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Improving DVB-S2 Performance Through Constellation Shaping and Iterative Demapping

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Outline

- Introduction
- Constellation Shaping
- Implementation
- Conclusion

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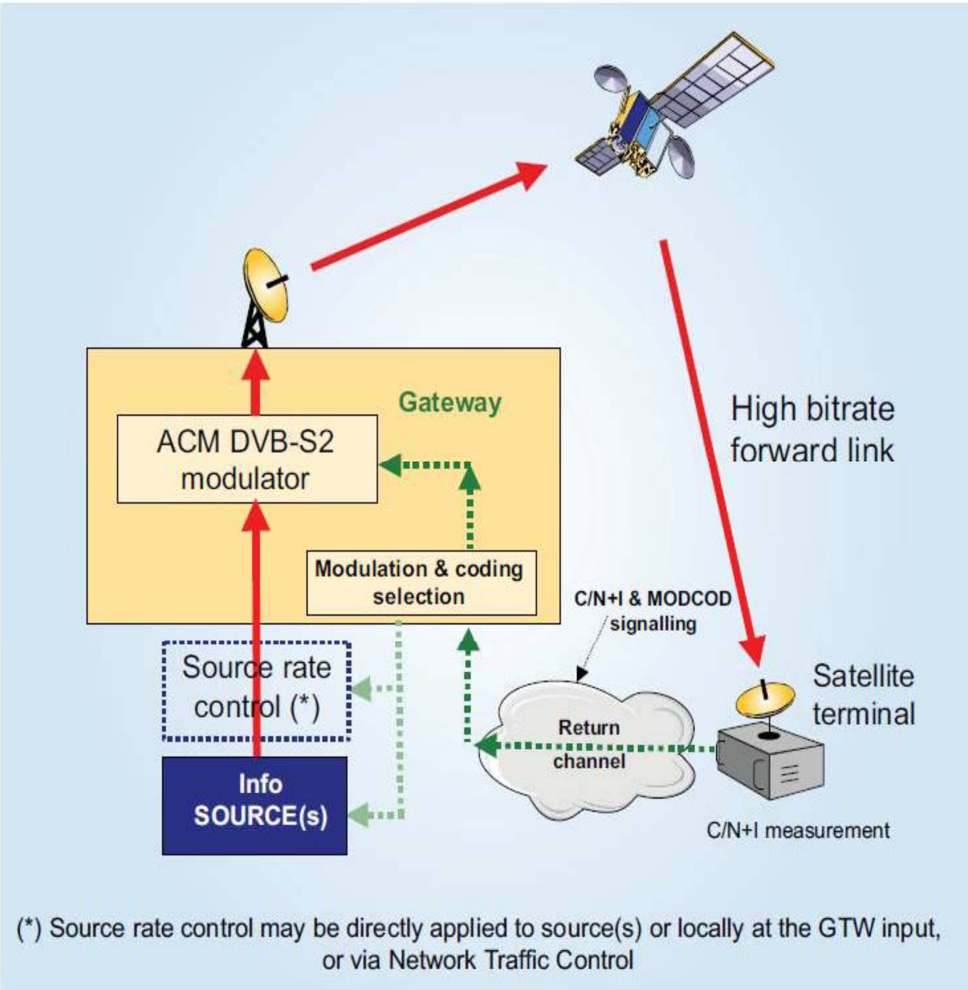
DVB-S2 Standard

DVB
Digital Video Broadcasting

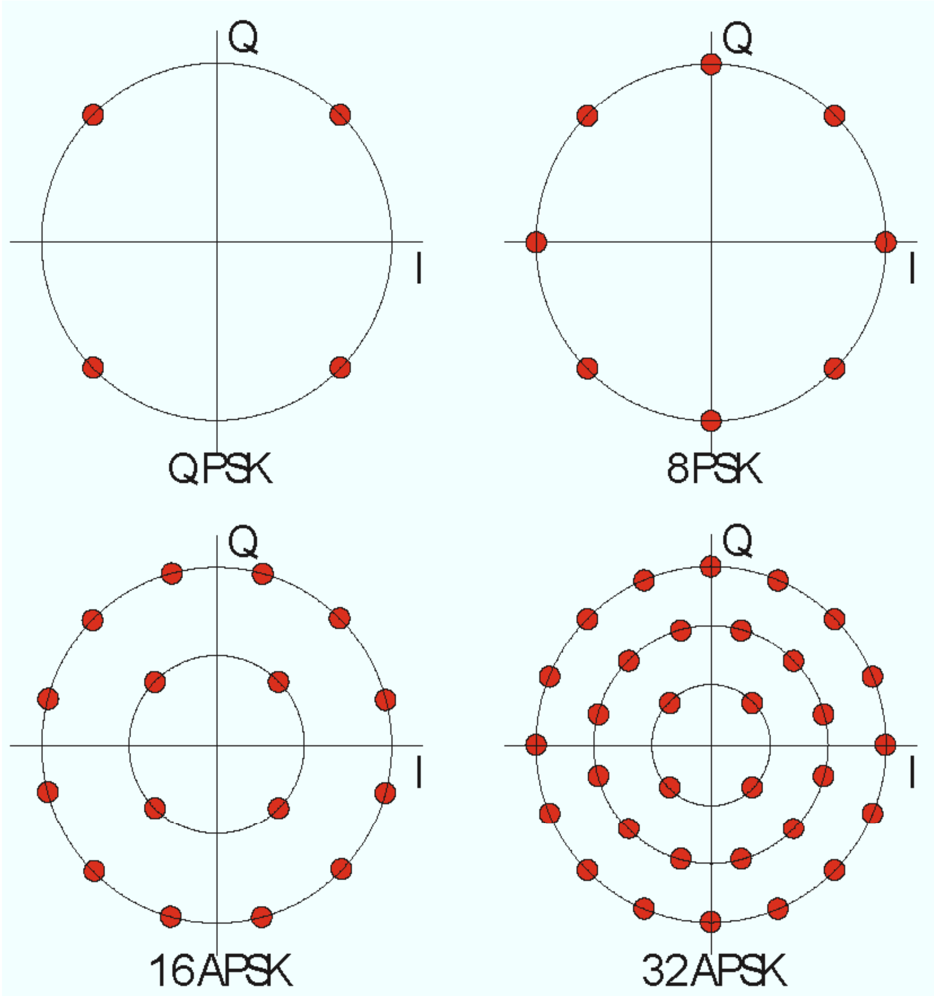
– DVB-S2 was introduced in 2003, based on but improves upon DVB-S with around 30% performance gain.

