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# Novel Transformations of Extrinsic Information applied to Innovative BICM-ID Receivers

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## ■ Fundamentals & Limits

M. Adrat, T. Osten, M. Tschauner, M. Antweiler (FhG FKIE)

J. Lewandowsky (UniBw M)

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# Motivation (1/2)

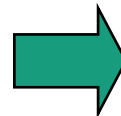
- Military tactical communications is taking its next evolution step
  - Key enabler: modern **Software Defined Radio** (SDR) Technology
- Before new Wideband Networking Waveforms (WNW) are available
  - Key challenge:

## Concepts for Porting Legacy Waveforms to Software Defined Radios

Legacy Radio



© Thales Def. Deu



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Software Defined Radio

# Motivation (2/2)

## ■ Different concepts for porting signal processing

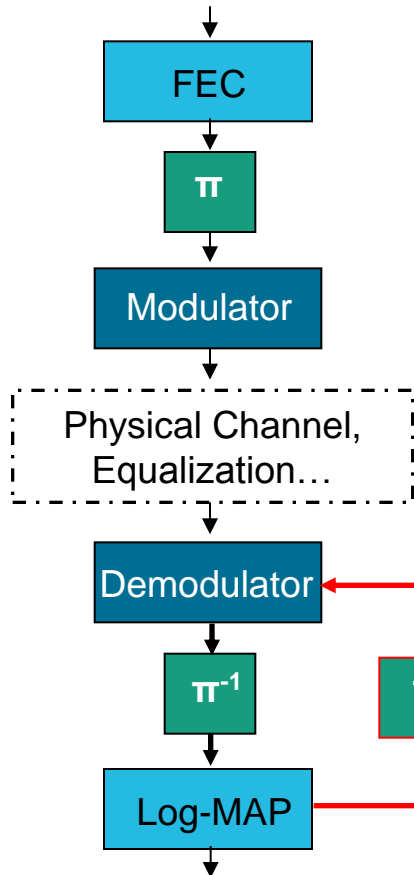
- one-to-one porting of signal processing → guaranteed interoperability
- introduce novel receiver signal processing → keep interoperability, provide added value to SDR operators
- introduce novel transceiver signal processing → hard to keep interoperability to legacy radios

## ■ Scenario



# Review First Approach (1/3)

*Bit Interleaved Coded Modulation with Iterative Decoding (BICM-ID)*



## ■ Application of modern Signal Processing at Receiver

- „*Legacy Waveforms on Software Defined Radios: Benefits of Advanced Digital Signal Processing*“, in Proc. of NATO RTO IST-Panel Symposium (IST - 092 / RSY - 022), Breslau (Poland), Sept. 2010
- new: iterative feedback of **extrinsic information**

