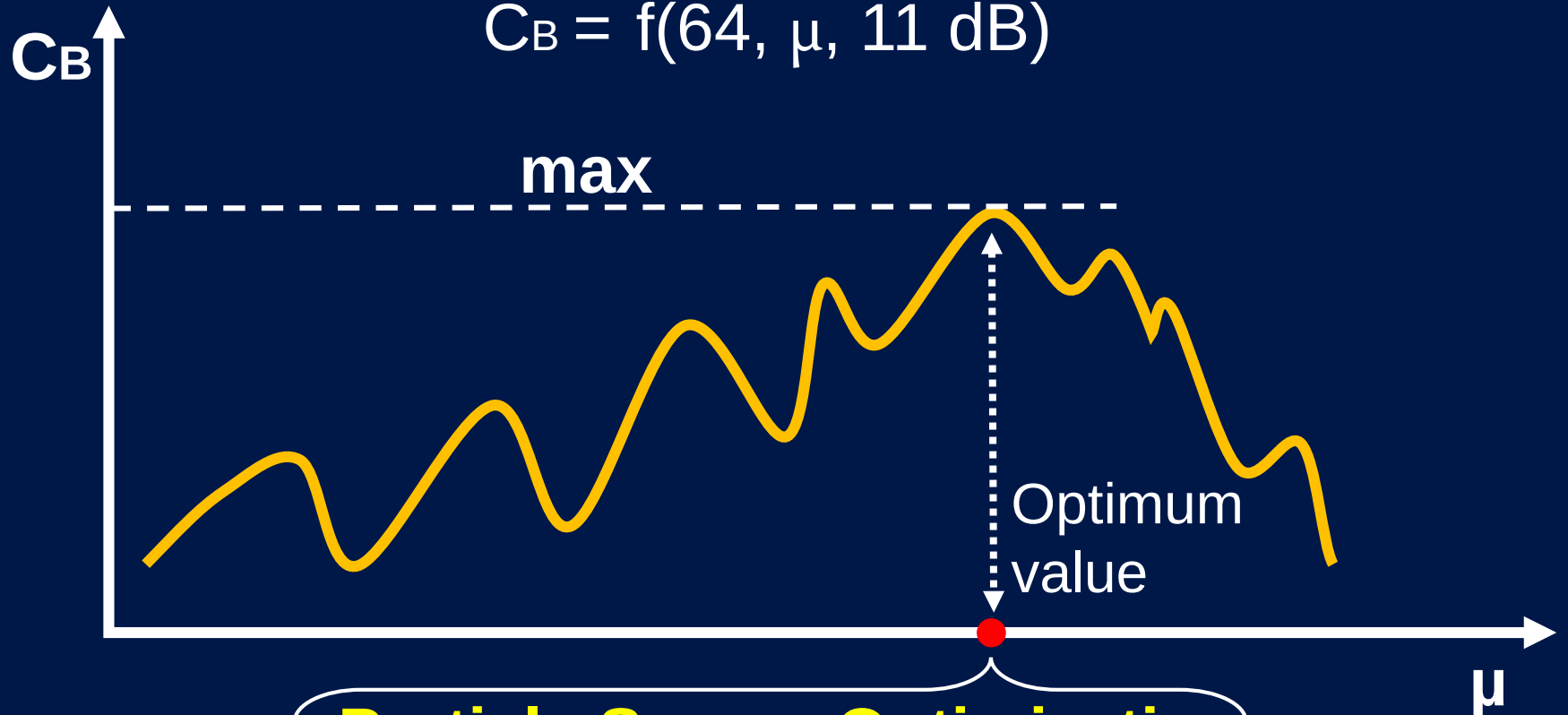
Constellation Capacity Equation, C_B

$$C_B[64, \mu, 11\ dB] = M - \frac{1}{2^{M+1}\pi\sigma^2} \iint_{-\infty}^{\infty} \sum_{m=0}^{M-1} \sum_{b=0}^{1} \sum_{x_l \in X_b^m} [\quad] dx\,dy$$

$$e^{\frac{-1}{2\sigma^2}\left[(x-Re[x_l])^2+(y-Im[x_l])^2\right]} log_2 \frac{\sum_{x_l' \in X} e^{\frac{-1}{2\sigma^2}\left[(x-Re[x_l'])^2+(y-Im[x_l'])^2\right]}}{\sum_{x_l'' \in X_b^m} e^{\frac{-1}{2\sigma^2}\left[(x-Re[x_l''])^2+(y-Im[x_l''])^2\right]}}$$

C_B as function of the constellation shape (μ)