- Powerful coding scheme based on LDPC code.
- VCM (Variable coding and Modulation) and ACM (Adaptive Coding and Modulation) modes.
- Up to 32APSK (Amplitude phase-shift keying) modulation and additional code rates

DVB-S2 Standard



DVB-S2 Link example



DVB-S2 Signal Constellation

System Design Methodology

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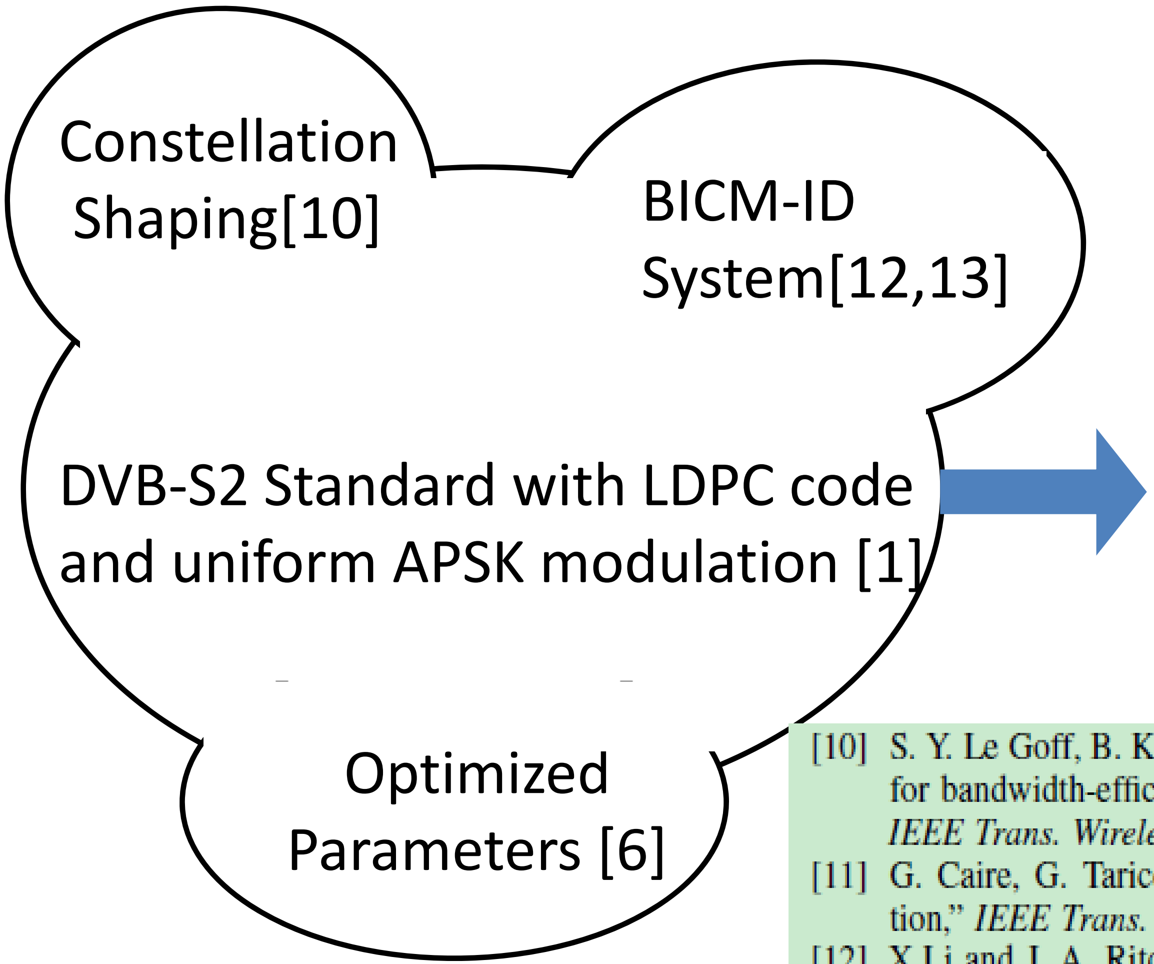

Performance improvement

(Shaping Gain)

[10] S. Y. Le Goff, B. K. Khoo, and C. C. Tsimenidis, "Constellation shaping for bandwidth-efficient turbo-coded modulation with iterative receiver," *IEEE Trans. Wireless Comm.*, vol. 6, pp. 2223–2233, Jun. 2007.

[11] G. Caire, G. Taricco, and E. Biglieri, "Bit-interleaved coded modulation," *IEEE Trans. Inform. Theory*, vol. 44, pp. 927–946, May 1998.

[12] X.Li and J. A. Ritcey, "Bit-interleaved coded modulation with iterative decoding using soft feedback," *Electronics Letters*, vol. 34, pp. 942–943, May 1998.

[13] Q. Xie, K. Peng, J. Song, and Z. Yang, "Bit-interleaved LDPC-coded modulation with iterative demapping and decoding," in *Vehicular Technology Conference 2009*, (Barcelona, Spain), April 2009.

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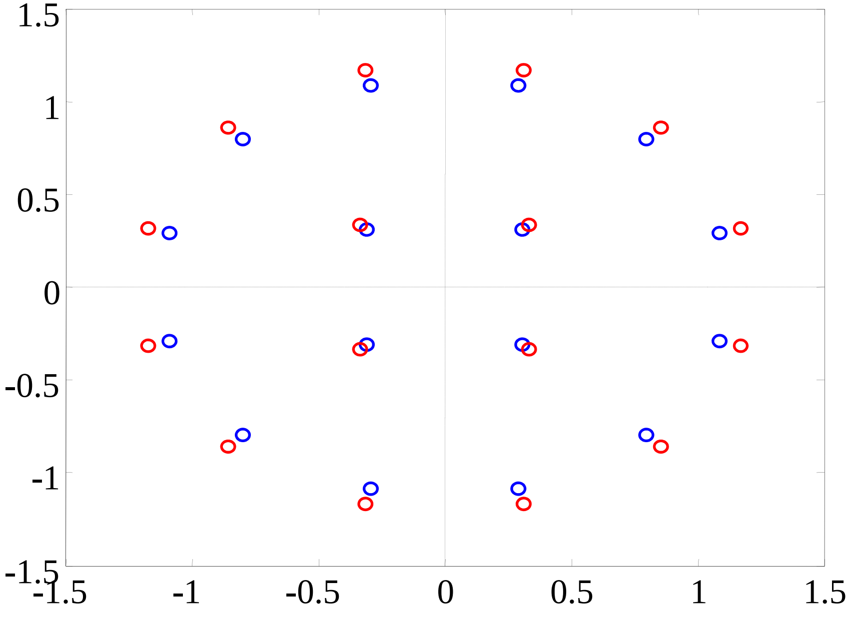
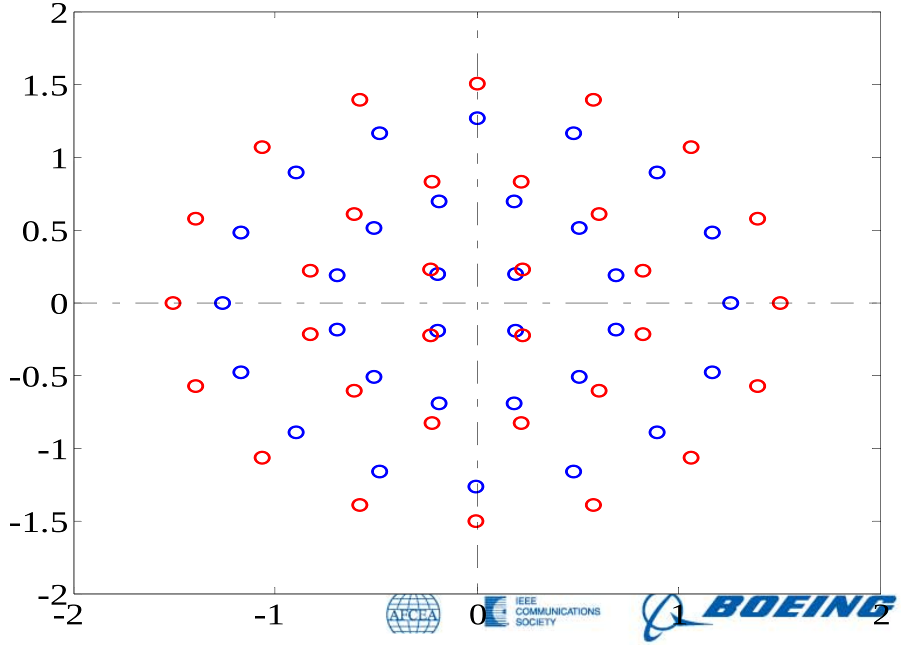
Constellation Shaping

