

On Signal Space Diversity for Non Binary Coded Modulation Schemes

Ahmed Abdmouleh, Emmanuel Boutillon, Laura Conde-
Canencia, Charbel Abdel Nour, Catherine Douillard

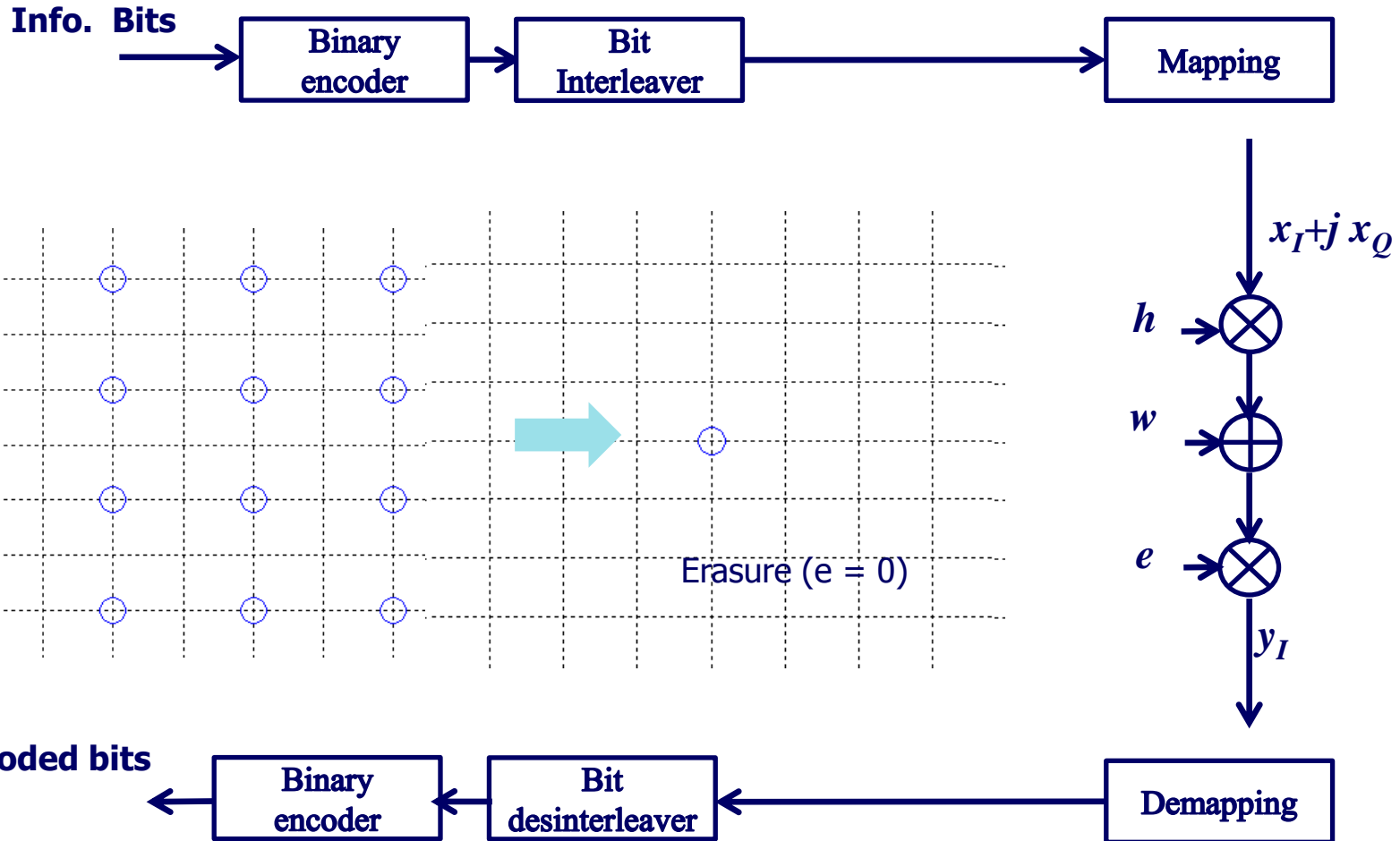
Lab-STICC

Université de Bretagne Sud and Telecom Bretagne

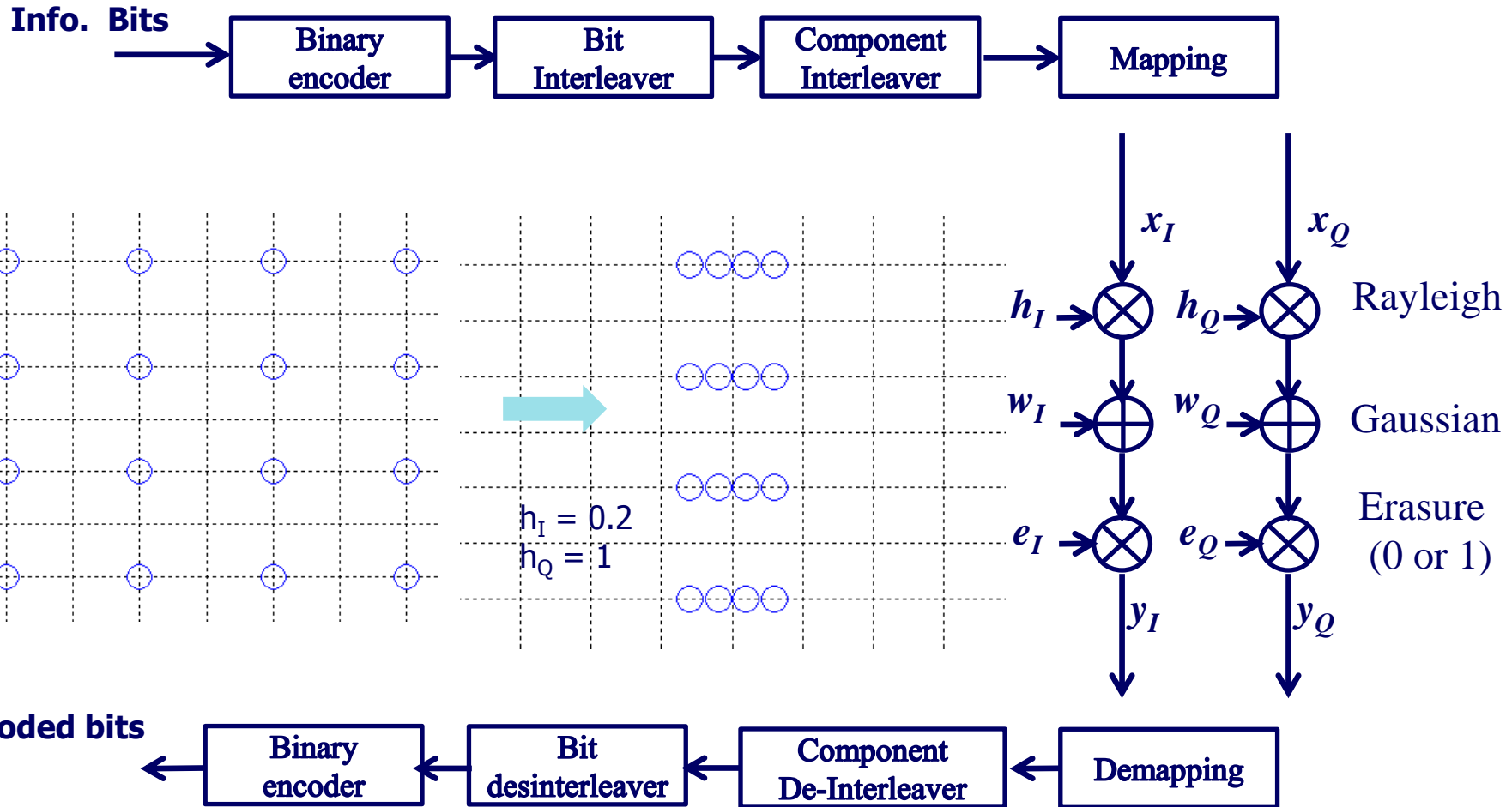
18 May 2016



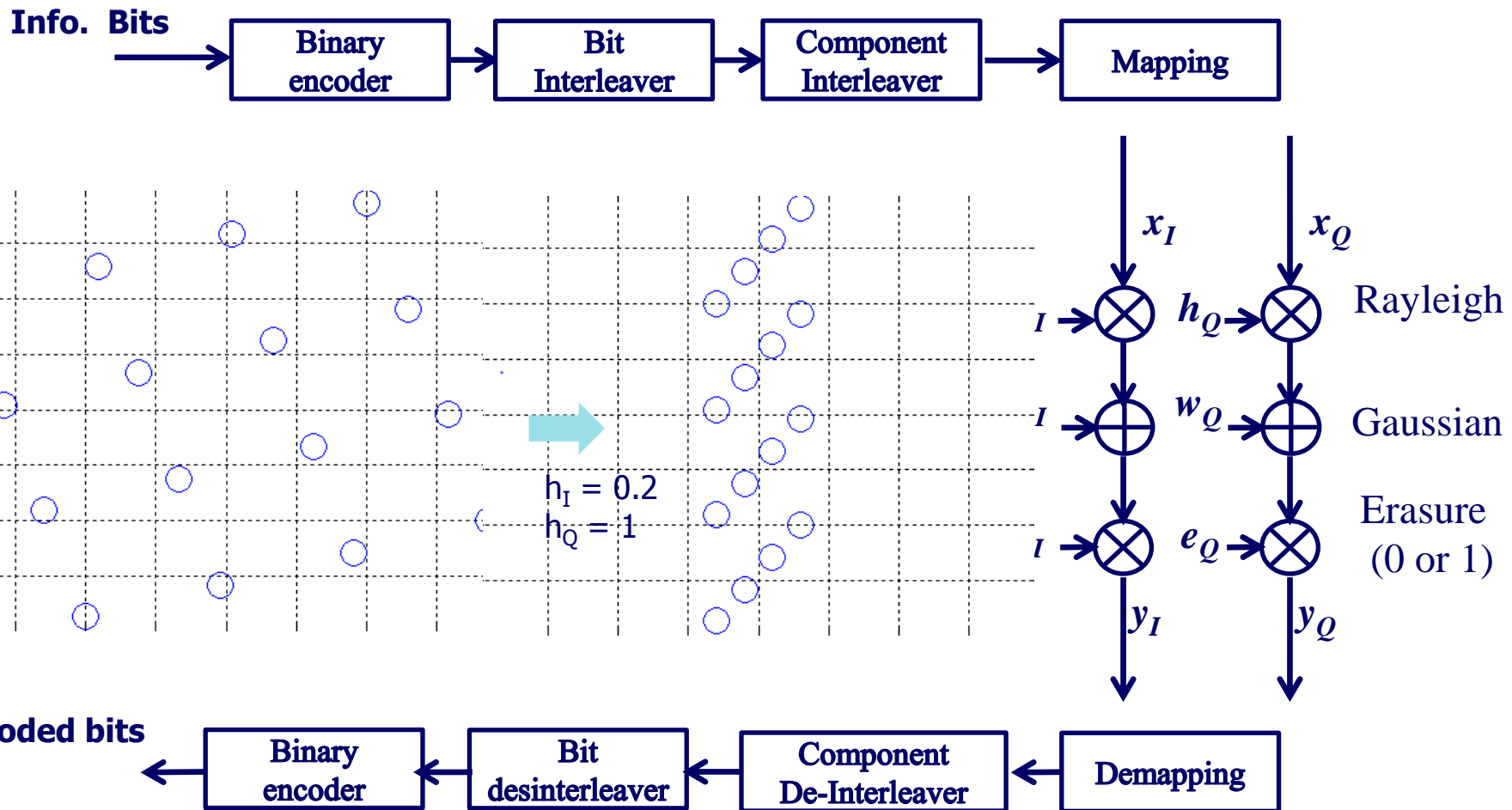
BICM and Signal Space Diversity



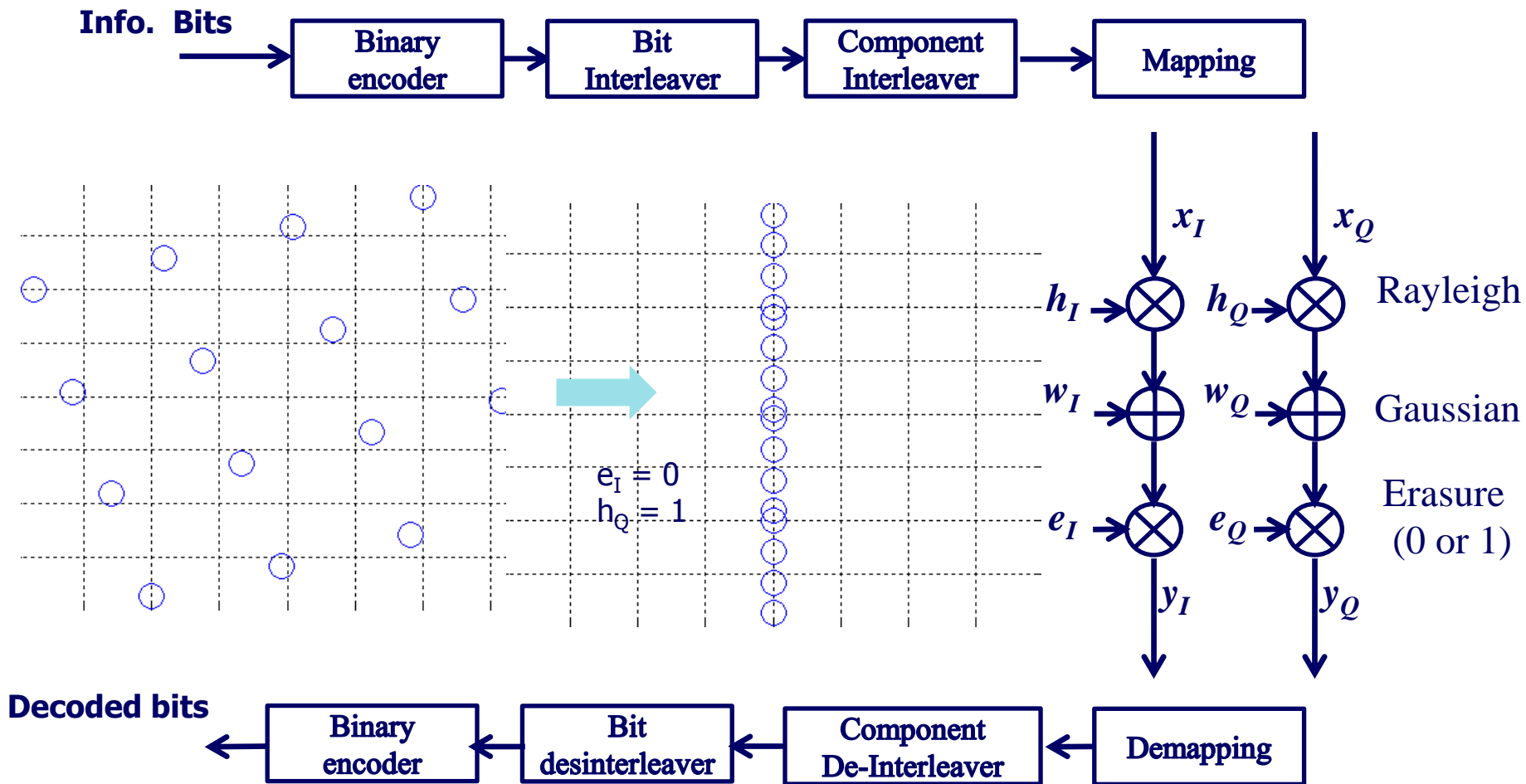
