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# On Hierarchically Modulated BICM-ID for Receivers with Different Combinations of Code Rate and Modulation Order

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M. Adrat, M.F.T. Oshim, M. Tschauner, M. Antweiler (  **Fraunhofer** )  
FKIE

B. Eschbach, P. Vary (  ,  )

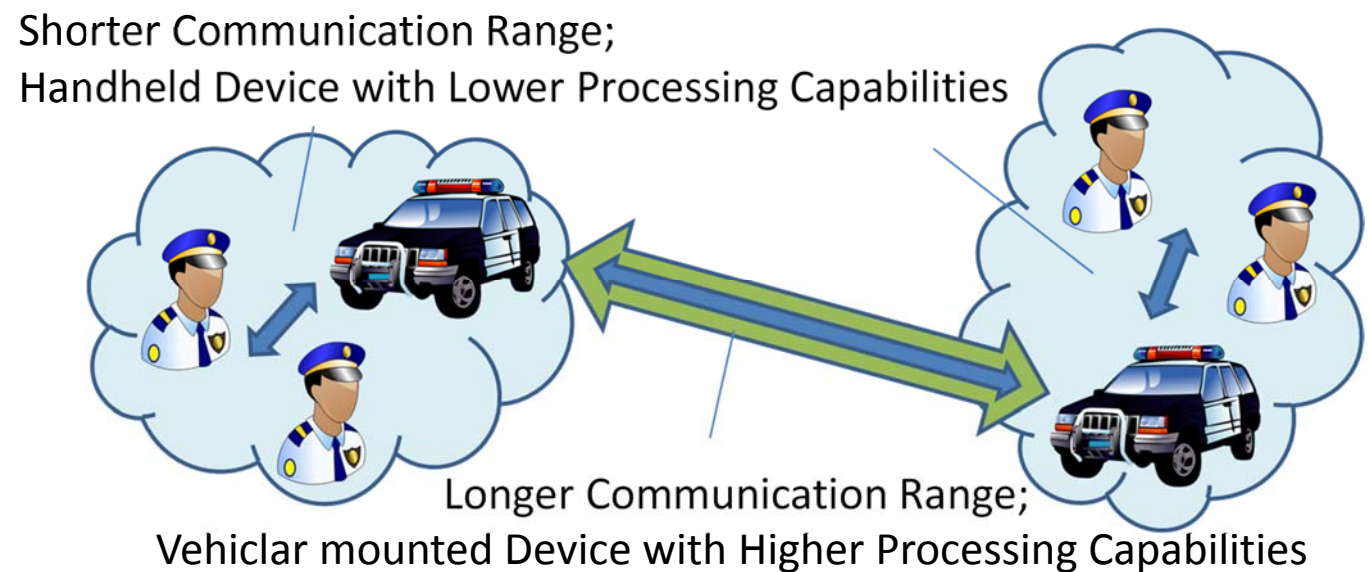
SDR15-WinnComm, San Diego (CA, USA), March 24<sup>th</sup> - 26<sup>th</sup>, 2015