- Idea: transmit constellation signal points with lower energy more frequently than those with higher energy
- Goal: save transmit power, or achieve performance gain under the same transmit power
- How: we use non-linear short length shaping code in our paper

❑ For a fixed average energy $\varepsilon_s = \sum_{i=0}^{M-1} p(x_i)\varepsilon_i = 1$, shaping strategy spreads out the symbols



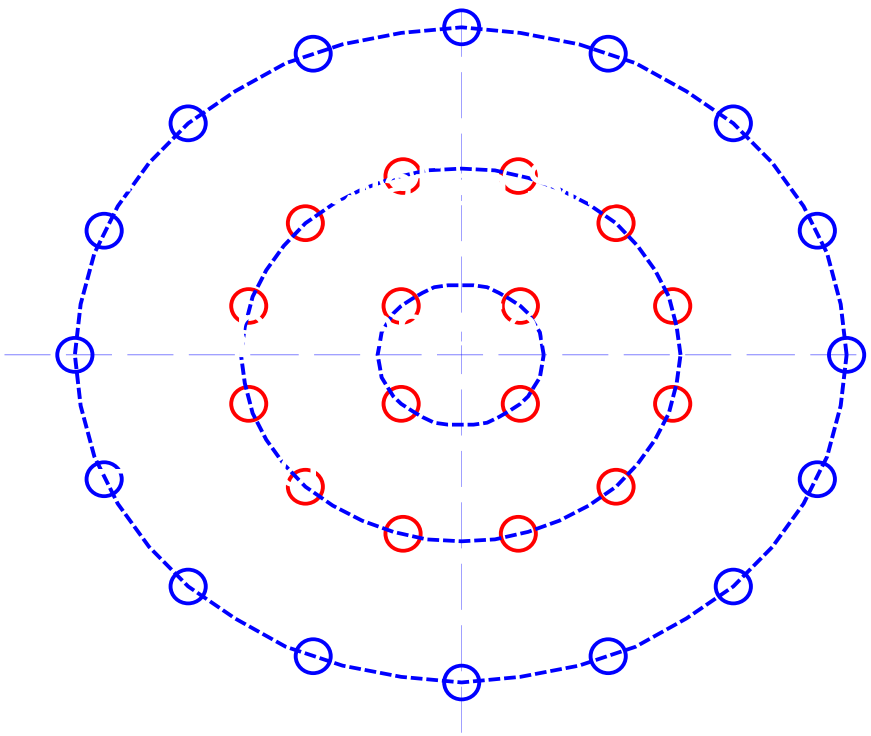
16APSK



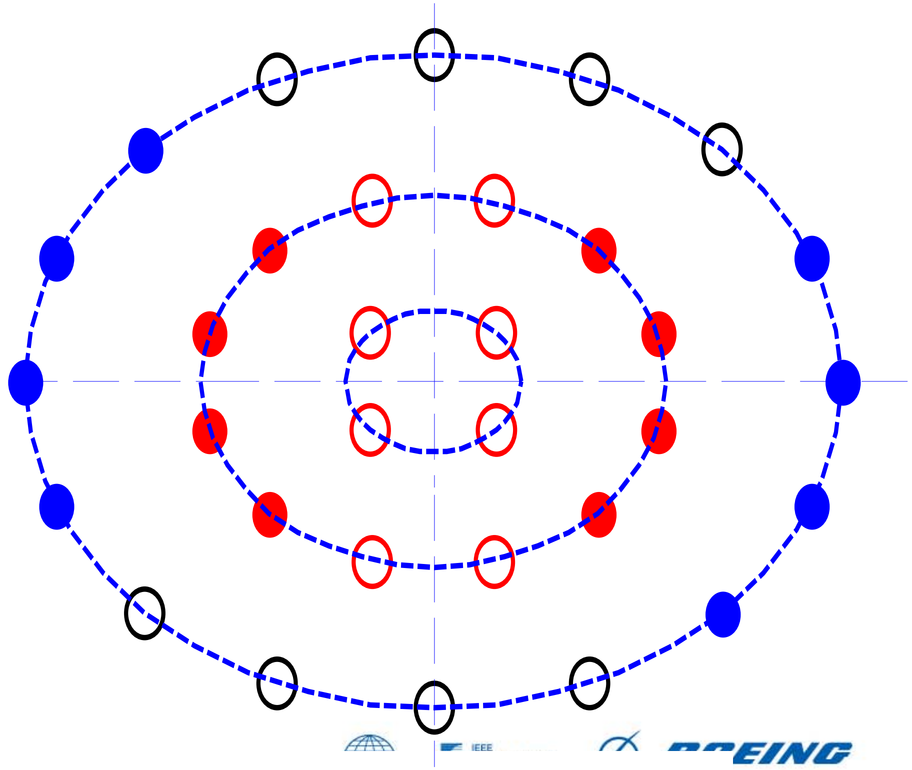
32APSK

Sub-Constellation

- Sub-constellation: a subordinate constellation including parts of the constellation symbols
- The number of symbols in each sub-constellation is the same
- Constellation symbols are chosen equally likely within the same sub-constellation