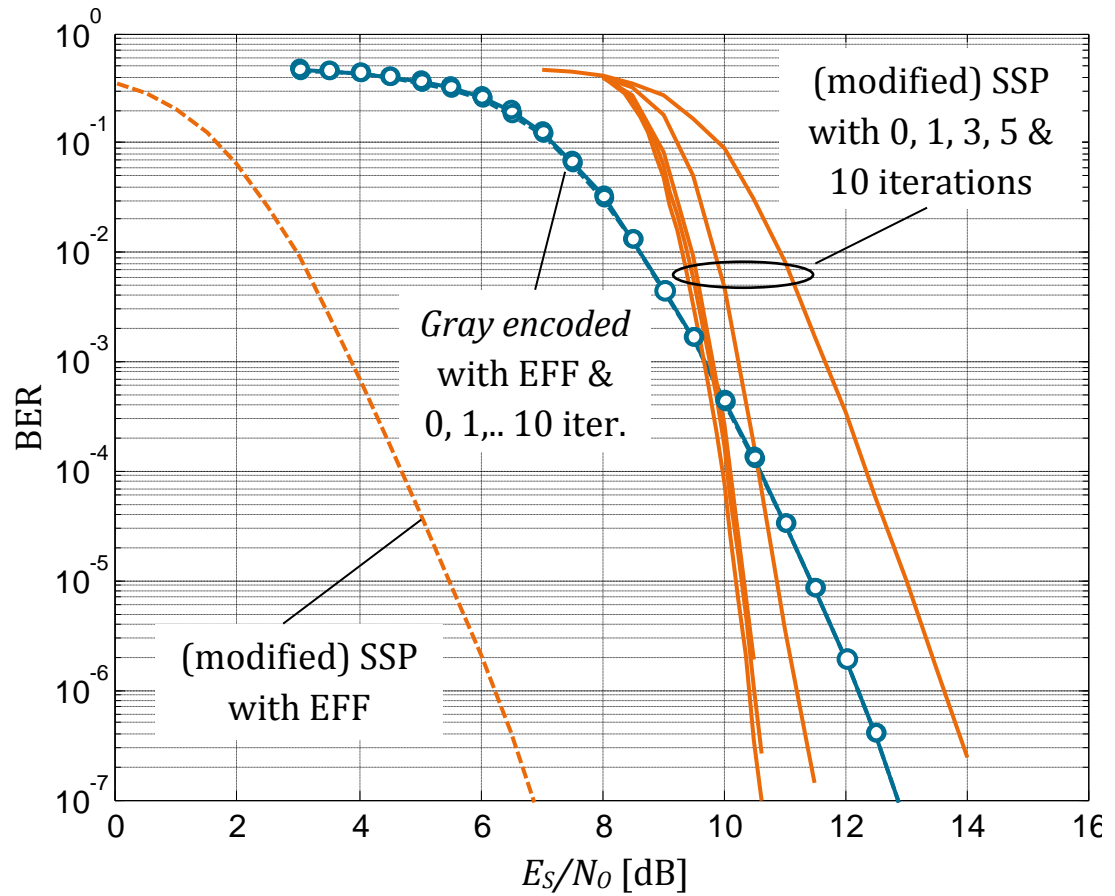
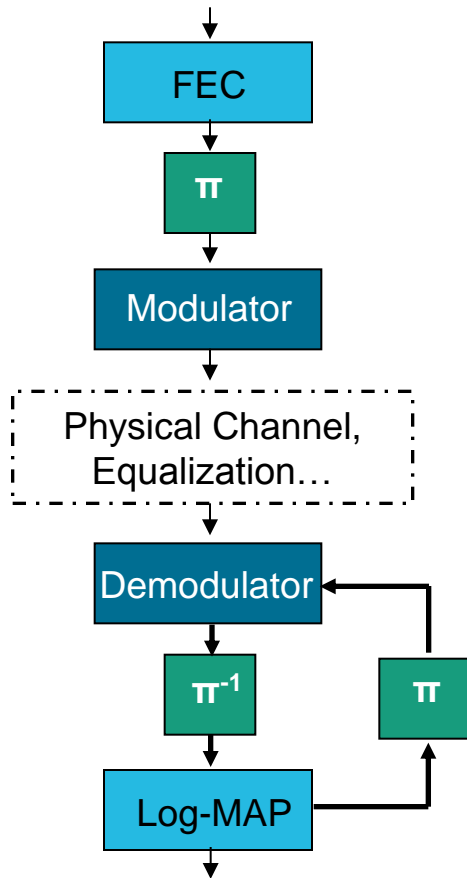
## ■ Results

- small gains if applied to standard configuration  
r=½ Conv. Code G(171,133), 8-PSK Modulation w. **Gray symbol labeling**
- huge gains if symbol labeling is modified  
→ loss of interoperability to legacy equipment

# Review First Approach (2/3)

## Exemplary Simulation Results

Conv. Code G(171,133) punctured to  $r=3/4$ ,  
8-PSK Modulation with **Gray** resp. (modified) **SSP** Symbol Labeling