# Motivation (1/2)

## Objective

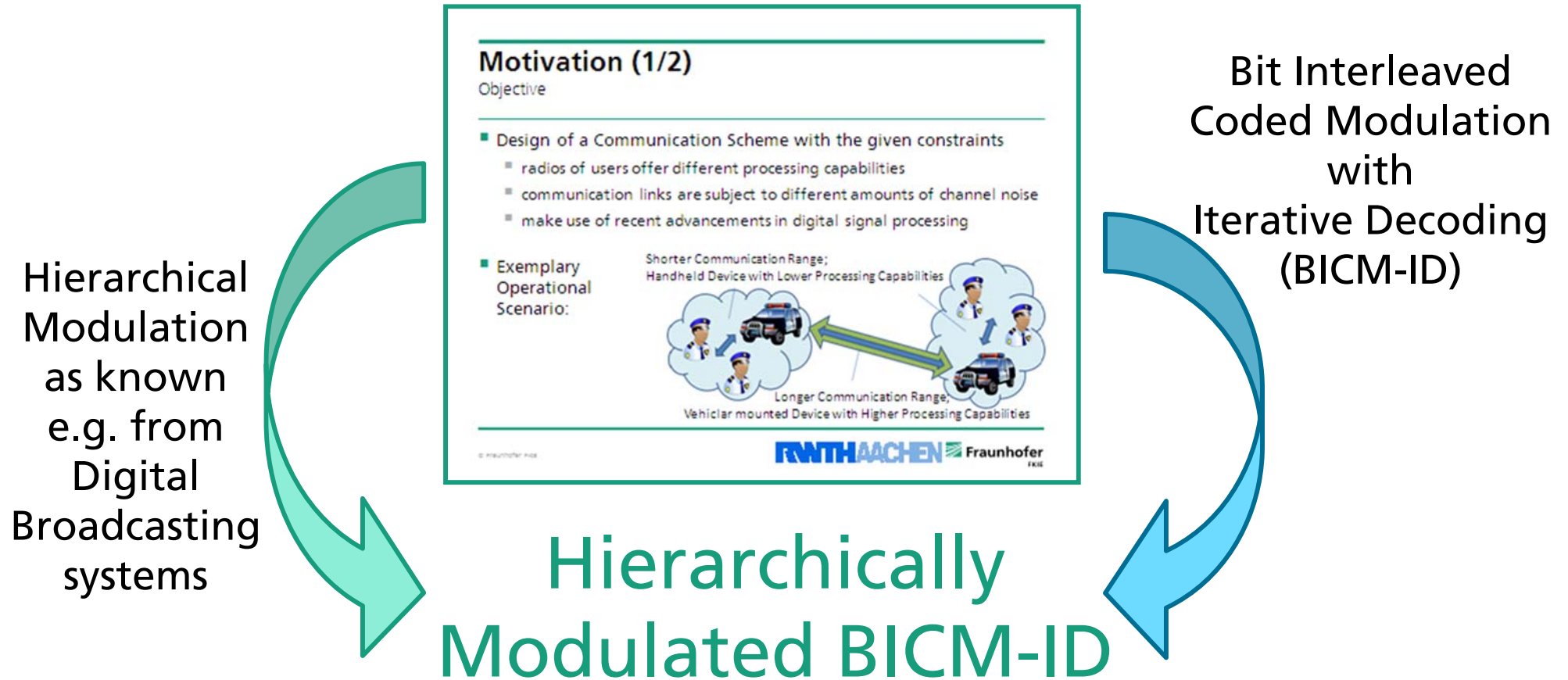
- Design of a Communication Scheme with the given constraints
  - radios of users offer different processing capabilities
  - communication links are subject to different amounts of channel noise
  - make use of recent advancements in digital signal processing

- Exemplary Operational Scenario:



# Motivation (2/2)

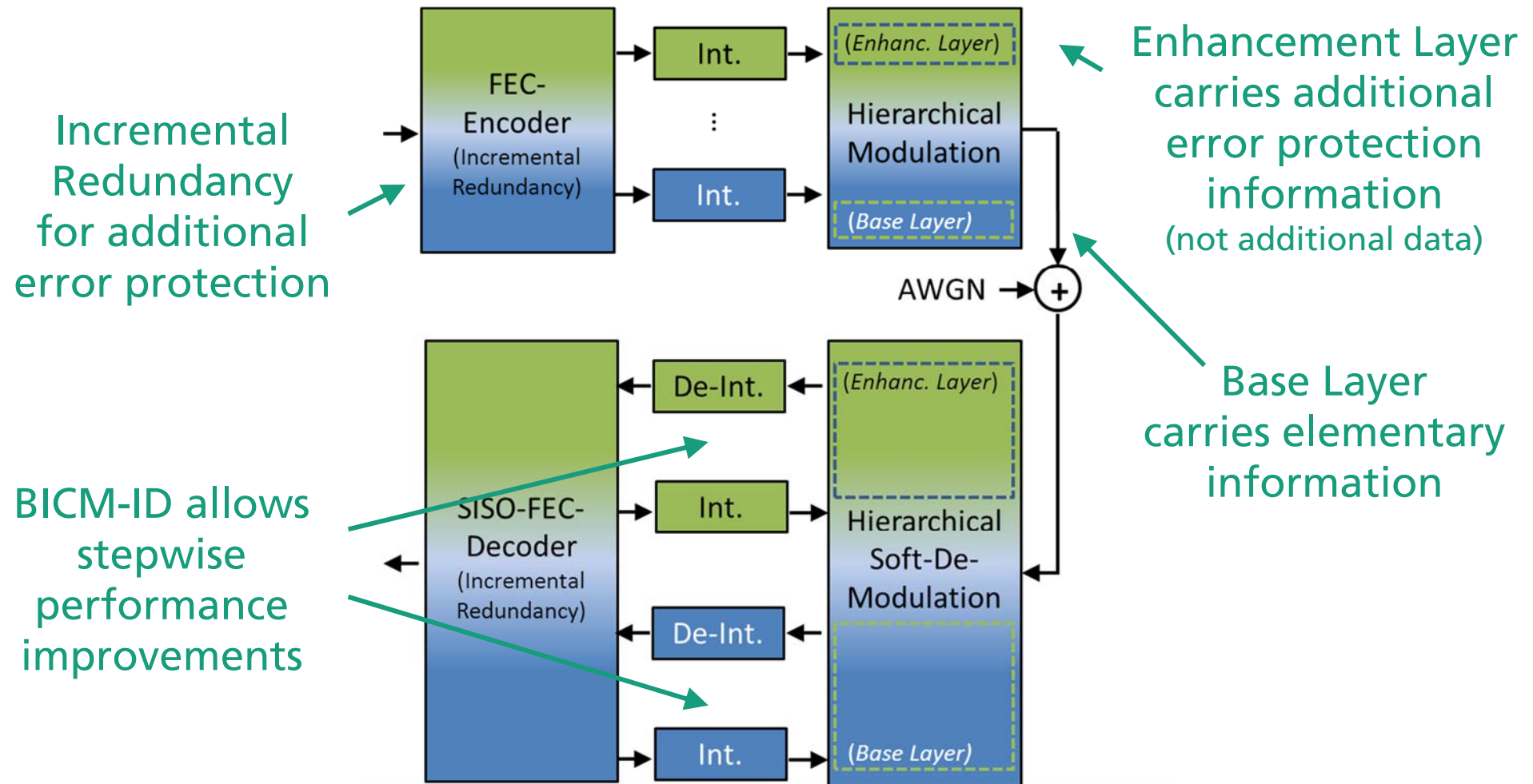
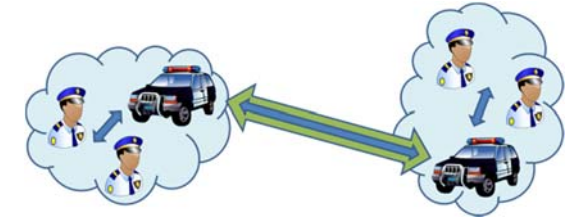
## *Proposed Solution*