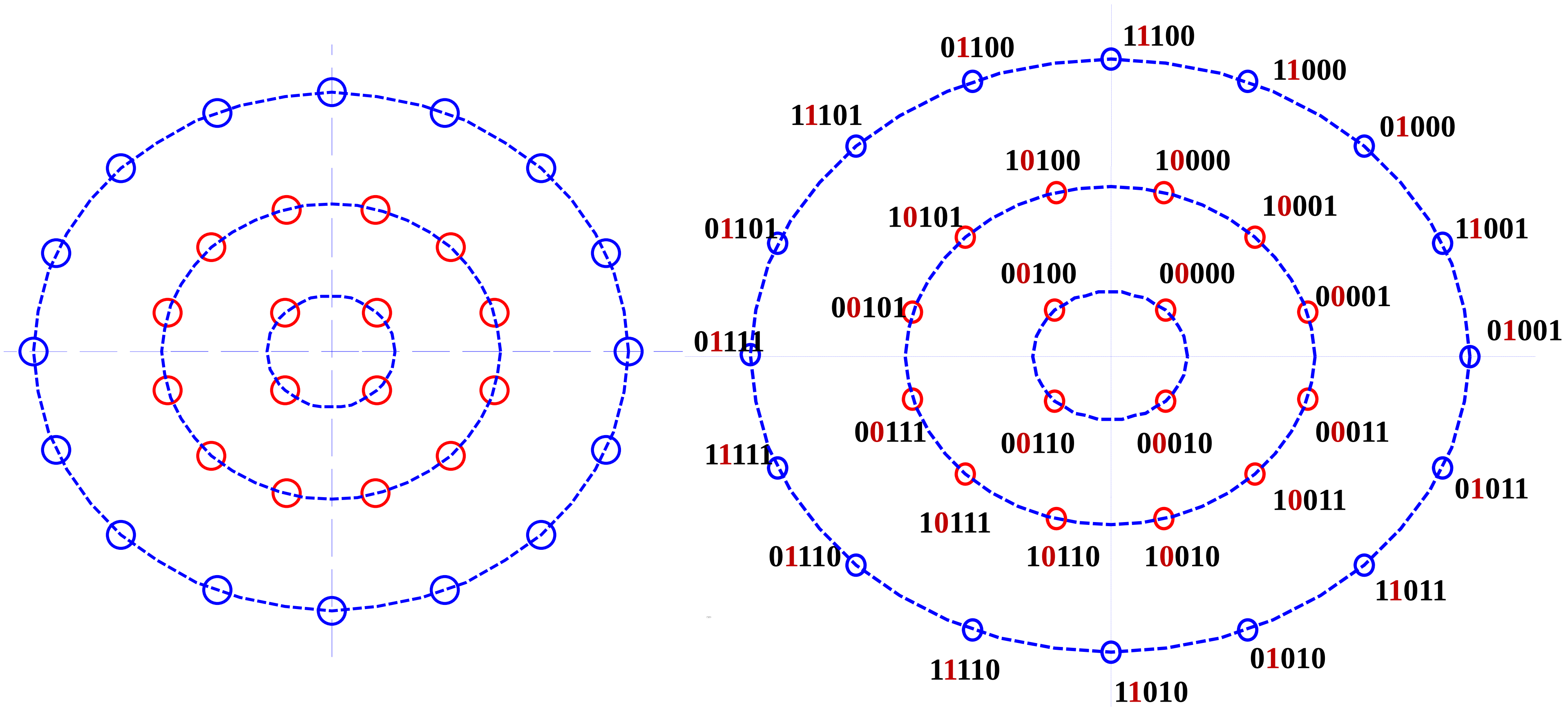
2 sub-constellations



4 sub-constellations

Sub-Constellation

- The grouping of the sub-constellations is based on the symbol energy and labeling.



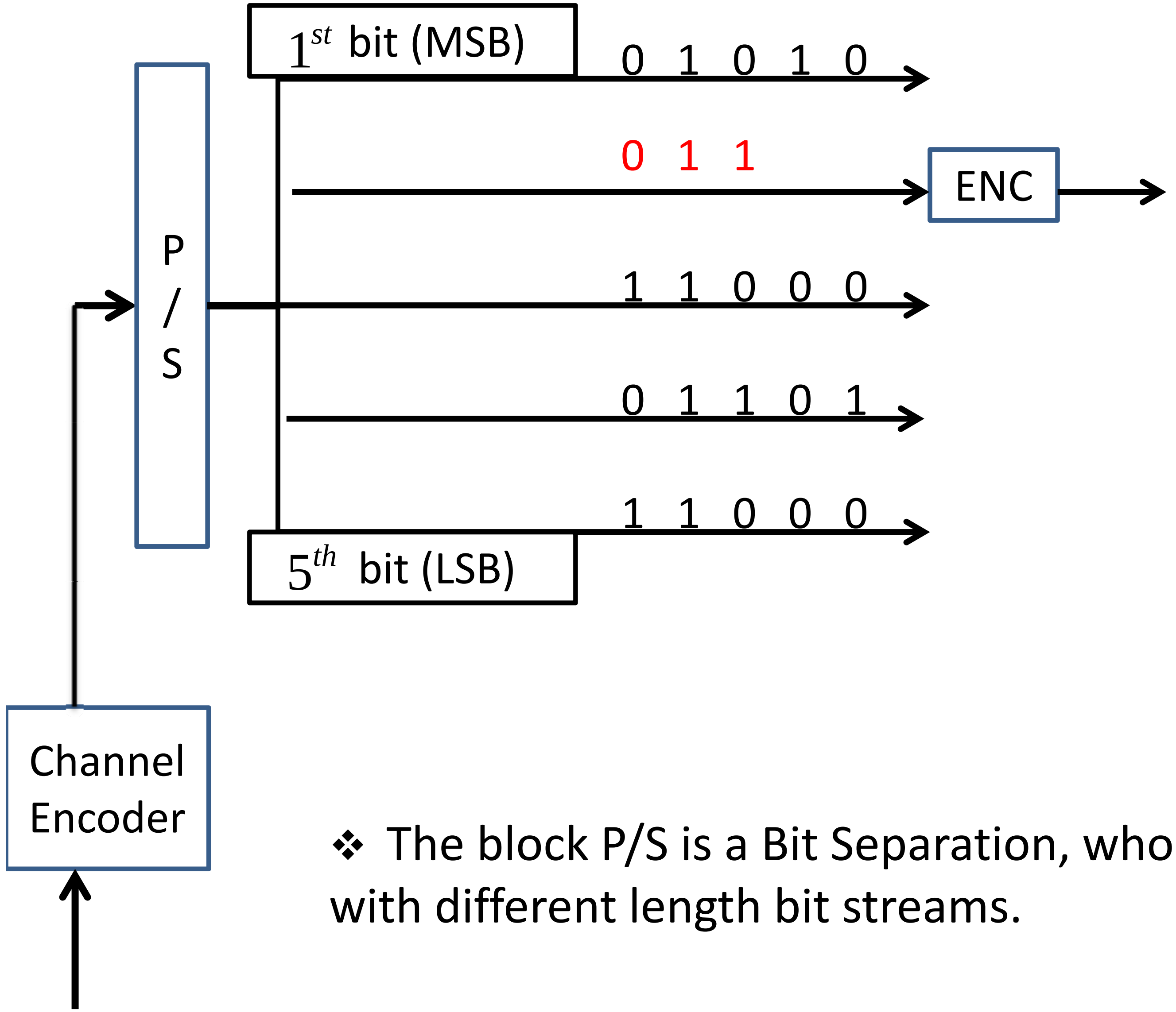
Shaping Encoder

– The shaping encoder maps K bits to N bits codeword, which has more zeros than ones. One example is (K=3, N=5):