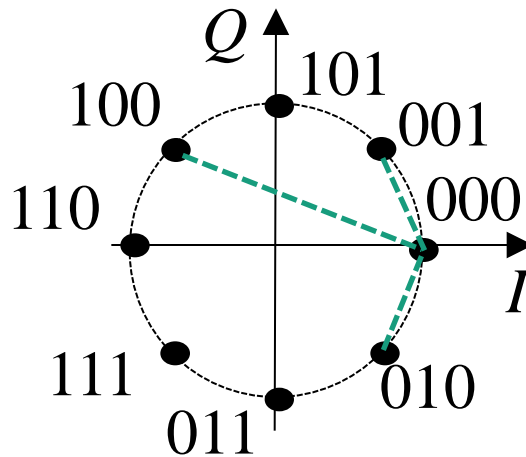


# Review First Approach (3/3)

## Symbol Labelings

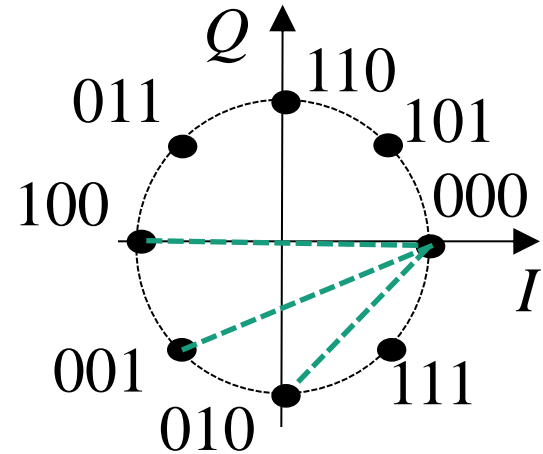
### ■ Key Reason

#### Gray Symbol Labeling



- symbol labels of neighbors differ in one bit only  
(noise on channel causes symbol errors)
- on average small distances

#### (Modified) Semi-Set Partitioning Symbol Labeling

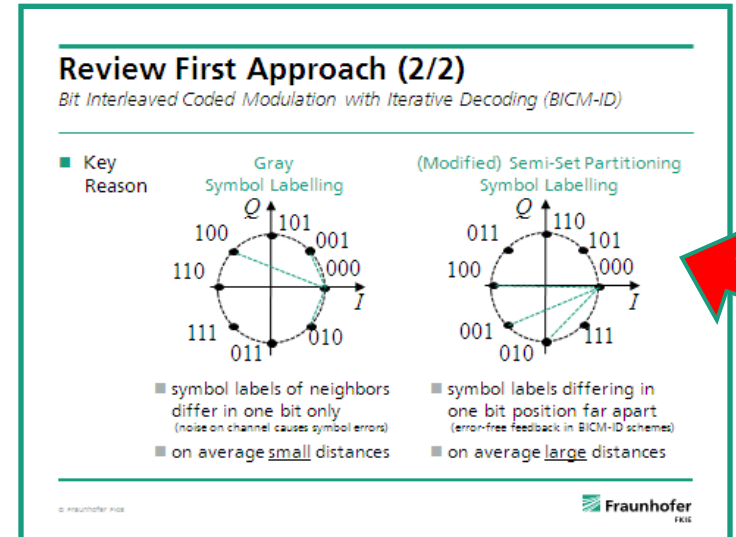


- symbol labels differing in one bit position far apart  
(error-free feedback in BICM-ID schemes)
- on average large distances