$C_B = f(64, \mu, 11\ dB)$



- Particle Swarm Optimization

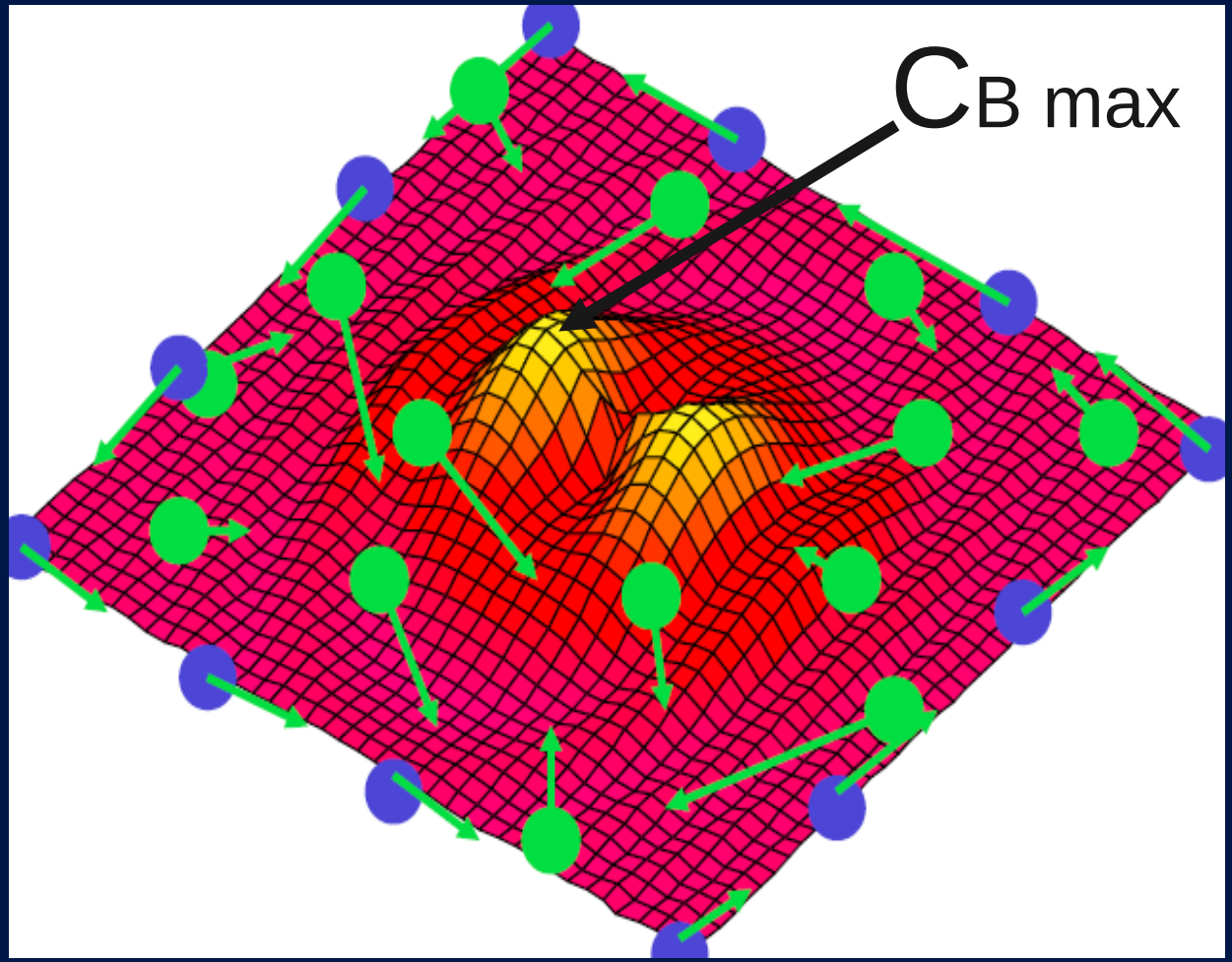
Particle Swarm Optimization

PSO

- Developed by Kennedy and Eberhart 1995.
- Metaheuristic Algorithms.
- Based on the paradigm of swarm intelligence.
- Inspired in the social behavior of animals, like the swarm of fishes and birds.
- Simpler and Powerful optimization algorithm.

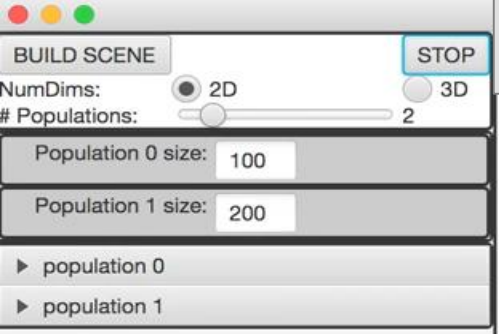
Initialization of the PSO algorithm

- Population size
- Positions
- Velocities
- Iterations

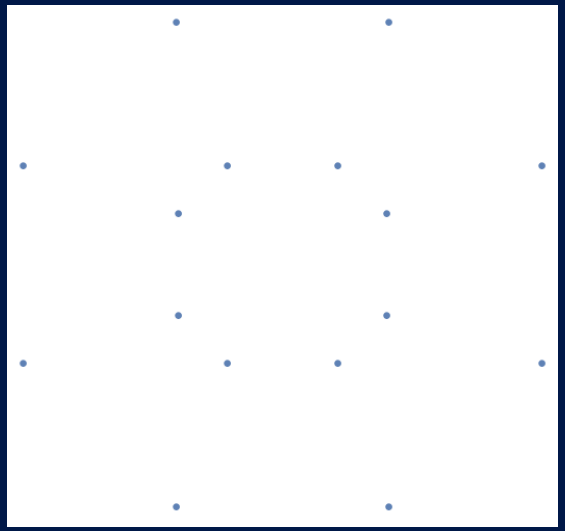


Particle Swarm Optimization Visualization

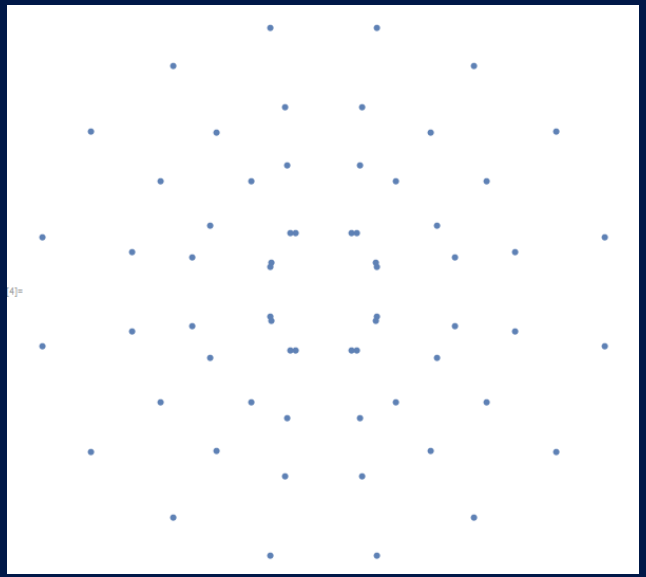
- Cognitive Component
- Social Component