3 Input data bits	5 output codeword bits
0 0 0	0 0 0 0 0
0 0 1	0 0 0 0 1
0 1 0	0 0 0 1 0
0 1 1	0 0 1 0 0
1 0 0	0 1 0 0 0
1 0 1	1 0 0 0 0
1 1 0	0 0 0 1 1
1 1 1	1 0 1 0 0

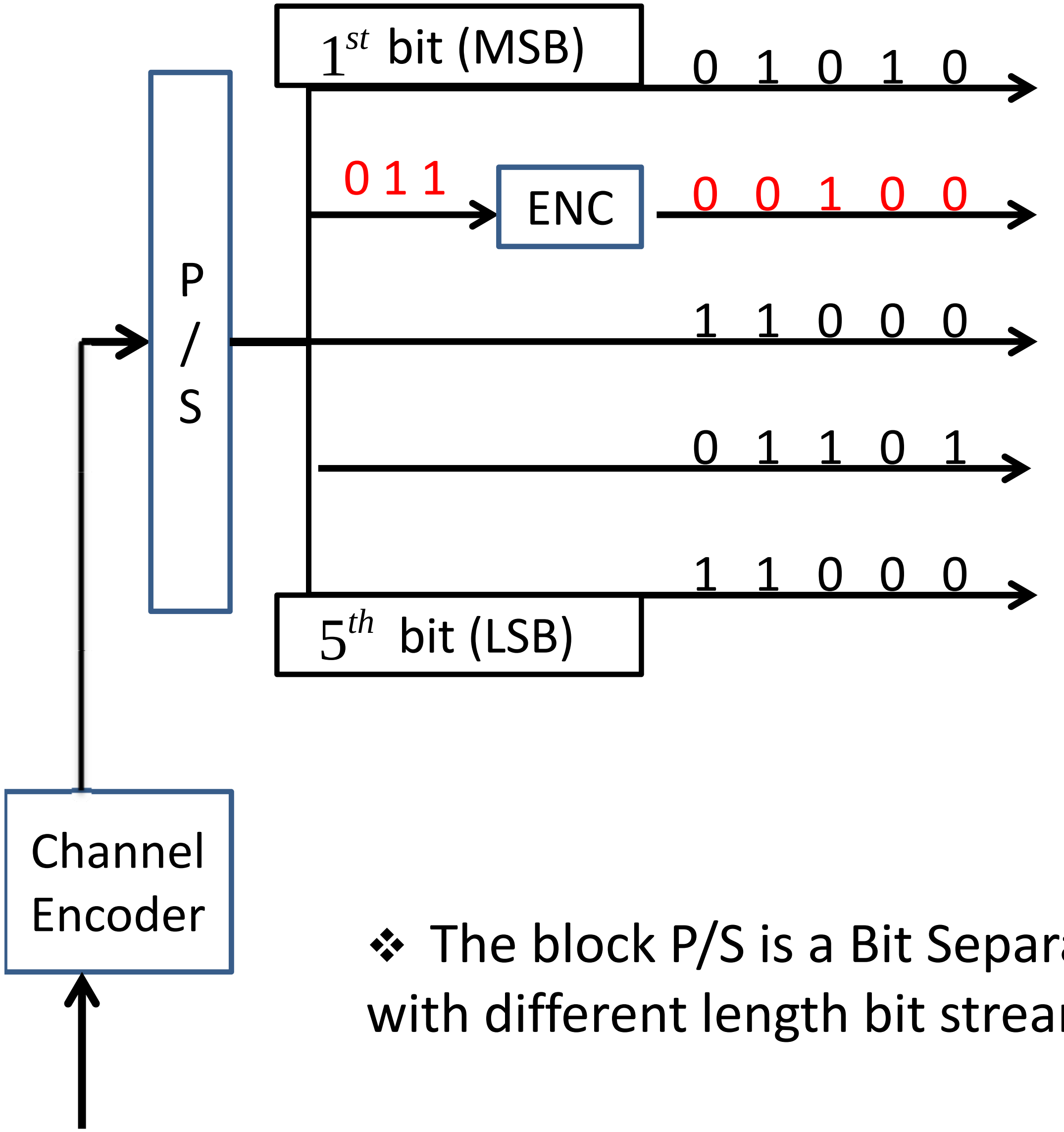
- p0: the probability of 0 in the codeword table, (p0 = 31/40 above)
- p1: the probability of 1 in the codeword table, (p1 = 9/40 above)