Receivers with different processing capabilities shall be able to decode the same transmit signal !

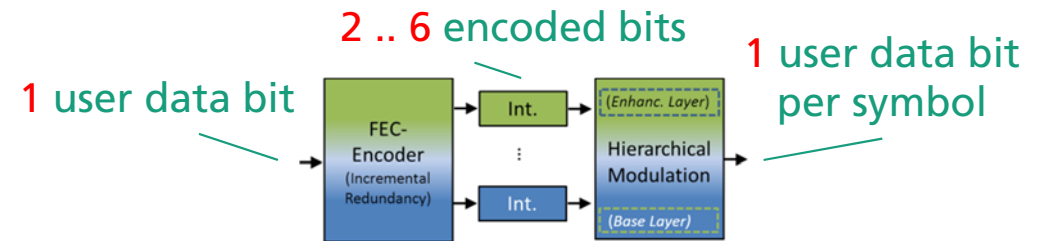
# Proposed System Design

## Block Diagramm



# Reference System

## System Configurations



Modes	Channel Code		Modulation Scheme	
Mode A	$r=1/2$ with $G(5,7)$ , $d_{\text{free}}=5$	<div>Increasing Error Robustness</div>	QPSK	<div>Decreasing Error Robustness</div>
Mode B	$r=1/4$ with $G(5,7,5,7)$ , $d_{\text{free}}=10$		16-QAM	
Mode C	$r=1/6$ with $G(5,7,5,7,7,7)$ , $d_{\text{free}}=16$		64-QAM	

■ Trade-off (note, the effective number of user data bits per symbol is the same for all modes)

- error robustness increases with stronger channel code
- at the same time, the modulation scheme becomes more sensitive