Optimization results, 2D NUCs

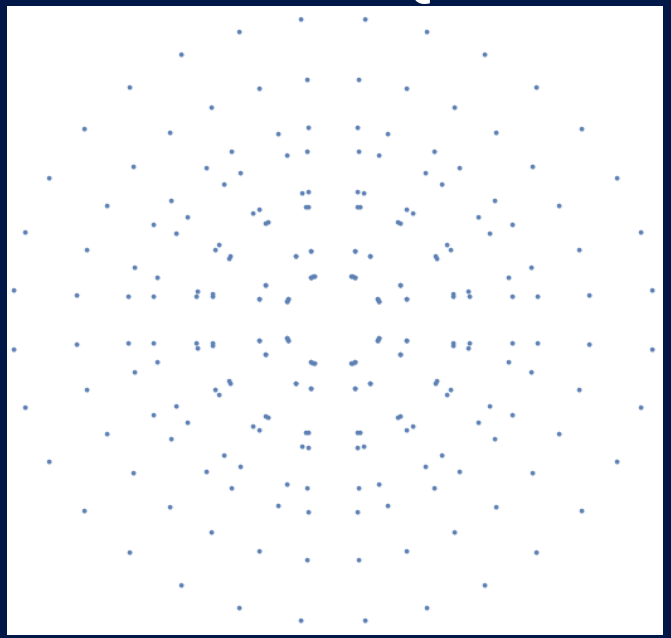


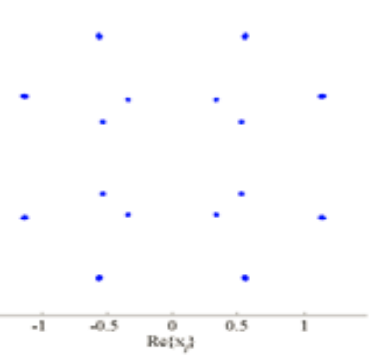
2D 16-QAM

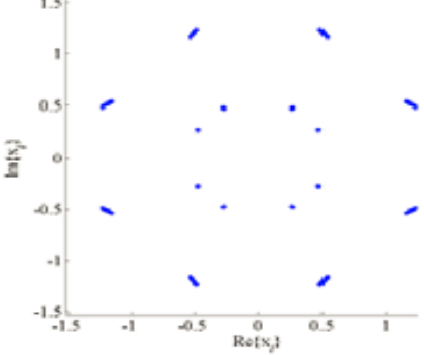


2D 64-QAM

2D 256-QAM

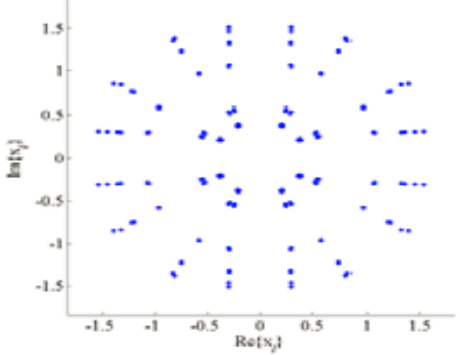




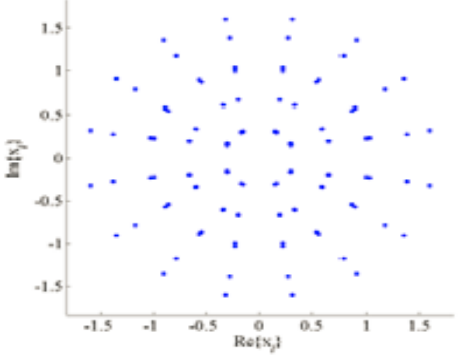


256NUC, CR 6/15

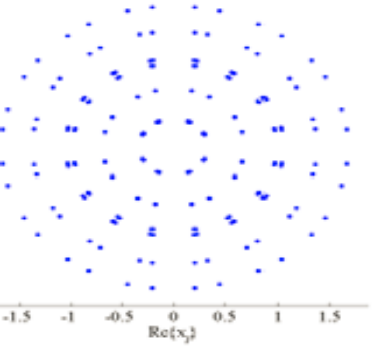
256NUC, CR 7/15

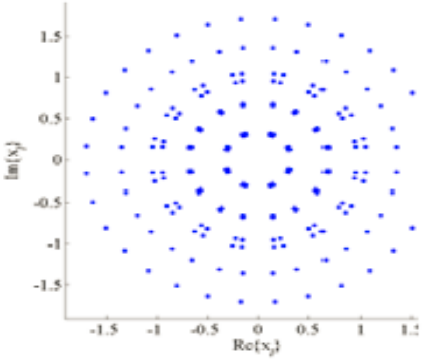


256NUC, CR 8/15



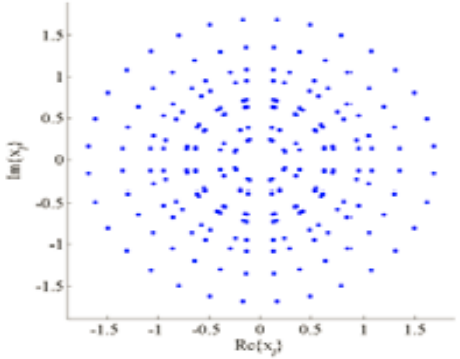
256NUC, CR 9/15



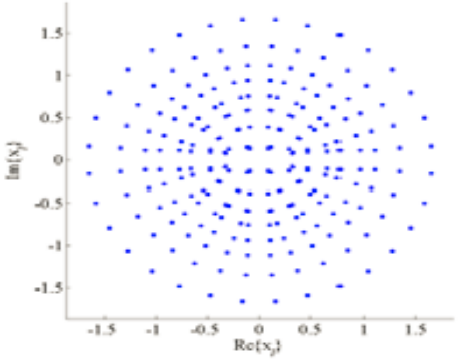