BICM and Signal Space Diversity



BICM and Signal Space Diversity



BICM and Signal Space Diversity





SSD was proposed in DVB-T2 standard

In [1], [2], extensive discussion on optimal rotation angle
(contradictory requirement between fading and erasure channel).

Result of compromise:

Constellation	Rotation Angle α value (degree)
QPSK	29.0°
16-QAM	16.8°
64-QAM	8.6°
256-QAM	3.6°

[1] Papers of Charbel/Catherine

[2]



SSD was proposed in DVB-T2 standard

In [1], [2], extensive discussion on optimal rotation angle
(contradictory requirement between fading and erasure channel).

Result of compromise:

Constellation	Rotation Angle α value (degree)
QPSK	29.0°
16-QAM	16.8°
64-QAM	8.6°
256-QAM	3.6°

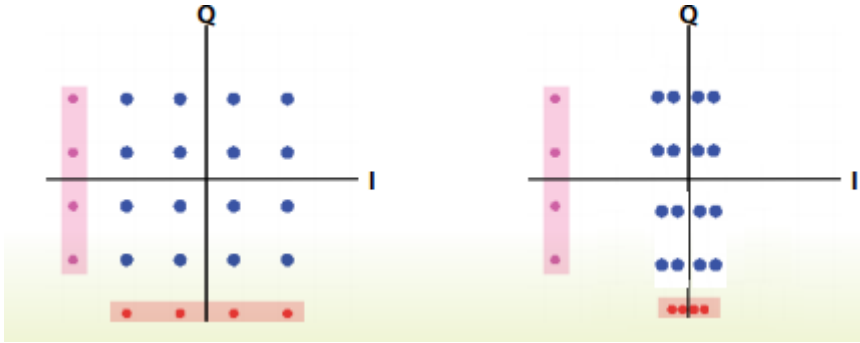
[1] Papers of Charbel/Catherine

[2]

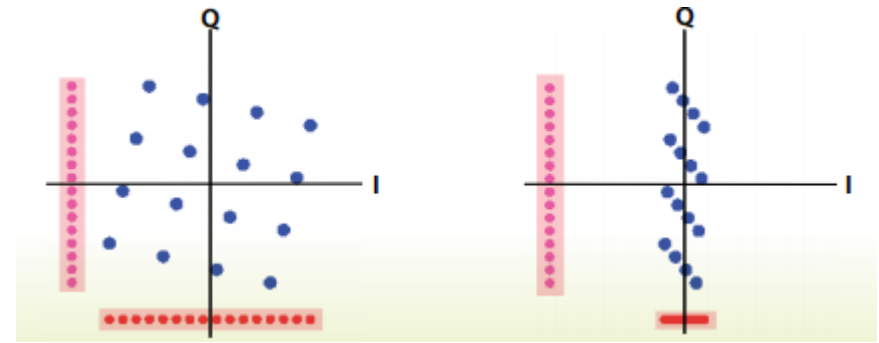


BICM and Signal Space Diversity

We can take the 16-QAM constellation as an example of application:



16-QAM Constellation



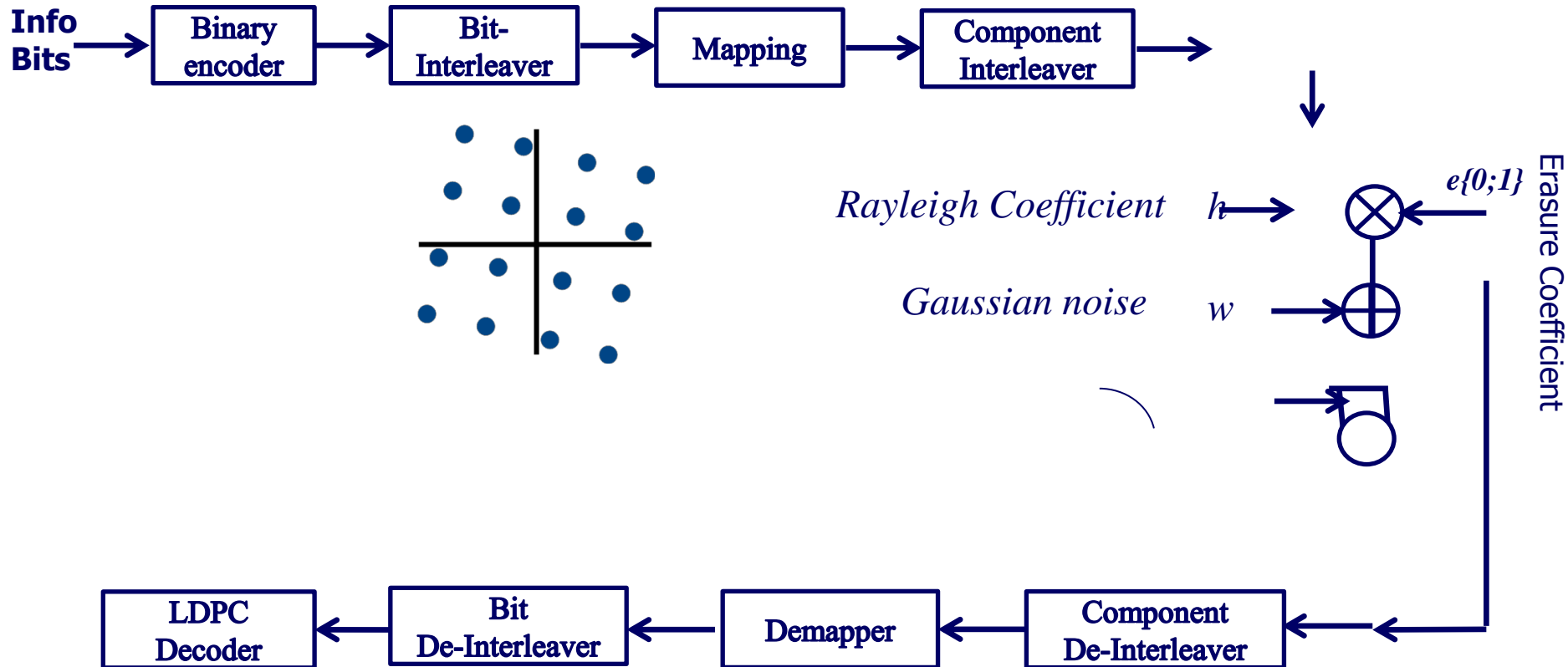
Rotated 16-QAM Constellation

Compressed constellation with rotation offers more protection against the noise effects.

Hamming distance enhancement for rotated constellation components.

An interleaver/deinterleaver is required.

BICM and Signal Space Diversity : BICM transmission scheme





BICM and Signal Space Diversity : BICM transmission scheme

Previous works have proposed methods to optimise the SSD technique under BICM scheme.

Our reference in the proposed work will be the DVB-T2 standard.

DVB-T2 standard has proposed the rotation angles for q-QAM modulations:

Constellation	Rotation Angle (degree)
QPSK	29.0°
16-QAM	16.8°
64-QAM	8.6°
256-QAM	3.6°



How does SSD technique work under the CM scheme ?





Outline

- Coded Modulation and signal space diversity
- Mutual Information Computation
- Mutual information as a function of rotation angle
- Simulation results
- Conclusion.



Outline

- Coded Modulation and signal space diversity
- Mutual Information Computation
- Mutual information as a function of rotation angle
- Simulation results
- Conclusion.



CM and signal space diversity

The association of q -ary code with a high-order modulation with the same cardinality correspond to the Coded Modulation (CM) scheme.

We can consider NB-LDPC codes defined over a Galois Field of cardinality equal to $q \ll GF(q) \gg$ and the q -QAM modulation.

We will perform SSD technique optimisation under the CM scheme.

We compare the obtained performances with those the BICM scheme.



Outline

- Coded Modulation and spatial diversity
- **Mutual Information Computation**
- Mutual information as a function of rotation angle
- Simulation results
- Conclusion.



Mutual Information Computation

Mutual Information measures how much one random variable tells us about another.

The higher Mutual information between the transmitter and the receiver -> the better decoding performance.

Our approach to optimise the SSD technique -> Mutual Information maximization.



Mutual Information Computation

Let us define X and Y as the random variables that represent the input and output of the transmission channel.

The mutual information $I(X;Y)$ is given by:

$$I(X;Y) = H(X) - H(X|Y)$$

The Mutual Information (MI) expression can be derived for both CM and BICM schemes.



Mutual Information Computation

A simple algorithm can be applied then repeated.

1. We select the random symbol to transmit.
2. We apply two different random attenuations on both components (Rayleigh channel).
3. We compute the amount of received information.