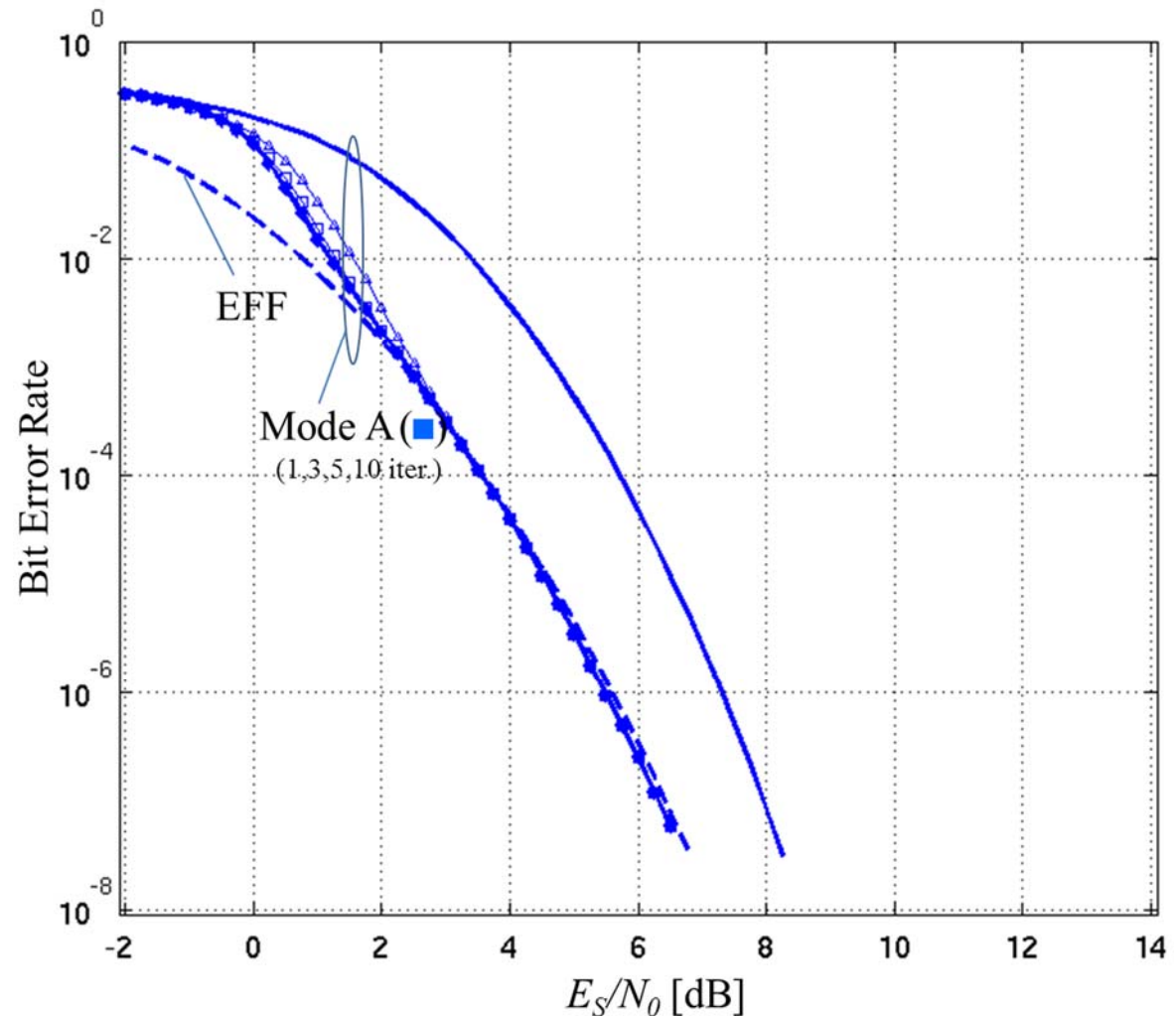
Which of the two effects is dominant in a BICM-ID scheme ?