256NUC, CR 10/15

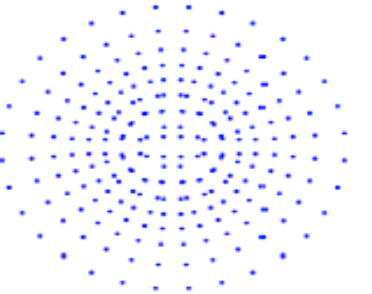
256NUC, CR 11/15

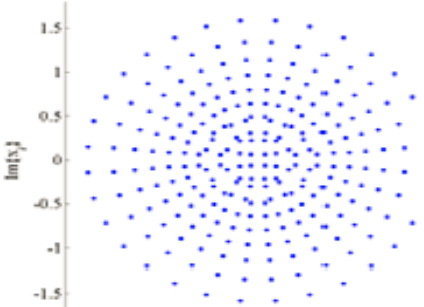


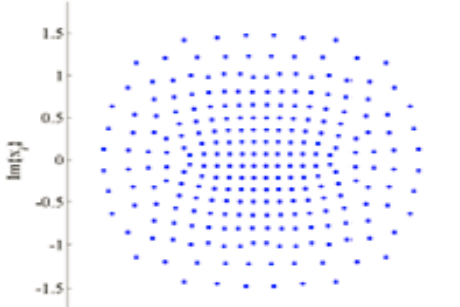
256NUC, CR 12/15

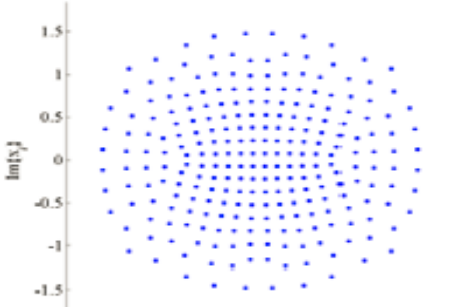


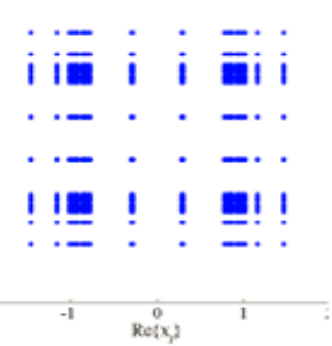
256NUC, CR 13/15



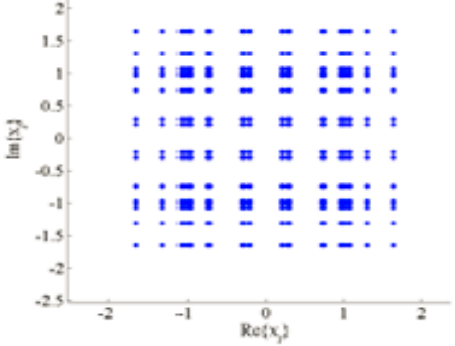








4kNUC, CR 6/15



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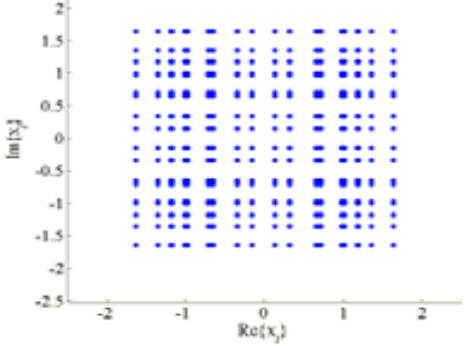
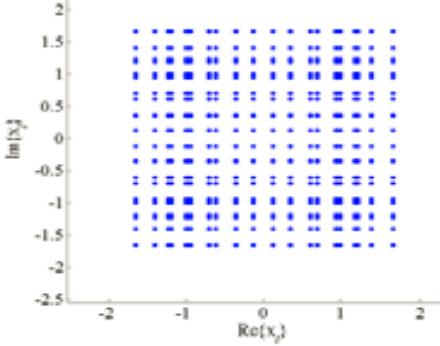
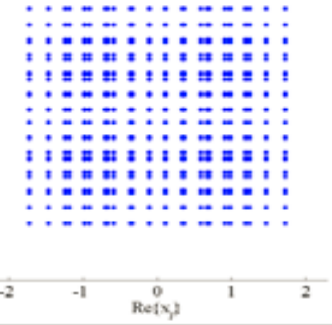