For Rayleigh channel with erasure we add a cancellation probability.



Outline

- Coded Modulation and spatial diversity
- Mutual Information Computation
- **Mutual information as a function of rotation angle**
- Simulation results
- Conclusion.



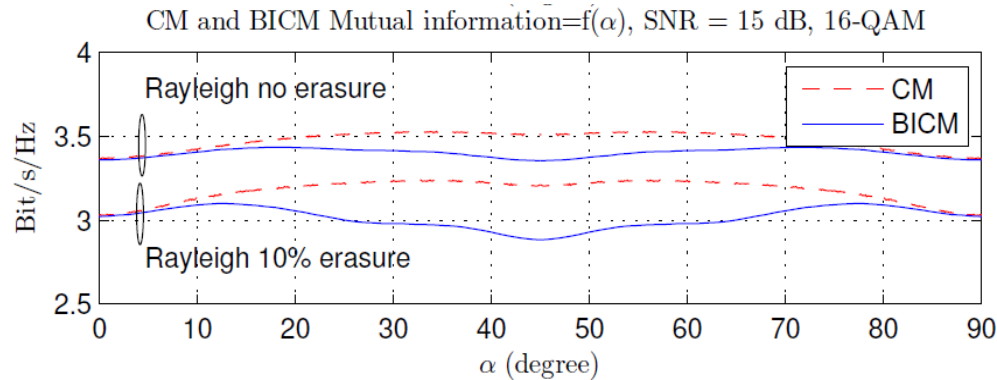
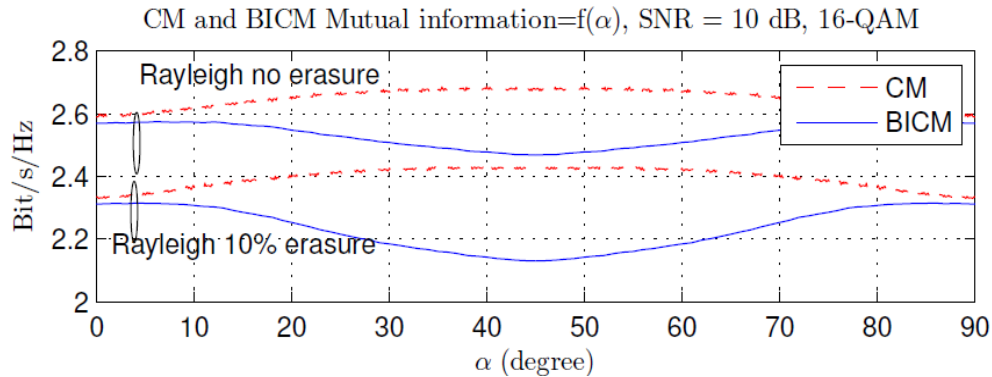
Mutual Information as a function of the rotation angle

For a fixed SNR we can compute the MI.

We considered the 16-QAM and 256-QAM modulations, Rayleigh channel and Rayleigh channel with erasure.

We performed MI computation for angles between 0° and 90° .

the rotation angle: 16-QAM modulation

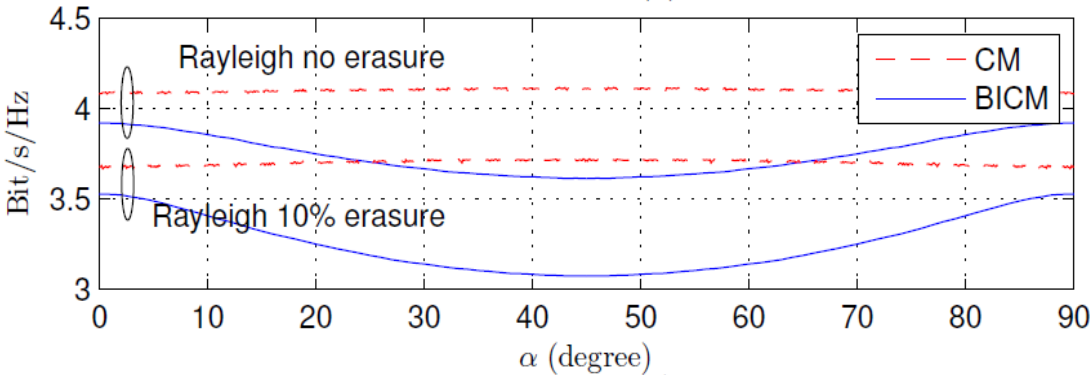


- CM presents for all rotation angles higher MI than BICM scheme.
- Rotation always provides gain for CM unlike for BICM.
- For Rayleigh channel with erasure SSD technique provide more significant gain