Shaping Encoder Operation



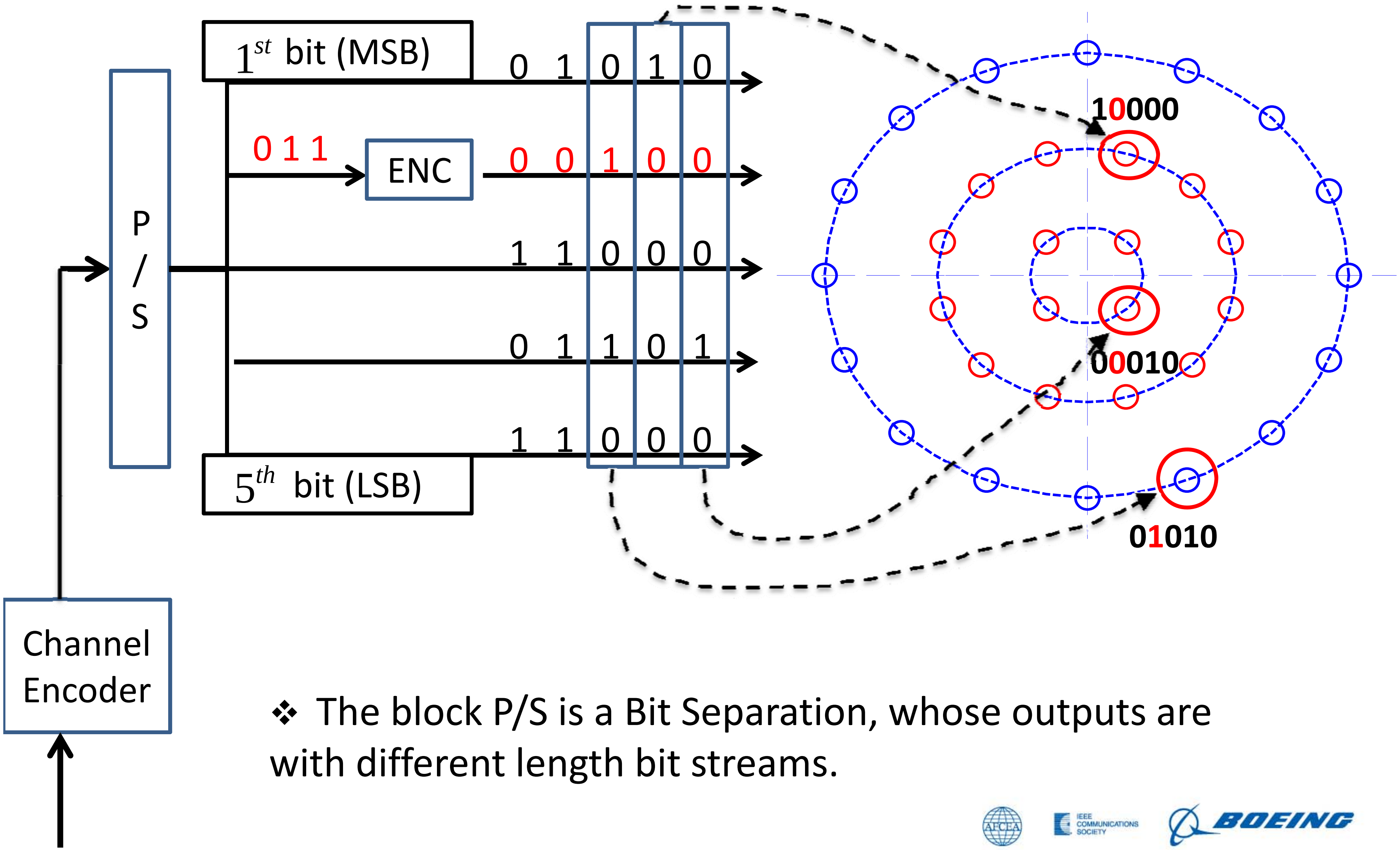
❖ The block P/S is a Bit Separation, whose outputs are with different length bit streams.

Shaping Encoder Operation



❖ The block P/S is a Bit Separation, whose outputs are with different length bit streams.

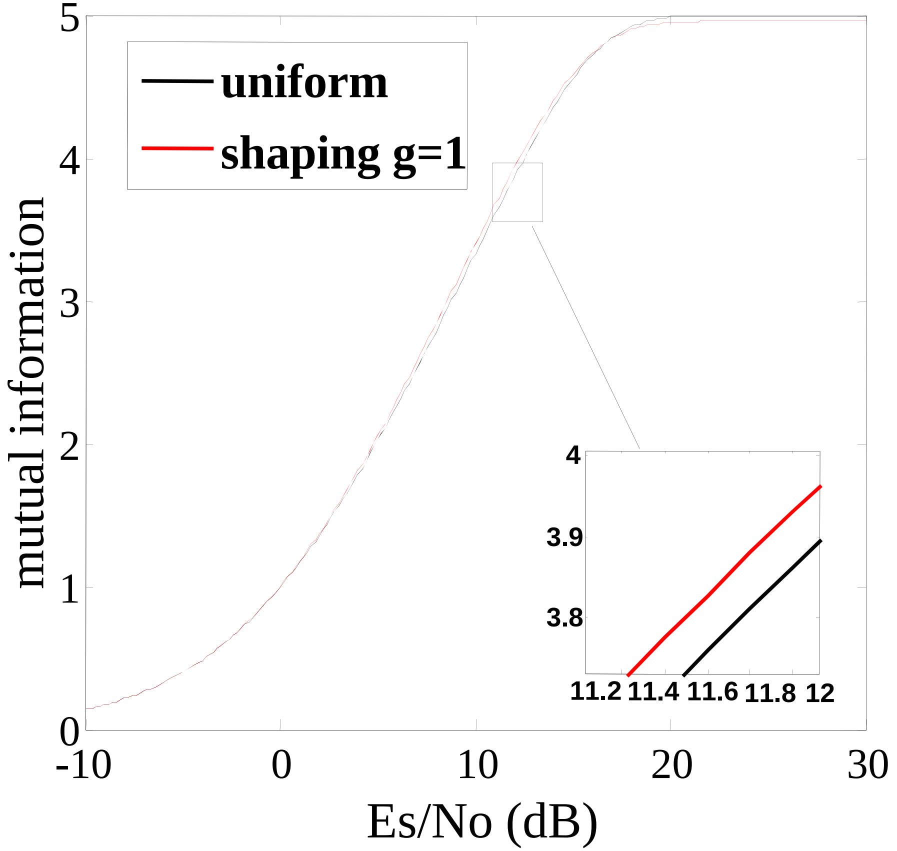
Shaping Encoder Operation

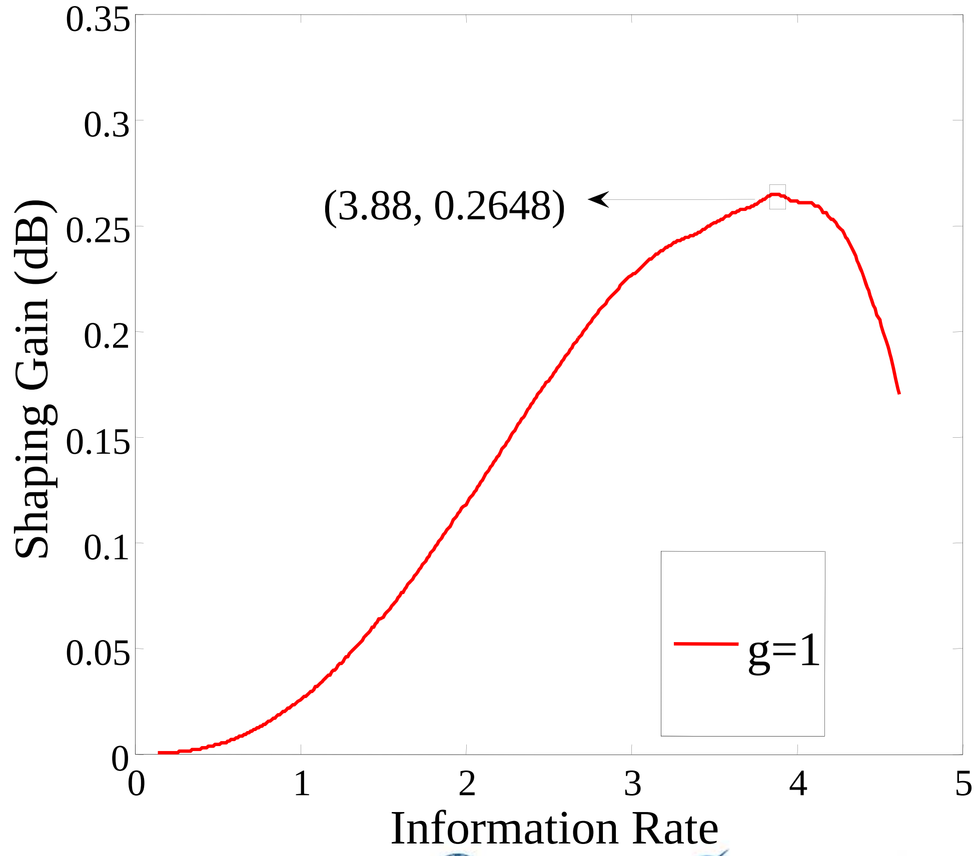


❖ The block P/S is a Bit Separation, whose outputs are with different length bit streams.