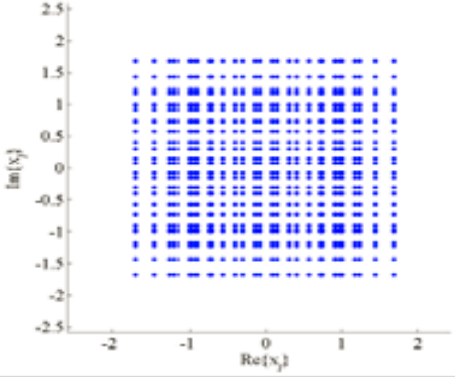
4kNUC, CR 8/15



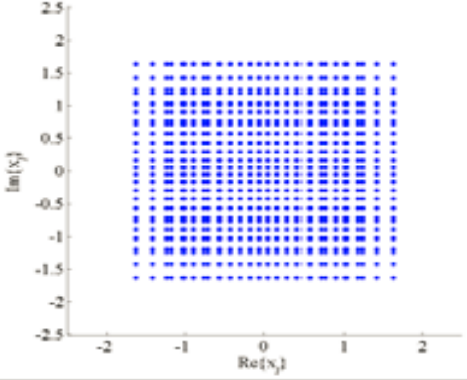
4kNUC, CR 9/15



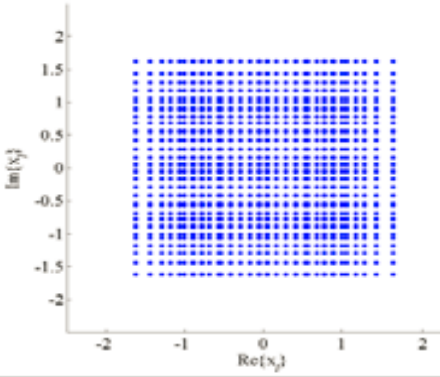
4kNUC, CR 10/15



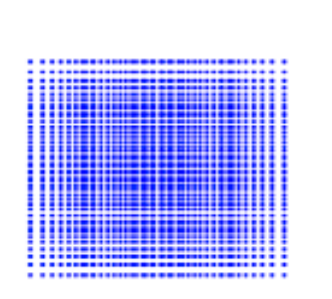
4kNUC, CR 11/15

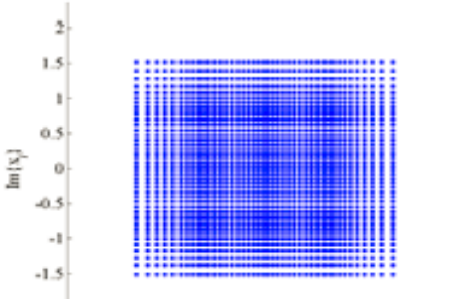


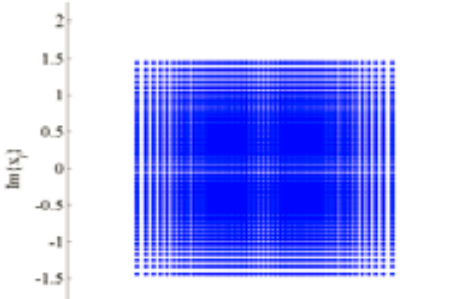
4kNUC, CR 12/15

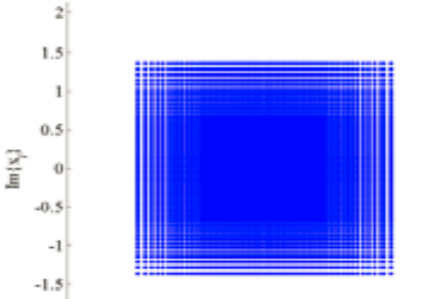


4kNUC, CR 13/15









Conclusions

- Non-Uniform Constellations were designed for the DTMB standard.
- With the proposed constellations we improve the performance of DTMB standard: robustness, spectral efficiency.
- A generic algorithm to design Non-Uniform Constellations is proposed.
    - Capacity Maximization.
    - Particle Swarm Optimization algorithm.

The **Future Belongs** to those who prepare for it today.

- Malcolm X

Thank You!

If you can’t **fly** then **run**,
If you can’t **run** then **walk**,
If you can’t **walk** then **crawl**,

But whatever you do,
You have to keep moving forward.

- Martin Luther King Jr.

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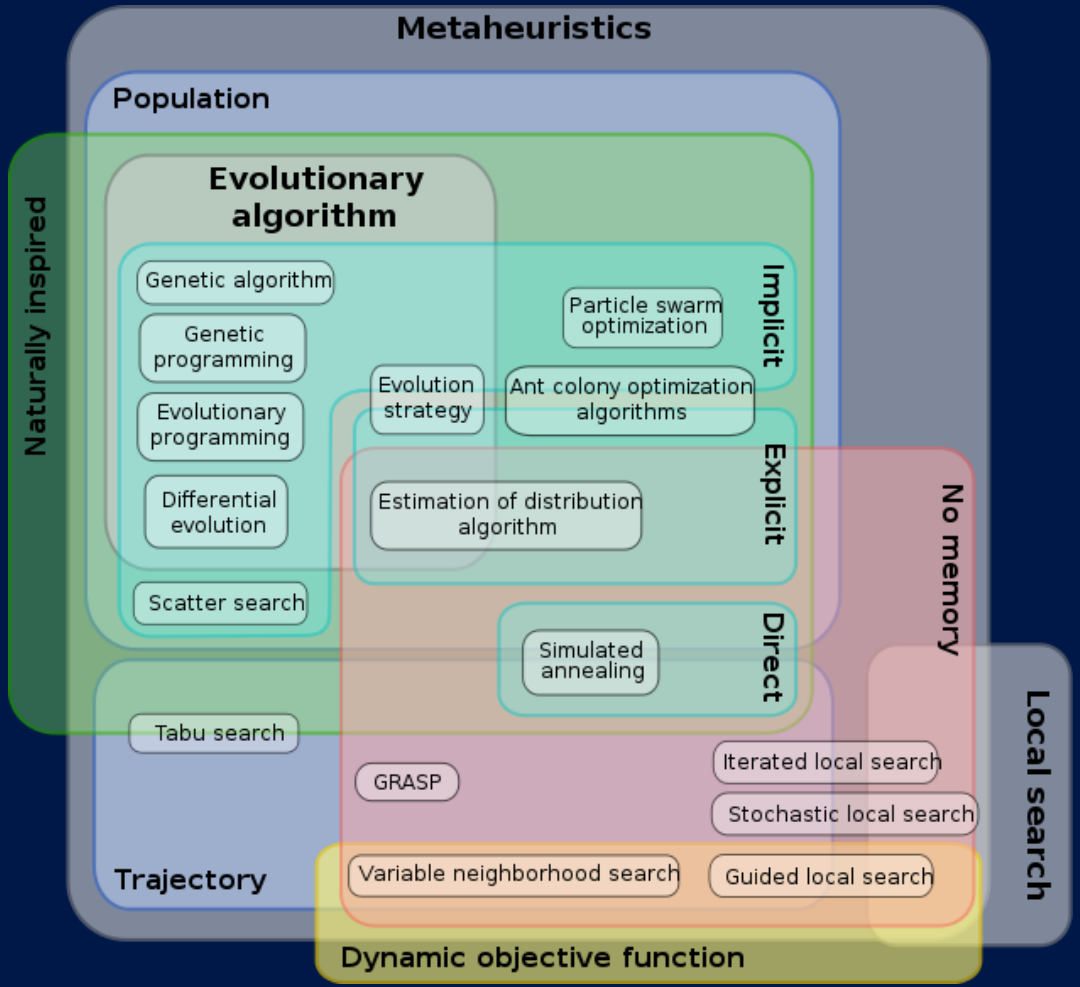
Introduction