Mutual Information as a function of the rotation angle: 256-QAM

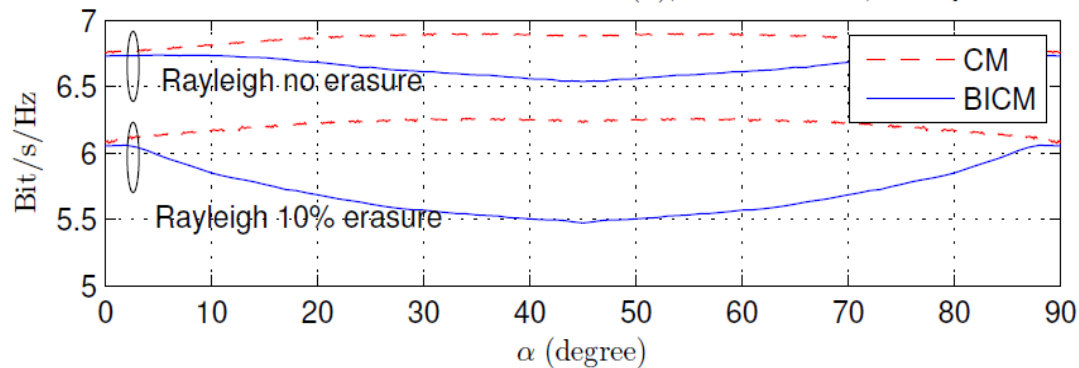


CM and BICM Mutual information= $f(\alpha)$, SNR = 15 dB, 256-QAM



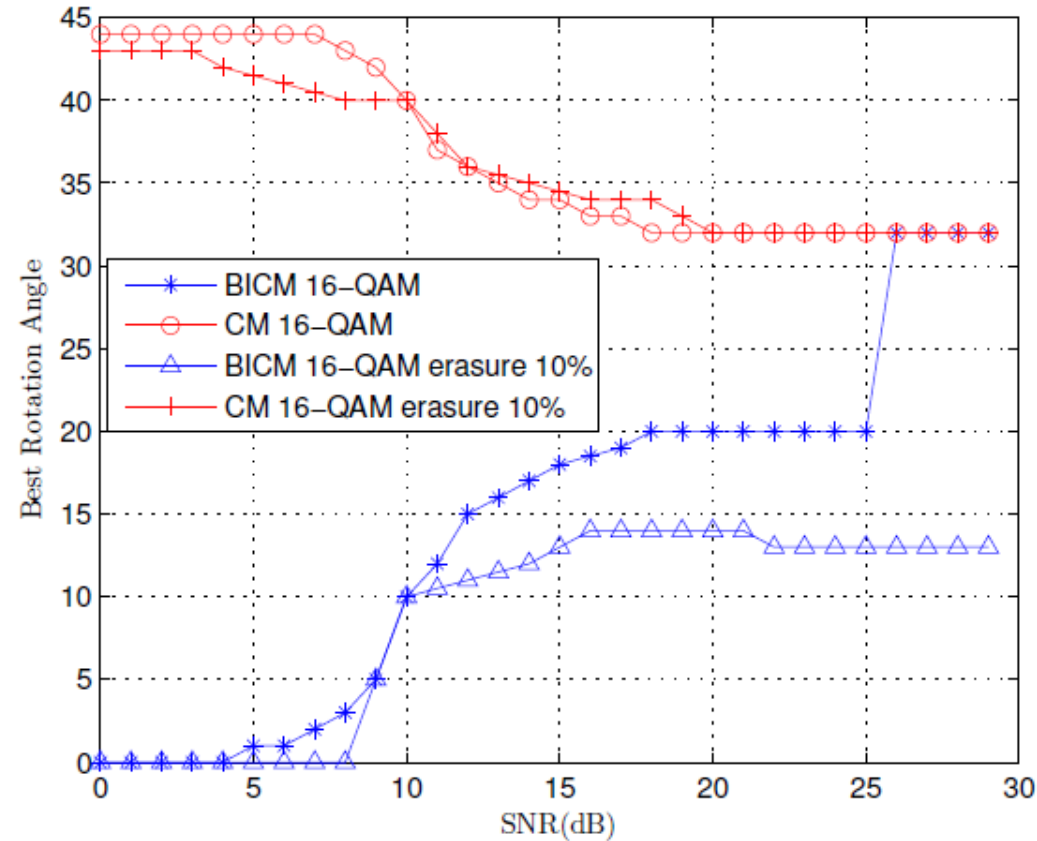
- Same conclusions are available for the 256-QAM modulation.
- BICM scheme does not take advantage of SSD technique unlike for CM one.

CM and BICM Mutual information= $f(\alpha)$, SNR = 25 dB, 256-QAM





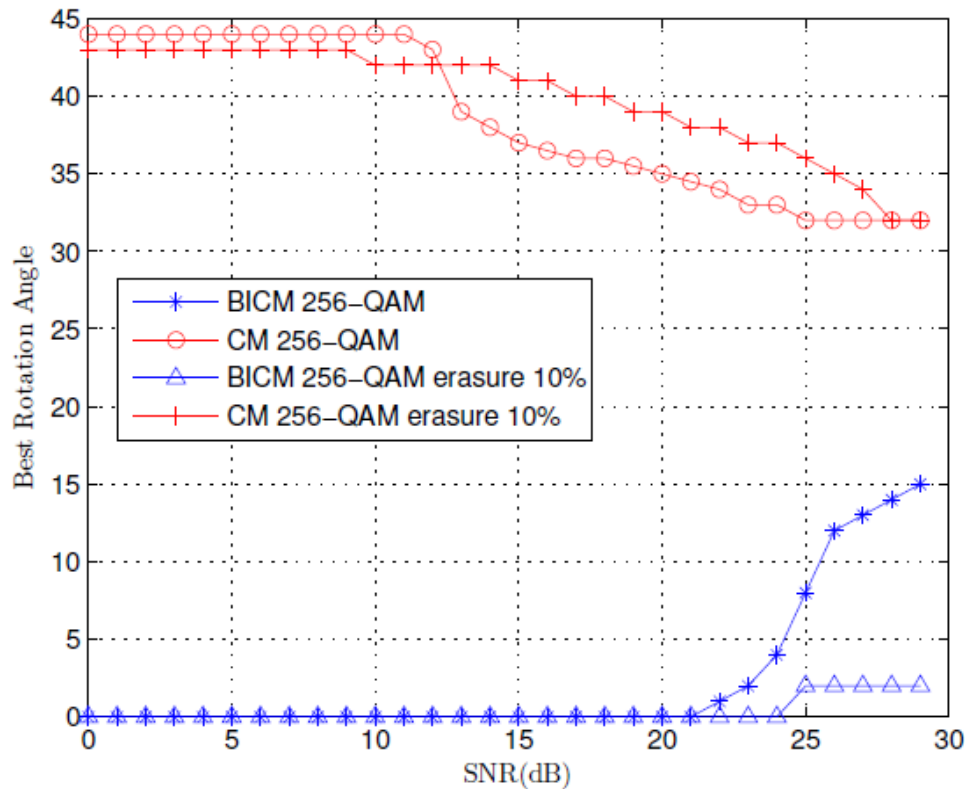
the rotation angle: 16-QAM modulation



- Best angle as a function of the SNR.
- CM: Same angle for both, Rayleigh and Rayleigh with erasure channels.
- BICM: Best angle is conditioned to more constraints.