# Reference System

## *Simulation Results for Non-Hierarchical BICM-ID Schemes*

### ■ Key Result

- each Mode has its specific benefits in a particular  $E_s/N_0$  Region



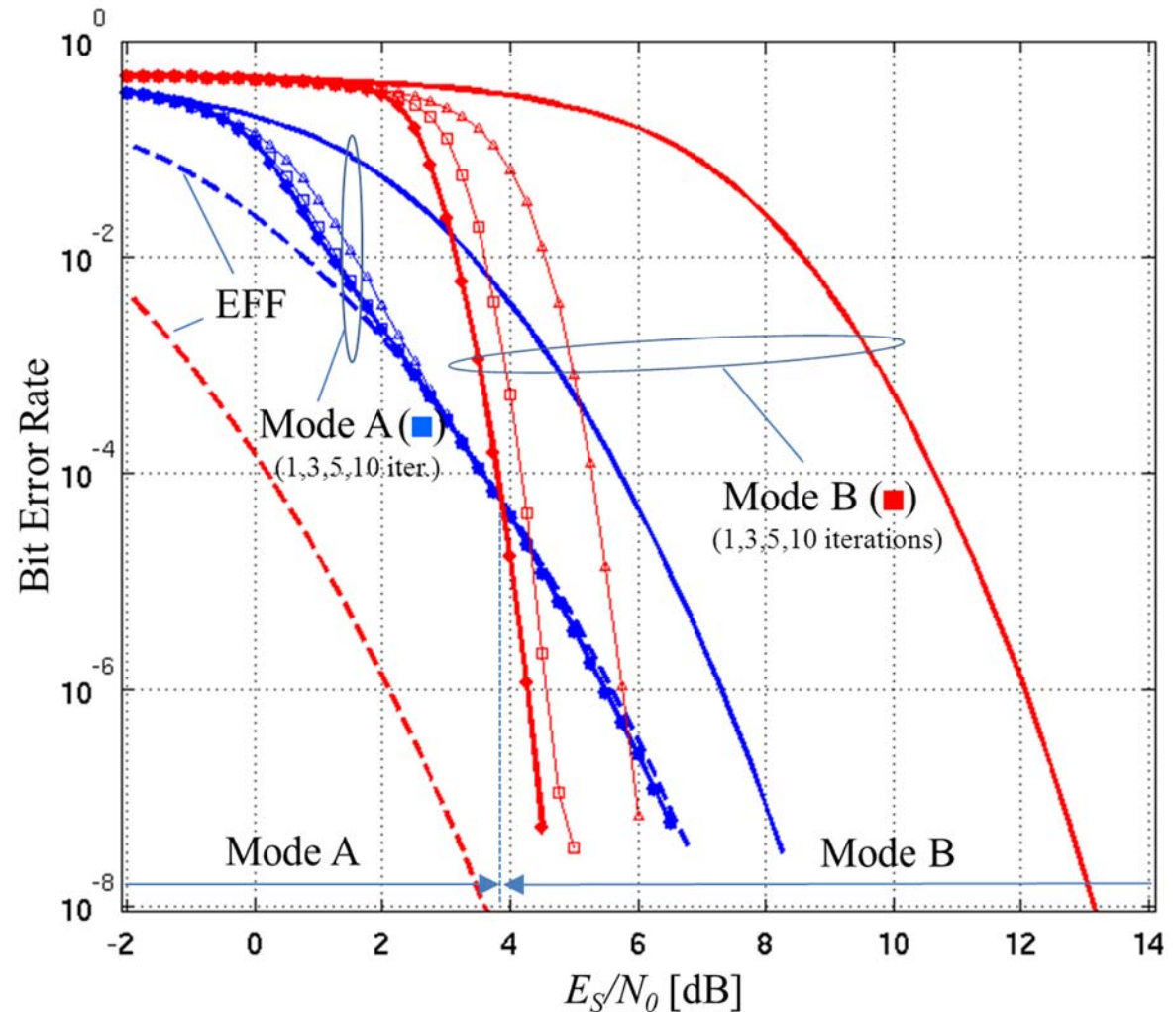
EFF – Error Free Feedback

# Reference System

## *Simulation Results for Non-Hierarchical BICM-ID Schemes*

### ■ Key Result

- each Mode has its specific benefits in a particular  $E_s/N_0$  Region



EFF – Error Free Feedback



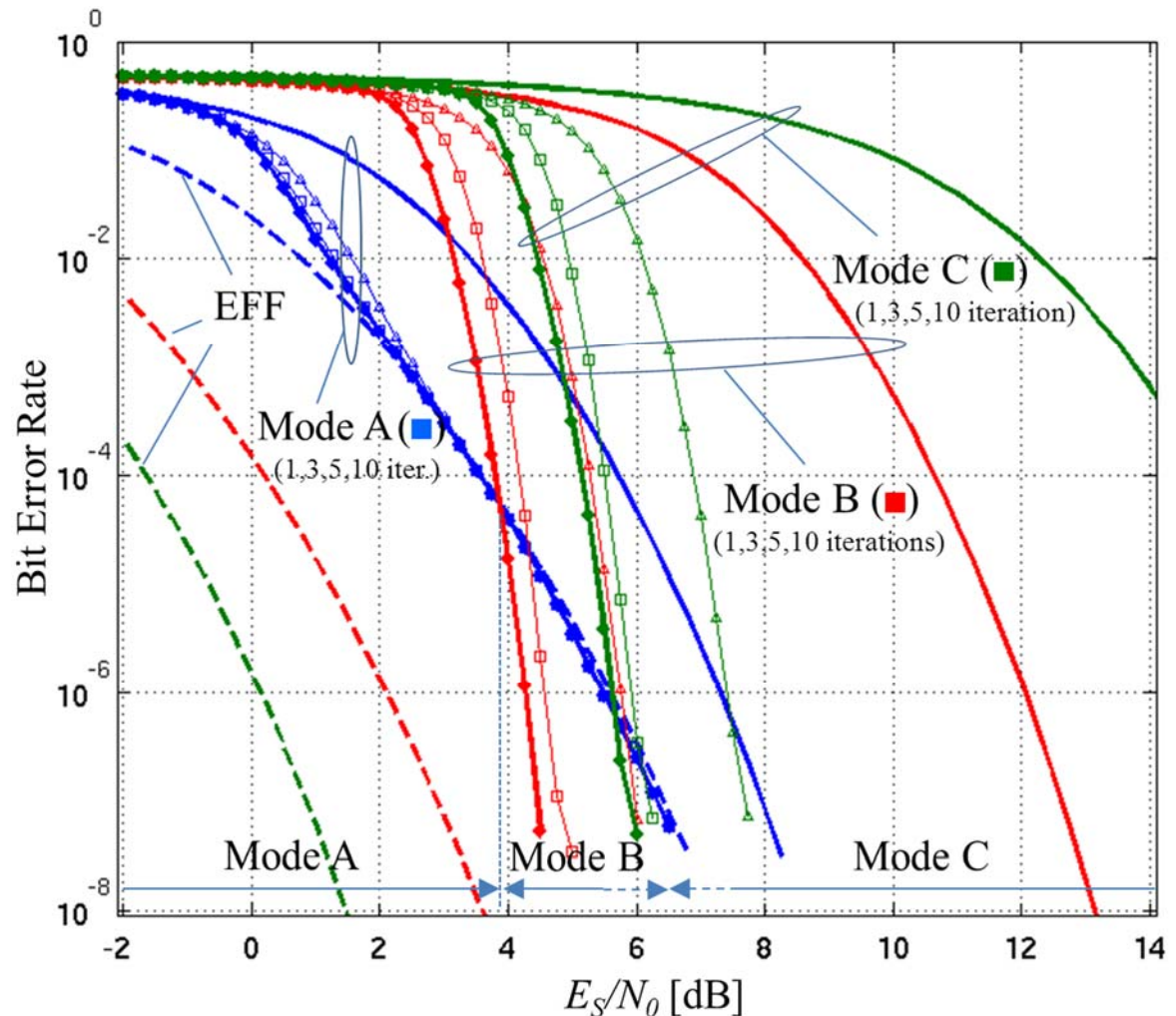