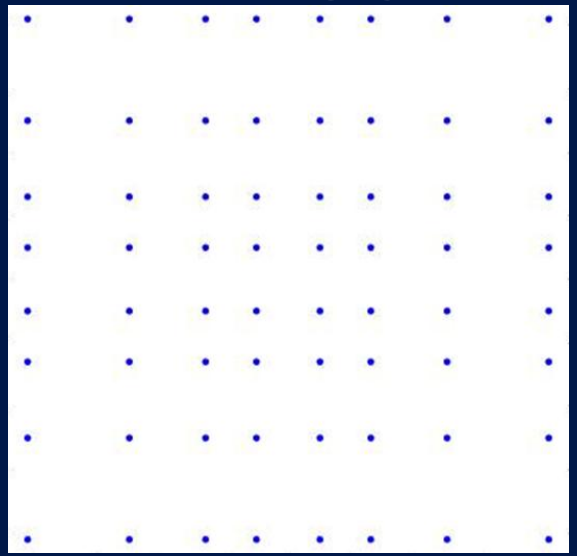
“The future of television is to stop thinking of television as television.”

- 1985
  Nicholas Negroponte

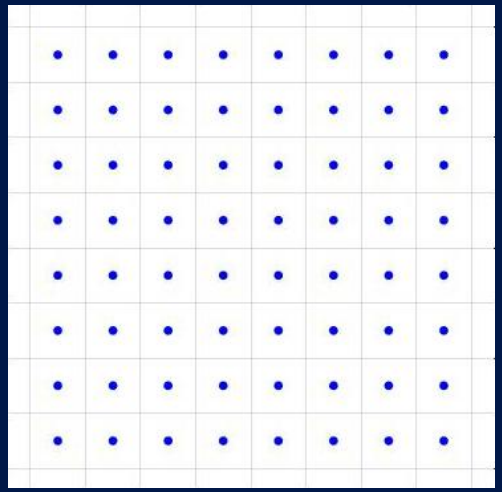

Metaheuristics
Population
Evolutionary algorithm
Naturally inspired
Genetic algorithm
Genetic programming
Evolutionary programming
Differential evolution
Scatter search
Particle swarm optimization
Evolution strategy
Ant colony optimization algorithms
Estimation of distribution algorithm
Simulated annealing
Implicit
Explicit
Direct
No memory
Local search
Tabu search
GRASP
Iterated local search
Stochastic local search
Variable neighborhood search
Guided local search
Trajectory
Dynamic objective function

Constelaciones No-Uniformes (NUC)