# Novel Idea (1/3)

## *Transformation of Extrinsic Information*

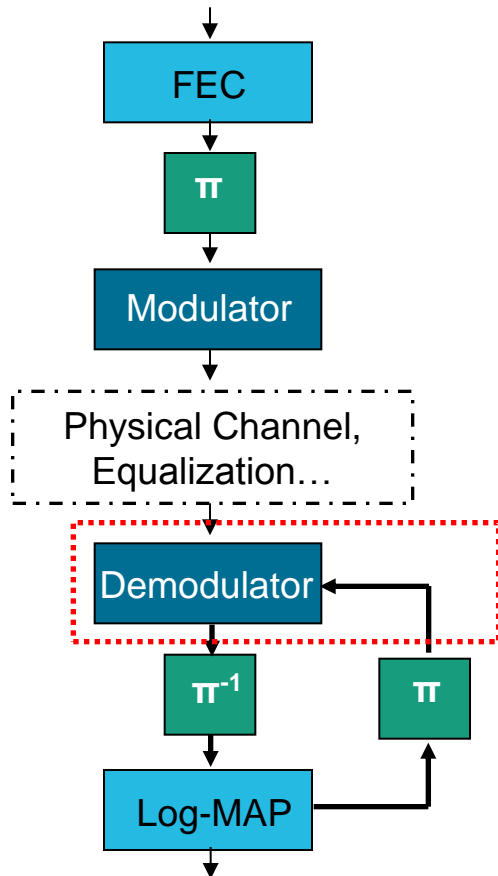
- Can we exploit the benefits of a (modified) SSP Symbol Labeling even in BICM-ID schemes where a Gray Symbol Labeling is used ?



- Proposed Novel Idea
  - Transformation of Extrinsic Information
    - between Gray and (modified) SSP domain

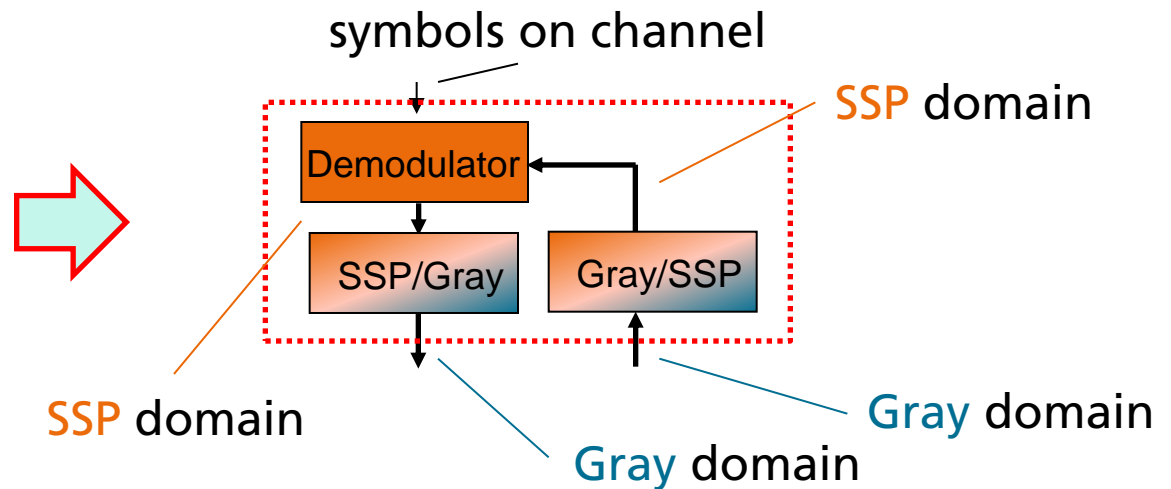
# Novel Idea (2/3)

## Transformation of Extrinsic Information



### ■ Modified Demodulator

- external interfaces still in the Gray domain
- internal interfaces in the (modified) SSP domain