# Reference System

## Simulation Results for Non-Hierarchical BICM-ID Schemes

### ■ Key Result

- each Mode has its specific benefits in a particular  $E_s/N_0$  Region

Can this benefit also be realized in a Hierarchical BICM-ID system ?



EFF – Error Free Feedback

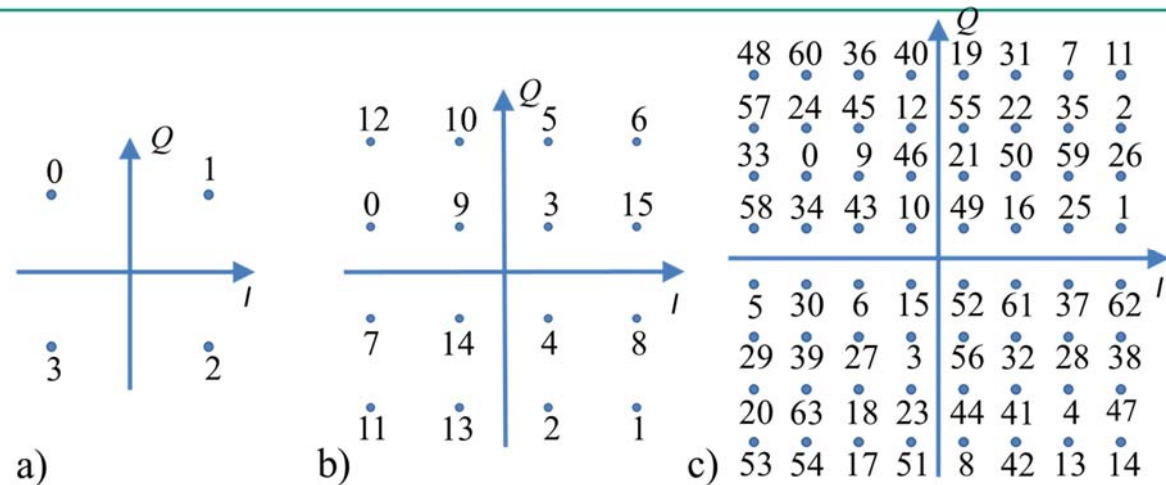


# Hierarchical BICM-ID System

Key Design Parameter: Symbol Labelling

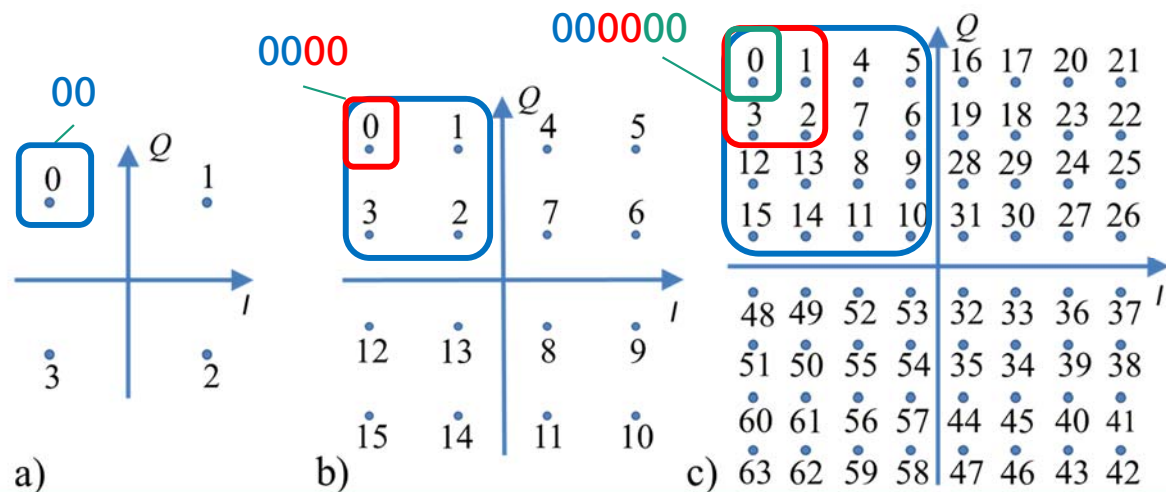
- Symbol labelling in a Non-Hierarchical BICM-ID System