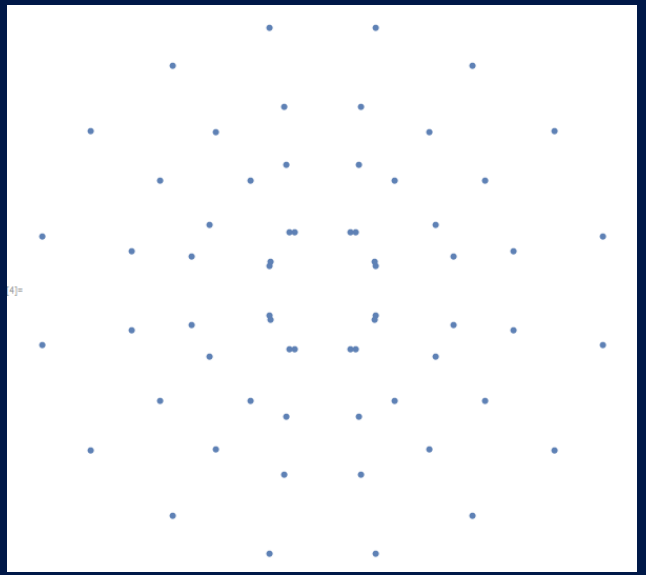
1D-NUC



UC



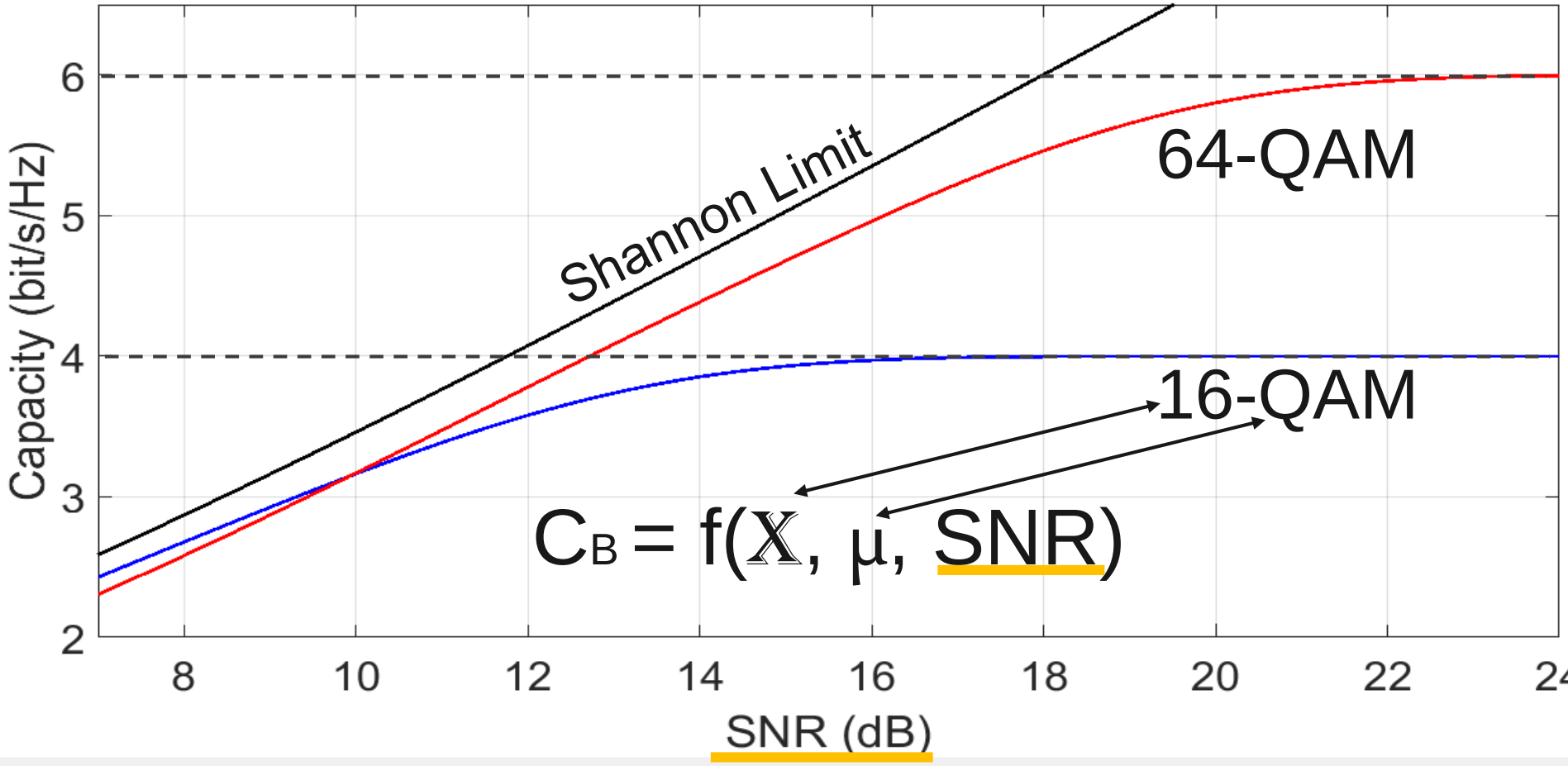
2D-NUC



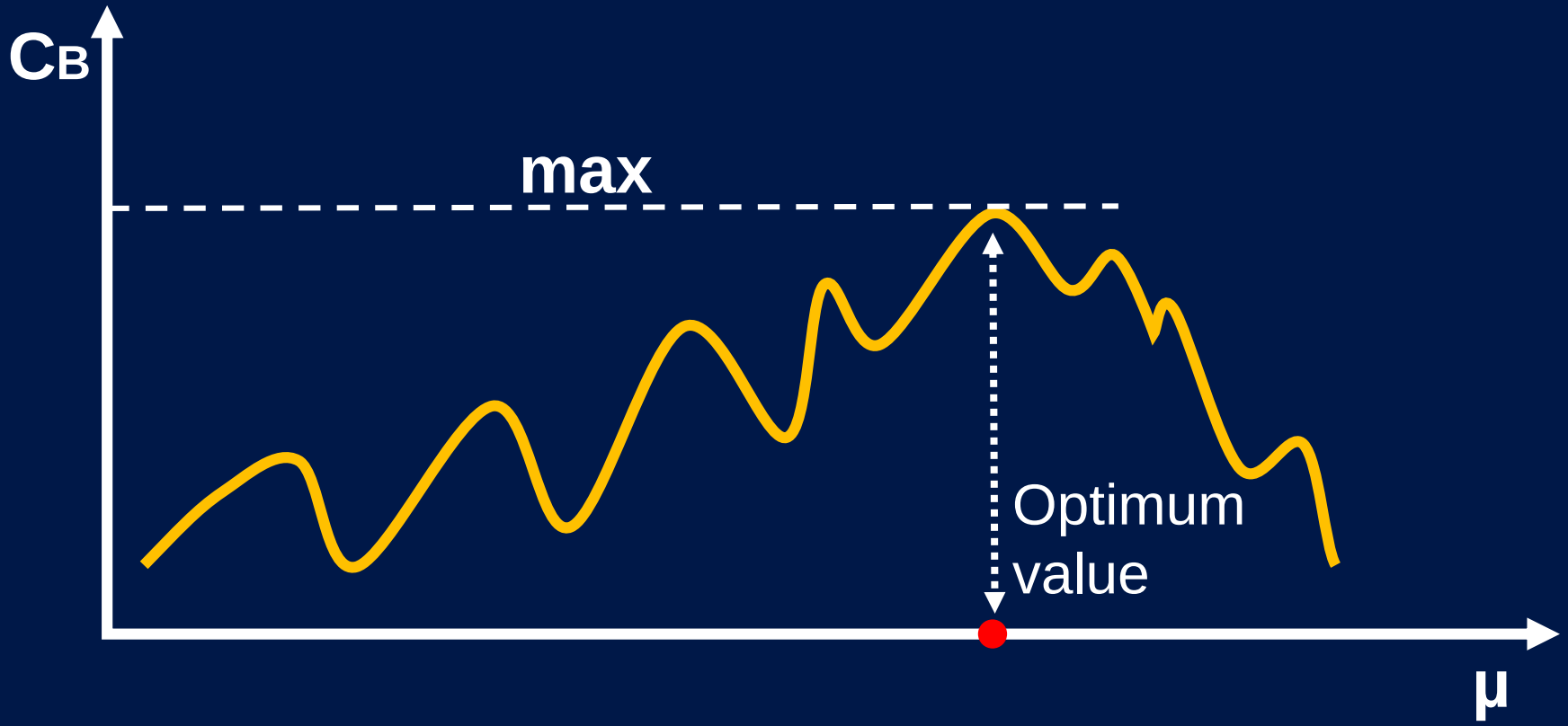
$\mathbb{X}$:
alfabeto de símbolo.

μ:
forma de la constelación.