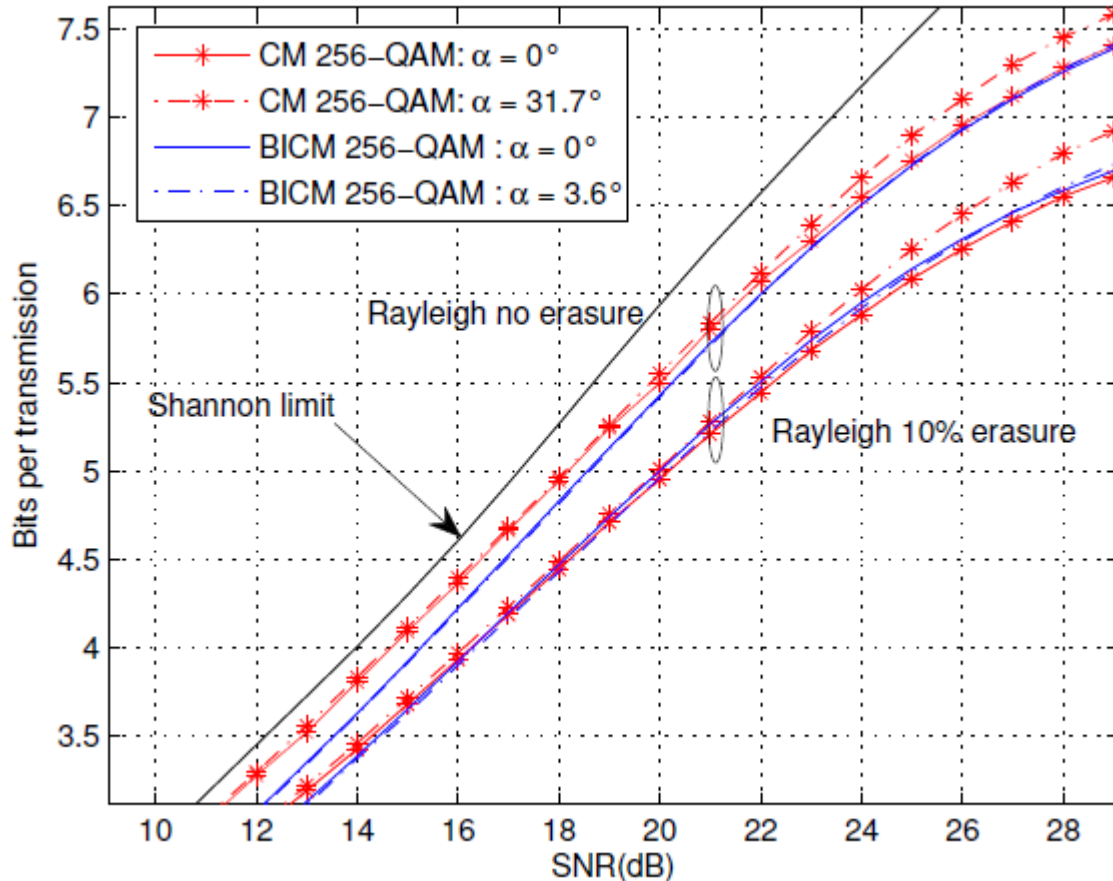


the rotation angle: 256-QAM modulation



- BICM: SSD is advantageous only for high SNRs.
- CM: SSD always enhances the MI.
- CM: The angle 31.7° represents the best angle for high SNRs
- CM: The angle 31.7° provide also gain for lower SNRs and the gain is close to the one provided by the best angle.

Mutual Information as a function of the SNR: 256-QAM modulation



CM with SSD outperforms the BICM with SSD scheme for:

- All SNRs.
- Rates.
- Rayleigh Channel with and without erasures.

Gain is more important for Rayleigh channel with erasure.



Outline

- Coded Modulation and spatial diversity
- Mutual Information Computation
- Mutual information as a function of rotation angle
- **Simulation results**
- Conclusion.



Simulation results

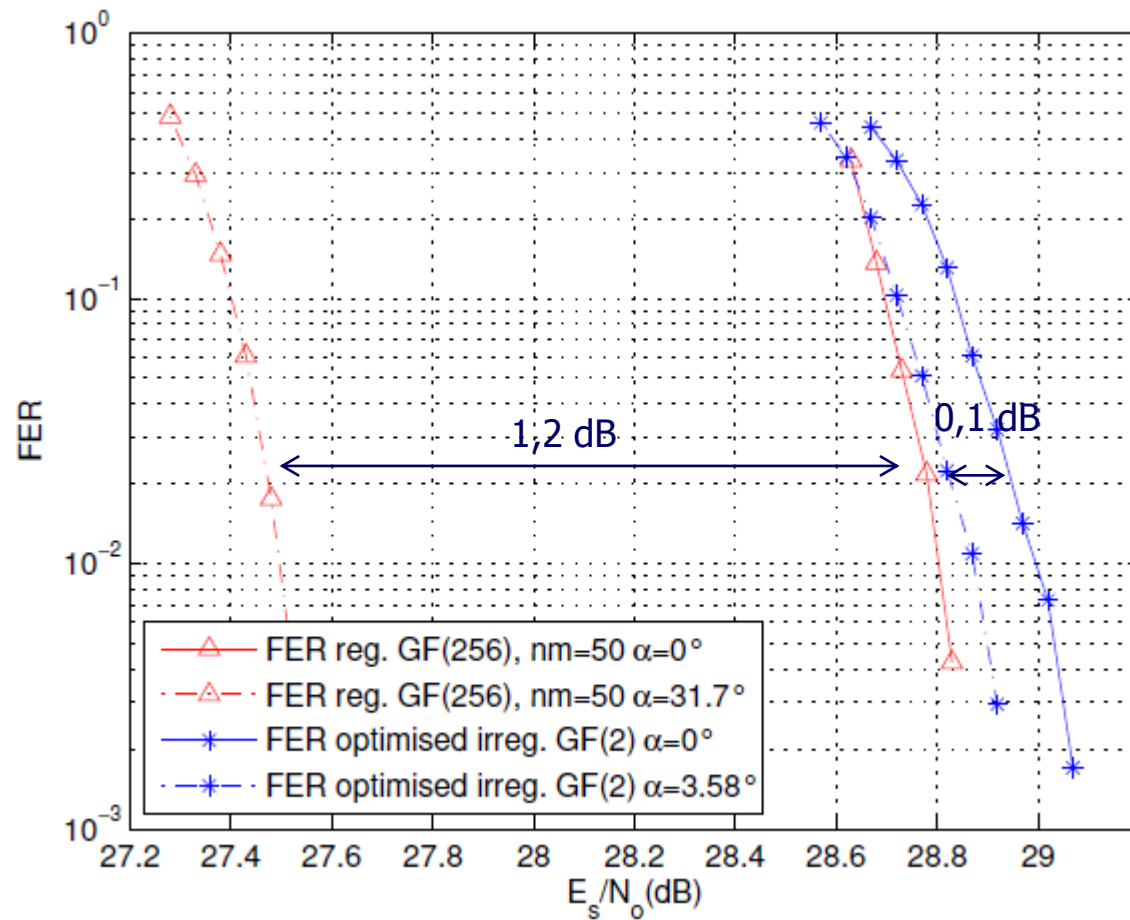
To perform simulations we have to choose the rotation angles for both CM and BICM schemes.