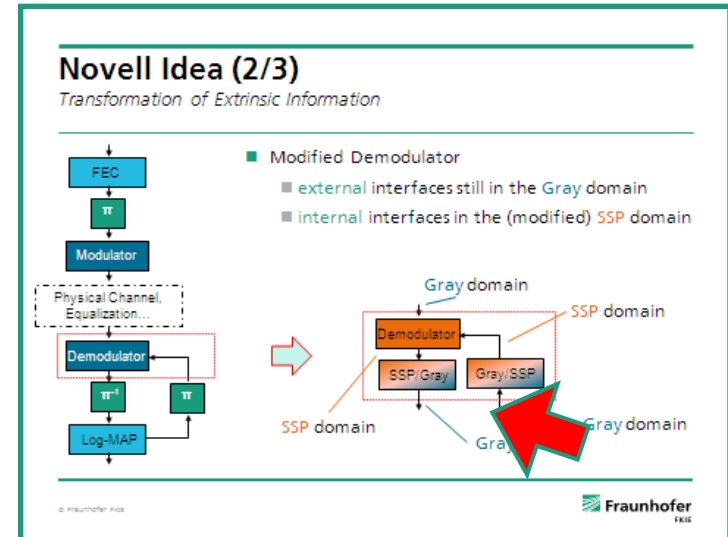


# Novel Idea (3/3)

## *Transformation of Extrinsic Information*

### ■ How do these Transformations look like?

Taking into account that we have to process Reliability Information (L-values)

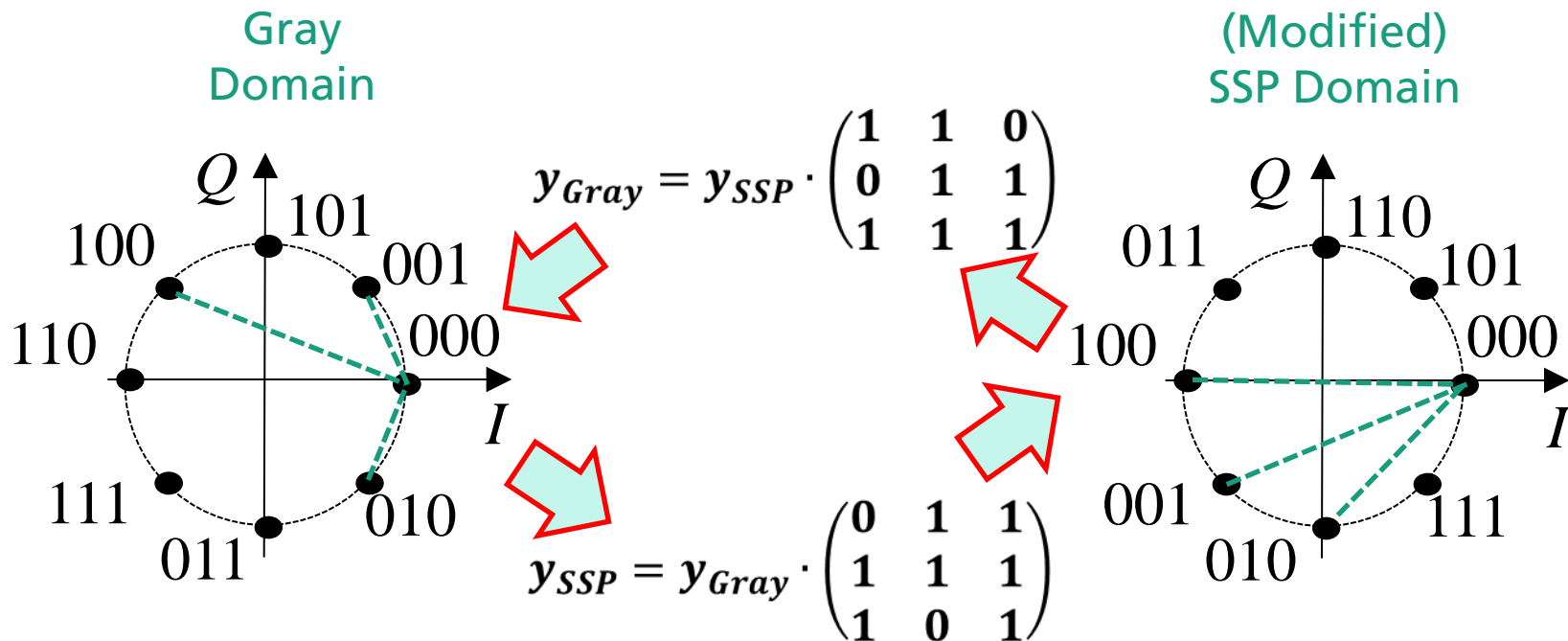


### ■ Two step approach

- to simplify matters, consider the extreme case of hard decisions first
- then, transfer findings to soft decisions (reliability information, L-values)