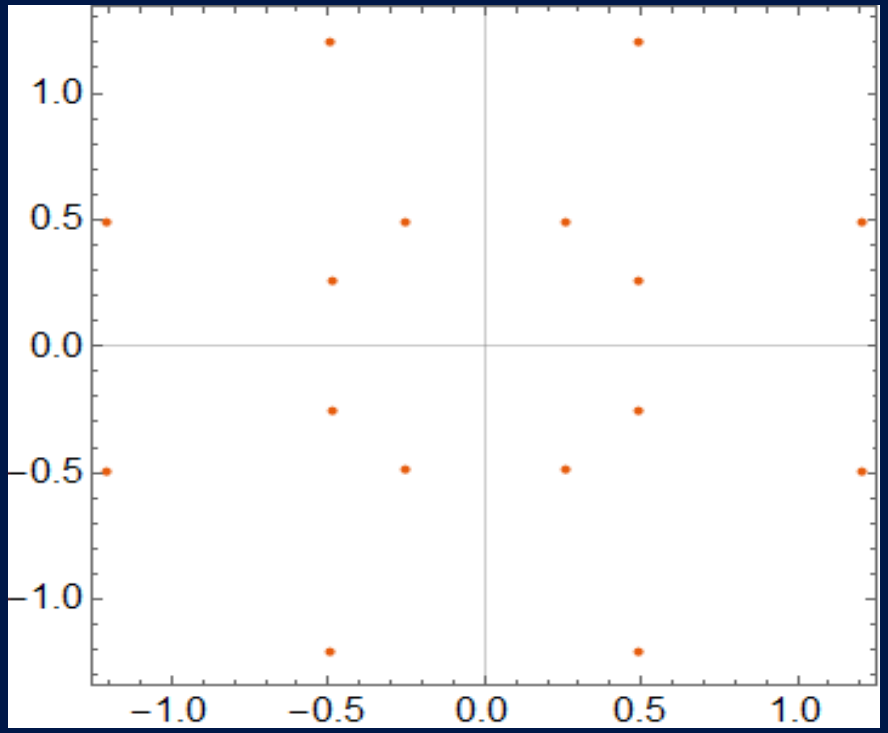
Capacity vs SNR

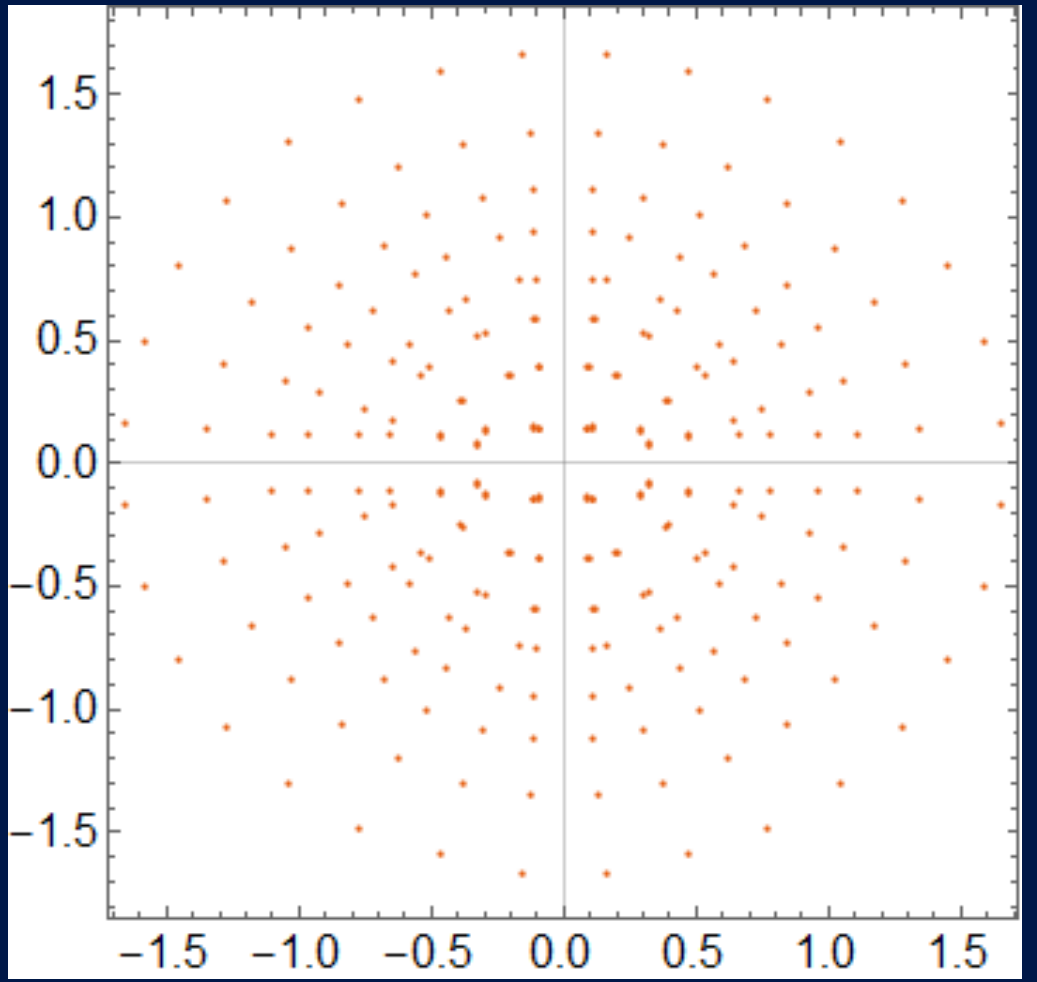


C_B as function of the constellation shape (μ)



Designed 2D-NUCs





Designed 2D-NUCs

NUCs design criterions for DTMB standard

$$C_B = f(\mathbb{X}, \mu, SNR)$$

X	**16**-QAM			**64**-QAM			**256**-QAM		
FEC	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8
SNR (dB)	**7.75**	**9.95**	**12.45**	**11.85**	**14.70**	**17.68**	**16.50**	**20.20**	**23.55**

¿ μ ? → maximize $C_{B\ max.}$