No Constraints  
on the Design  
of Symbol Labels



- Symbol labelling in a Hierarchical BICM-ID System

Lower-Layer Labels  
need to be considered  
in Higher Layers

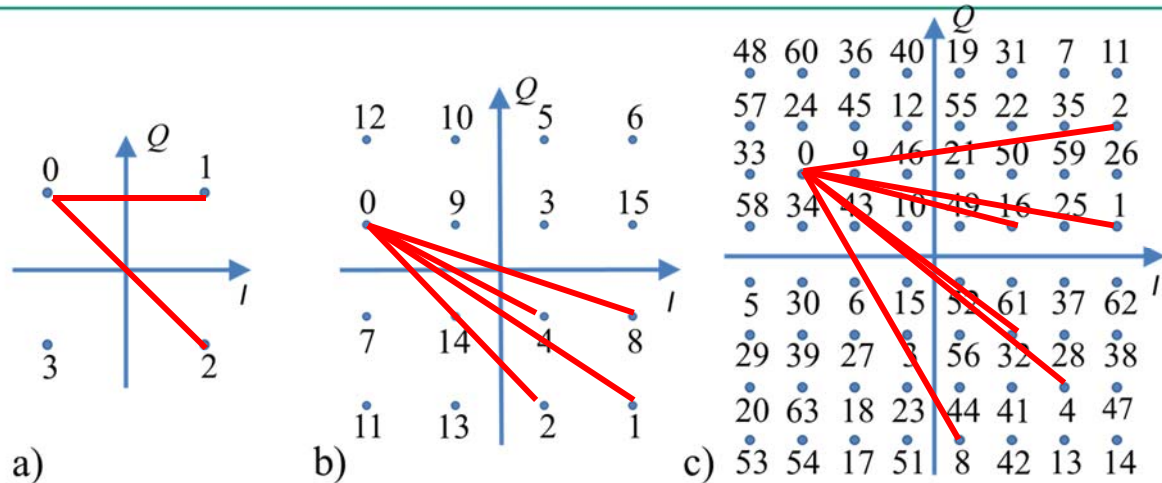


# Hierarchical BICM-ID System

Key Design Parameter: Symbol Labelling

- Symbol labelling in a Non-Hierarchical BICM-ID System

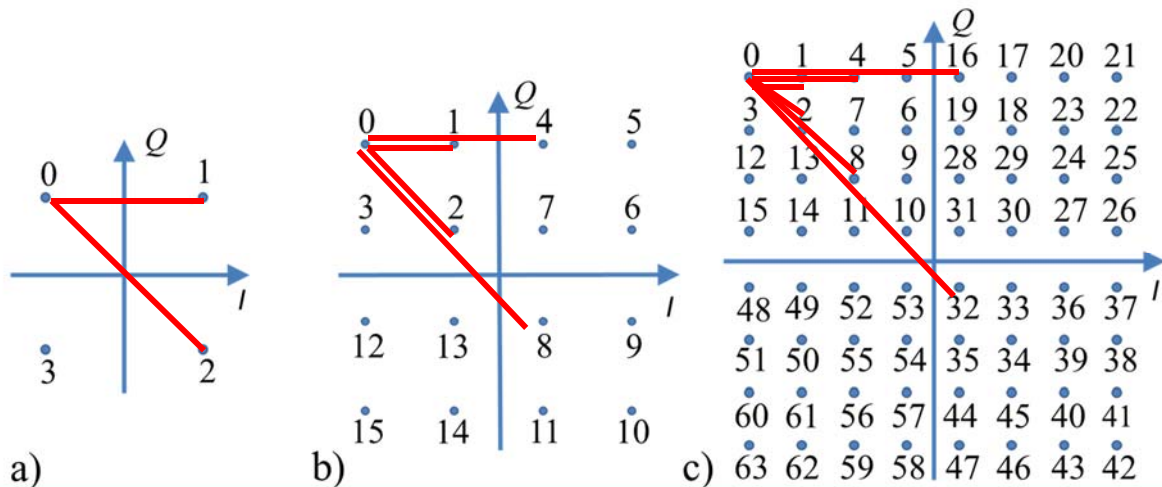
BICM-ID can benefit from larger Euclidean Distances