Shaping Gain and its evaluation

❖ The non-uniform capacity value is generated with respect to different P0, i.e., different probability distribution of sub-constellations





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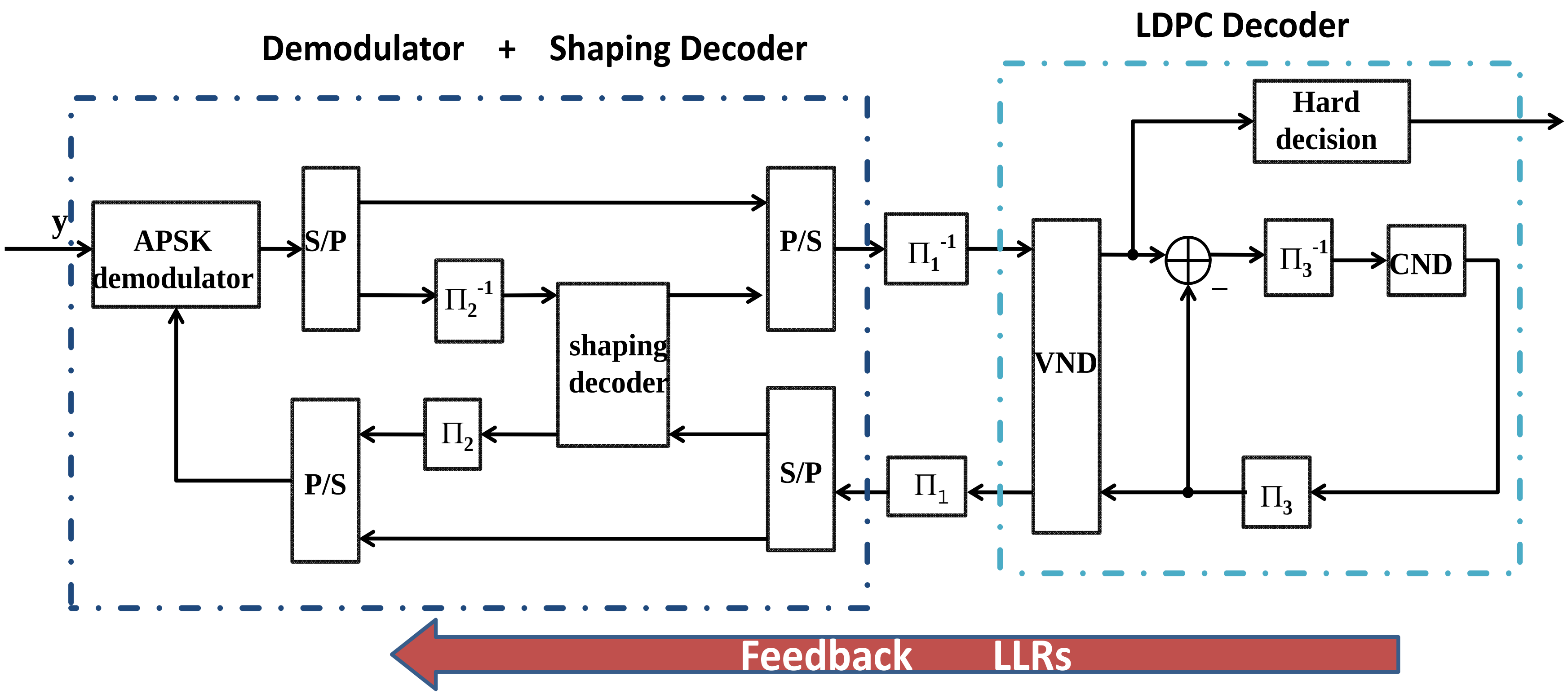
Receiver Implementation

– BICM-ID (bit-interleaved coded-modulation with iterative decoding) System



Complexity Consideration

– The additional complexity is due to the shaping decoder.

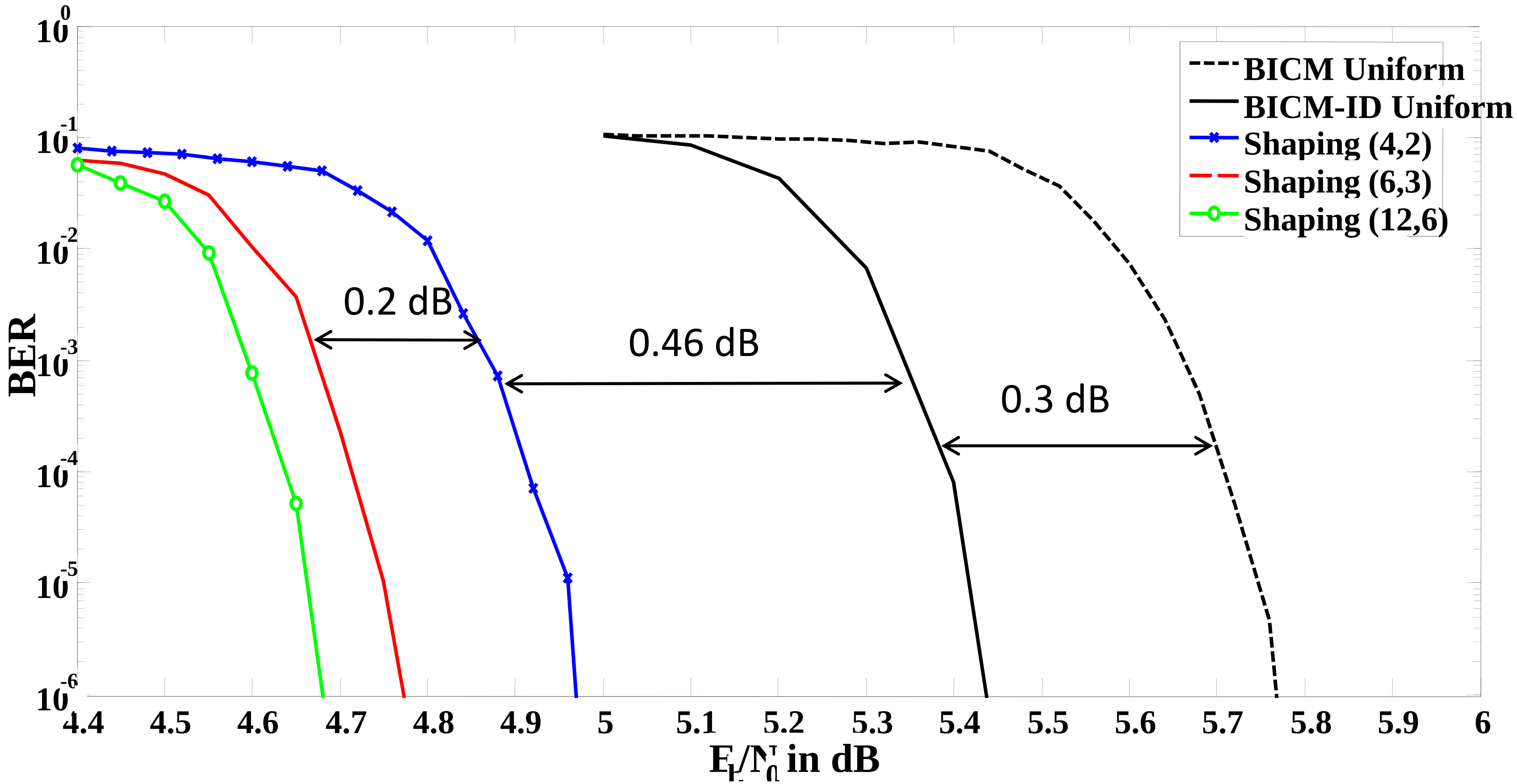
– Maximum a posteriori probability (MAP) algorithm is used for shaping decoding. It find the most possible data bits by comparing the shaping codeword with all existing shaping codeword.