# Solution (1/2)

*Extreme Case: Hard Decision Decoding*



In Hard Decision decoding (i.e. GF(2)), Transformations between the Gray domain and the (modified) SSP domain exists

# Solution (2/2)

*Soft Decision Decoding (Reliability Information, L-values)*

- Considering the famous **Box-Plus** Operation for L-values [Hagenauer96]

$$\mathbf{y}_{Gray} = \mathbf{y}_{SSP} \cdot \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \Rightarrow \begin{aligned} L^{GRAY}(y_1) &= L^{SSP}(y_1) \boxplus L^{SSP}(y_3) \\ L^{GRAY}(y_2) &= L^{SSP}(y_1) \boxplus L^{SSP}(y_2) \boxplus L^{SSP}(y_3) \\ L^{GRAY}(y_3) &= L^{SSP}(y_2) \boxplus L^{SSP}(y_3) \end{aligned}$$

resp. its inverse **Box-Minus** operation [Clevorn05]

$$\mathbf{y}_{SSP} = \mathbf{y}_{Gray} \cdot \begin{pmatrix} 0 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 0 & 1 \end{pmatrix} \Rightarrow \begin{aligned} L^{SSP}(y_1) &= L^{GRAY}(y_2) \boxminus L^{GRAY}(y_3) \\ L^{SSP}(y_2) &= L^{GRAY}(y_2) \boxminus L^{GRAY}(y_1) \\ L^{SSP}(y_3) &= L^{GRAY}(y_1) \boxminus (L^{GRAY}(y_2) \boxminus L^{GRAY}(y_3)) \end{aligned}$$