For the BICM scheme our reference will be angles chosen in the DVB-T2 standard, while for CM scheme 31.7° will be chosen.

To verify the theoretical results, we ran Monte-Carlo simulations for the different scenarios.



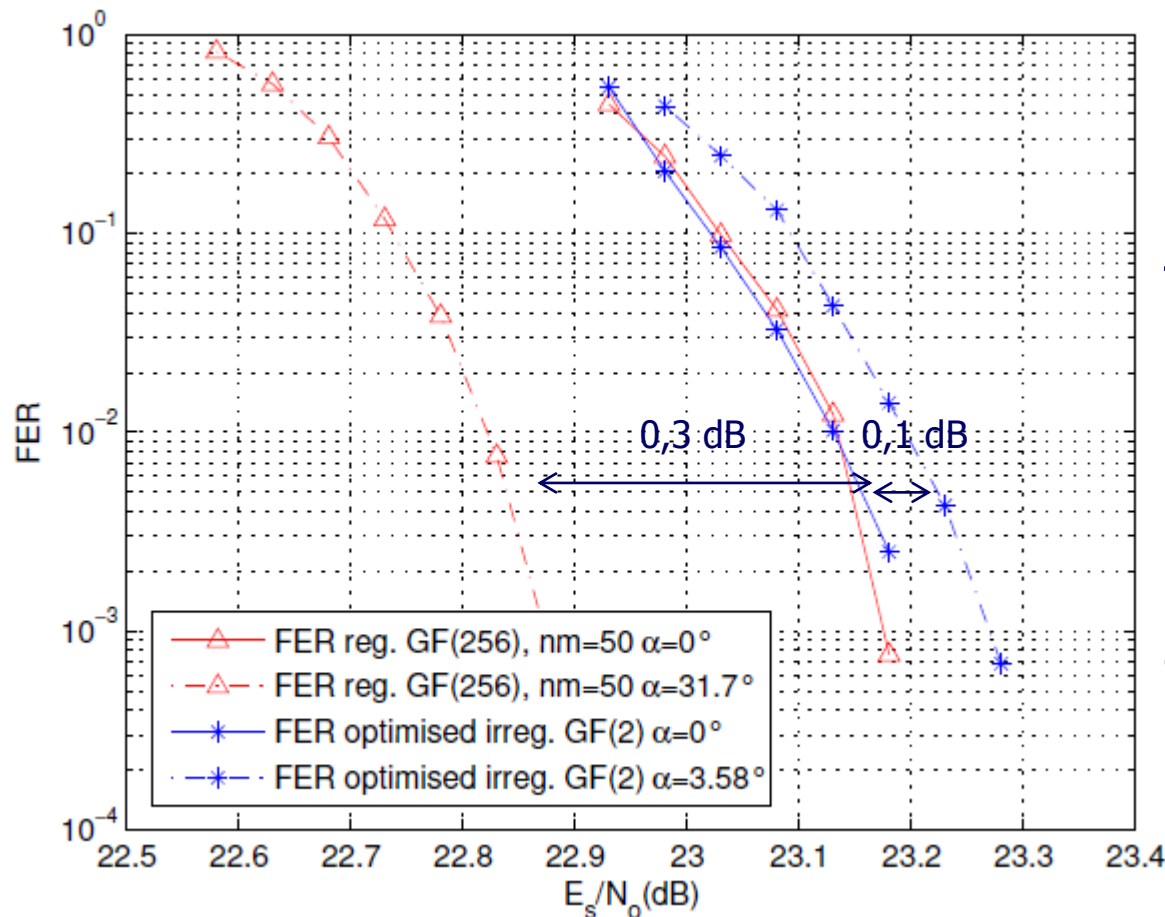
Simulation results: BICM-GF(2) vs CM-GF(256) Rayleigh channel and 256-QAM modulation



- $R = 9/10$
- Code length = 64,000 bits, 8,000 Symbols (size of codes in the DVB-T2 standard)
- The CM associated with SSD technique: gain of about 1,2 dB.
- The BICM associated with SSD technique: gain of about 0,1 dB.



Simulation results: BICM-GF(2) vs CM-GF(256) Rayleigh channel and 256-QAM modulation



Code rate equal to 3/4.

The BICM associated with SSD present performance decrease, wich is not the case for CM scheme.

Results can be preceded from MI curves.



Outline

- Coded Modulation and spatial diversity
- Mutual Information Computation
- Mutual information as a function of rotation angle
- Simulation results
- **Conclusion.**



Conclusion

- We have considered the application of the signal space diversity technique to high spectral efficiency communications in the context of next generation broadcasting systems.
- Selecting optimal rotation angles via MI maximization.
- CM takes better advantage of SSD technique than the BICM.
- The solutions that we proposed can lead to significant performance gains for next generation broadcasting systems.



Conclusion

NB-LDPC decoding has been investigated in the last years
-> possibility of use of the CM scheme in the next generation broadcasting systems.

For more informations you can visit our web-site :

http://www-labsticc.univ-ubs.fr/nb_ldpc/



*Thank you for your
attention*