– The MAP decoding algorithm increases the complexity exponentially with the length of uncoded shaping data bits K.

– $K \leq 6$ is used in this paper.

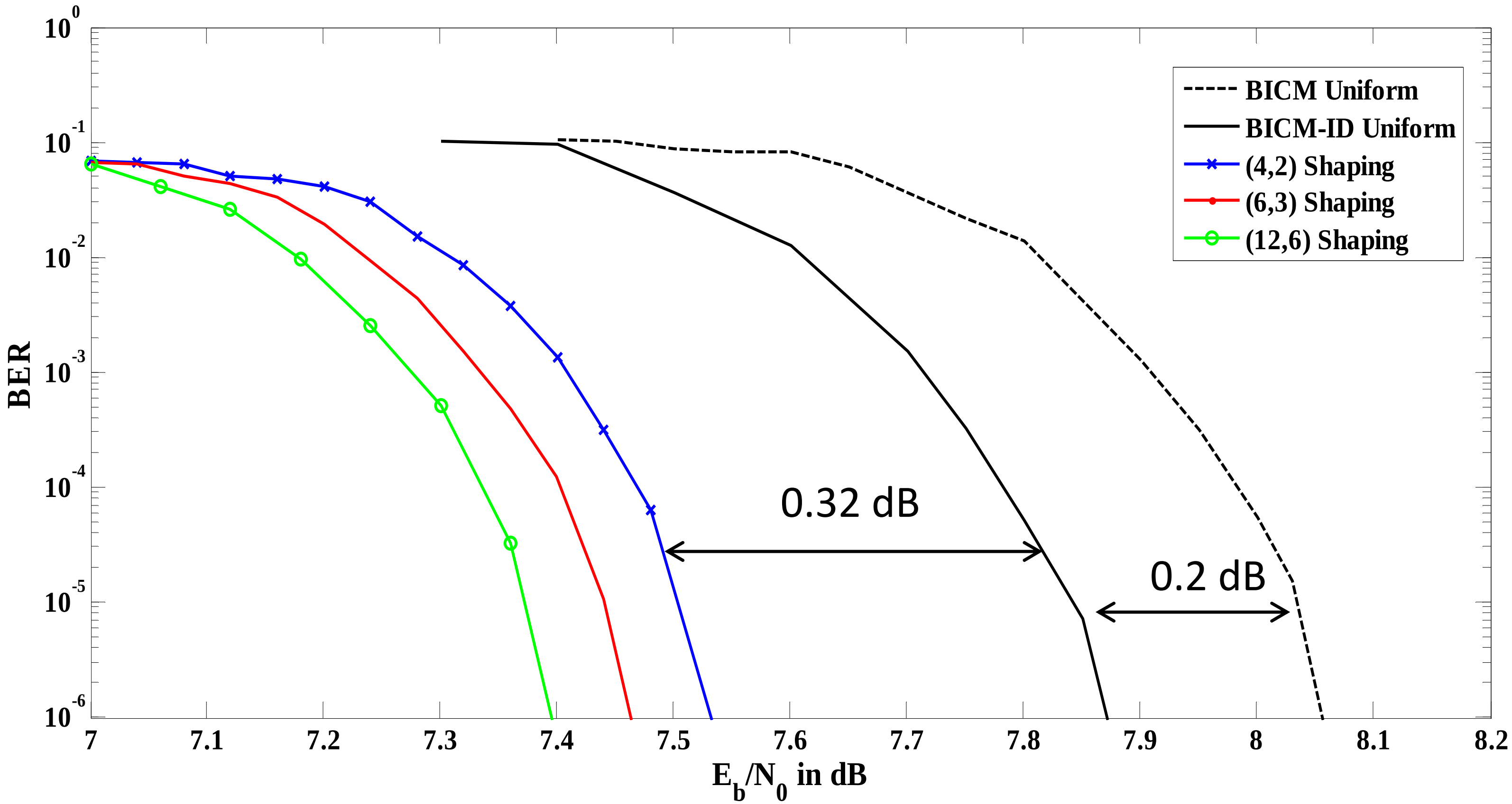
BER curves For AWGN channel

γ	R	Rc	Rs	ξ_b/N_0 (Capacity Value)
{2.64, 4.64}	3	3/5 (38880/64800)	1	4.029 dB
		2/3 (43200/64800)	1/2	3.829 dB



BER curves For Rayleigh fading channel

γ	R	Rc	Rs	ξb/N0 (Capacity Value)
{2.64 , 4.64}	3	3/5 (38880/64800)	1	6.259 dB
		2/3 (43200/64800)	1/2	6.099 dB



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Conclusion

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- BICM-ID system can provide better performance compared with BICM only system
- The simple constellation-shaping strategy considered in this paper can achieve shaping gains up to 0.7 dB.
- This whole system implementation is compatible with DVB-S2 standard
- The same rate but longer shaping codes yield better performance but lead to larger system complexity.
- The future work may involve the optimizing the LDPC code degree distribution to push the performance gain further.

Thank you