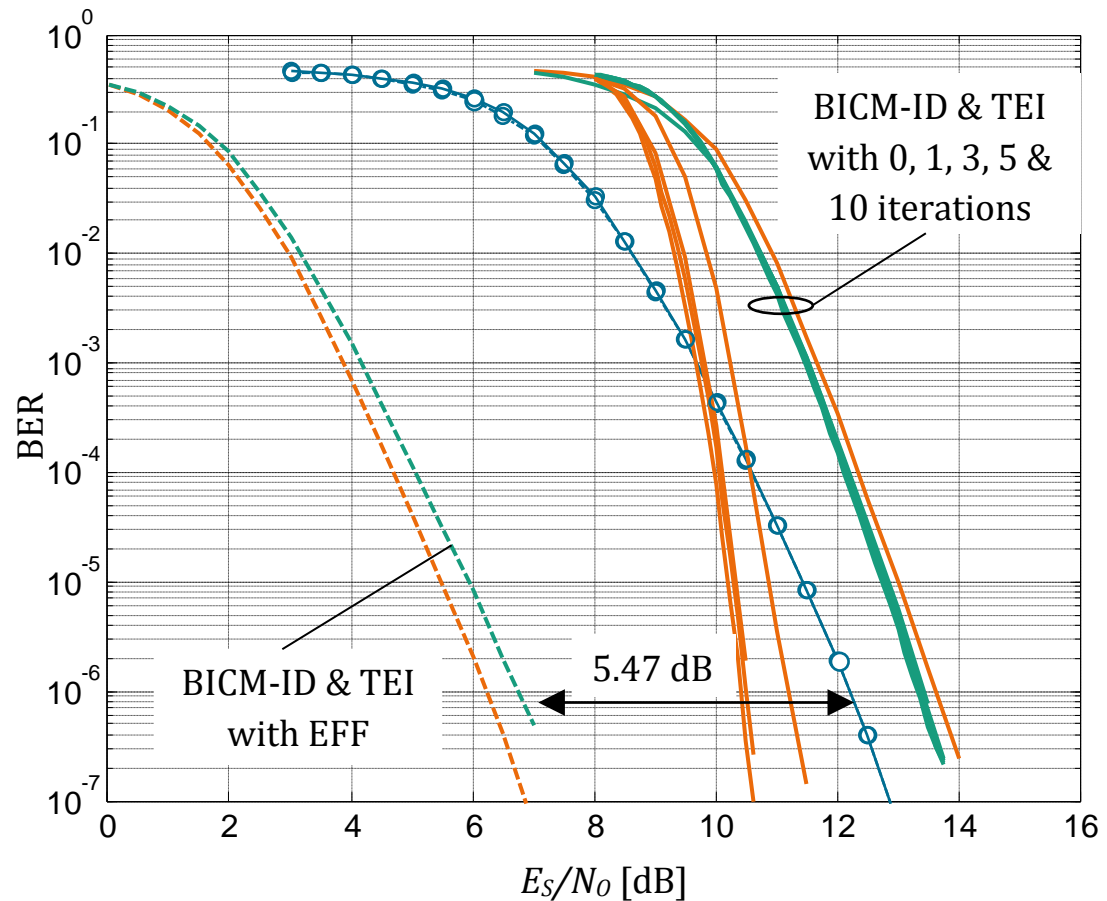
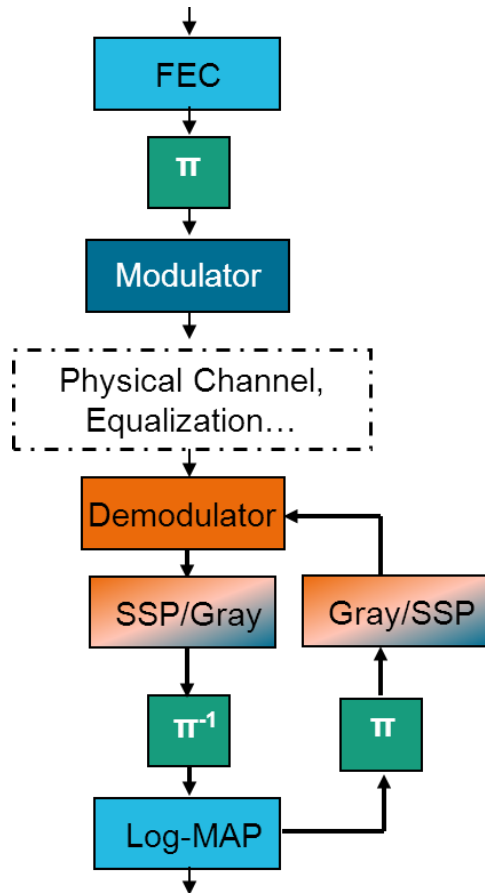
- Please note,

- the **Box-Minus** operation is the inverse to the **Box-Plus** operation
- but, it is only defined for  $L(x_A) \boxminus L(x_B) \in \mathbb{R}$  iff  $|L(x_A)| < |L(x_B)|$

# Transformation of Extrinsic Information

## Simulation Results

Conv. Code G(171,133) punctured to  $r=3/4$ ,  
8-PSK Modulation with **Gray** resp. (modified) **SSP** Symbol Labeling



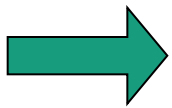
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# Conclusion

## BICM-ID with Transformation of Extrinsic Information

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- Transformation of Extrinsic Information in BICM-ID system
  - realize benefits of **SSP symbol labelings** in systems with **Gray labelings**
- Our aim is to offer the operator at an SDR an Added Value
- Results
  - transformations exist in both, Hard and Soft Decision Decoding
    - exploiting **Box-Plus** and **Box-Minus** Operations for L-Values
  - error-free feedback curve demonstrates that benefits are possible
  - however, no gains have been realized with first practical implementation



**Box-Minus Operation turned out to be a crucial operation which needs to be studied in more detail in the future**