- Symbol labelling in a Hierarchical BICM-ID System

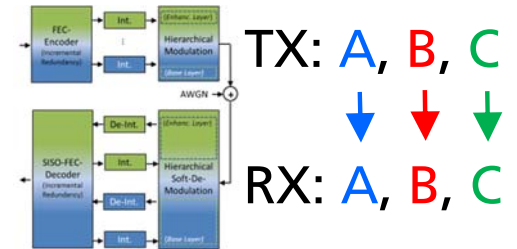
On average smaller Euclidean Distances

➡ BER loss very likely



# Hierarchical BICM-ID System

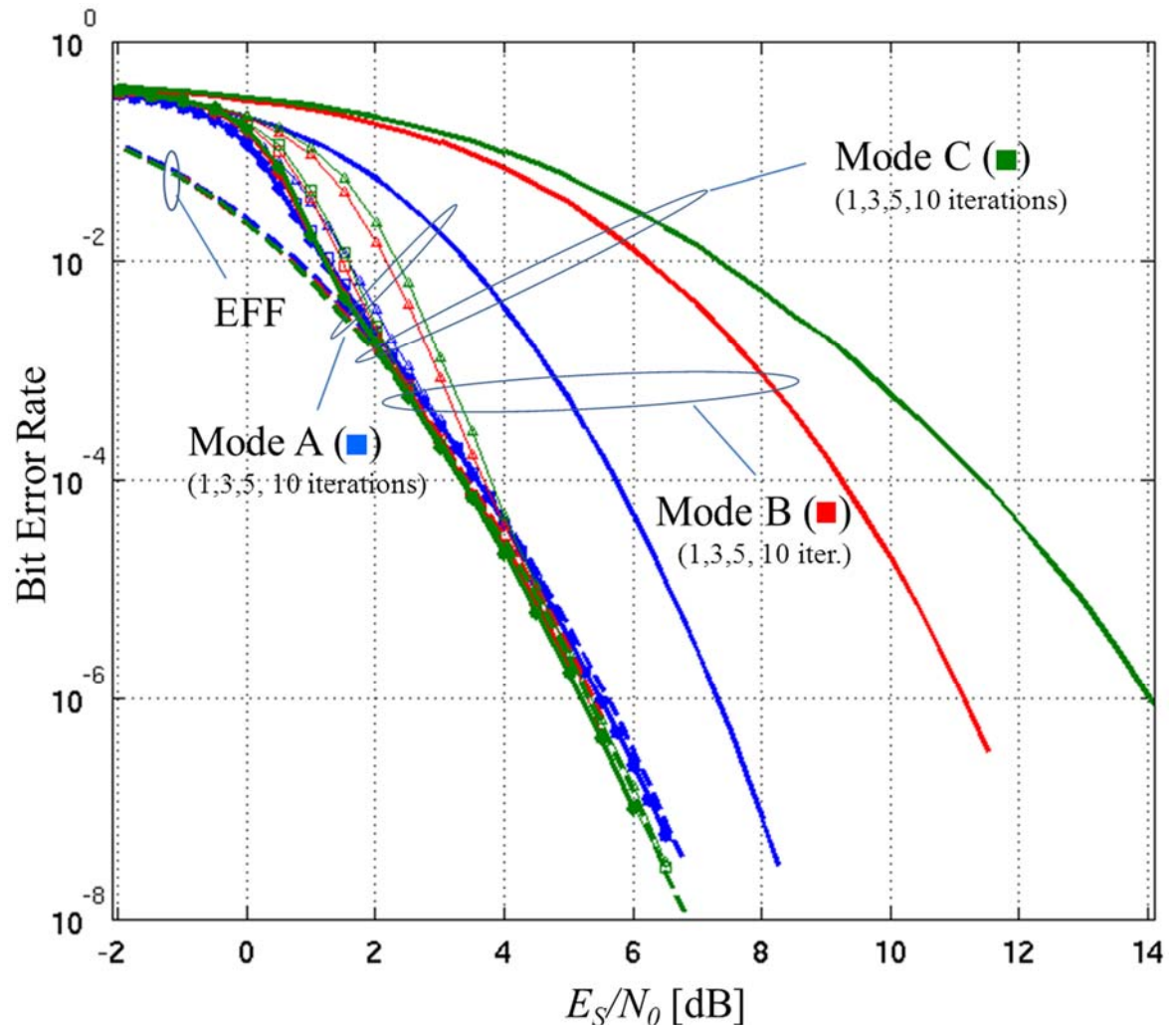
Simulation Results for *Hierarchical BICM-ID Schemes*



## Key Result

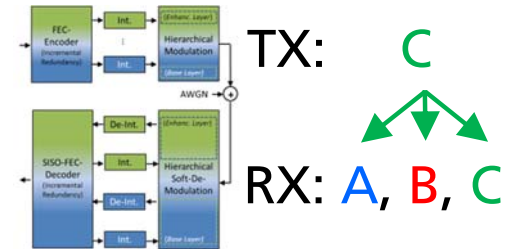
- BER performance of Modes B and C suffers considerably from the Constraint on the Design of Symbol Labels

What if  
Modes B and C  
shall decode a signal  
which was encoded  
with Mode C ?



# Hierarchical BICM-ID System

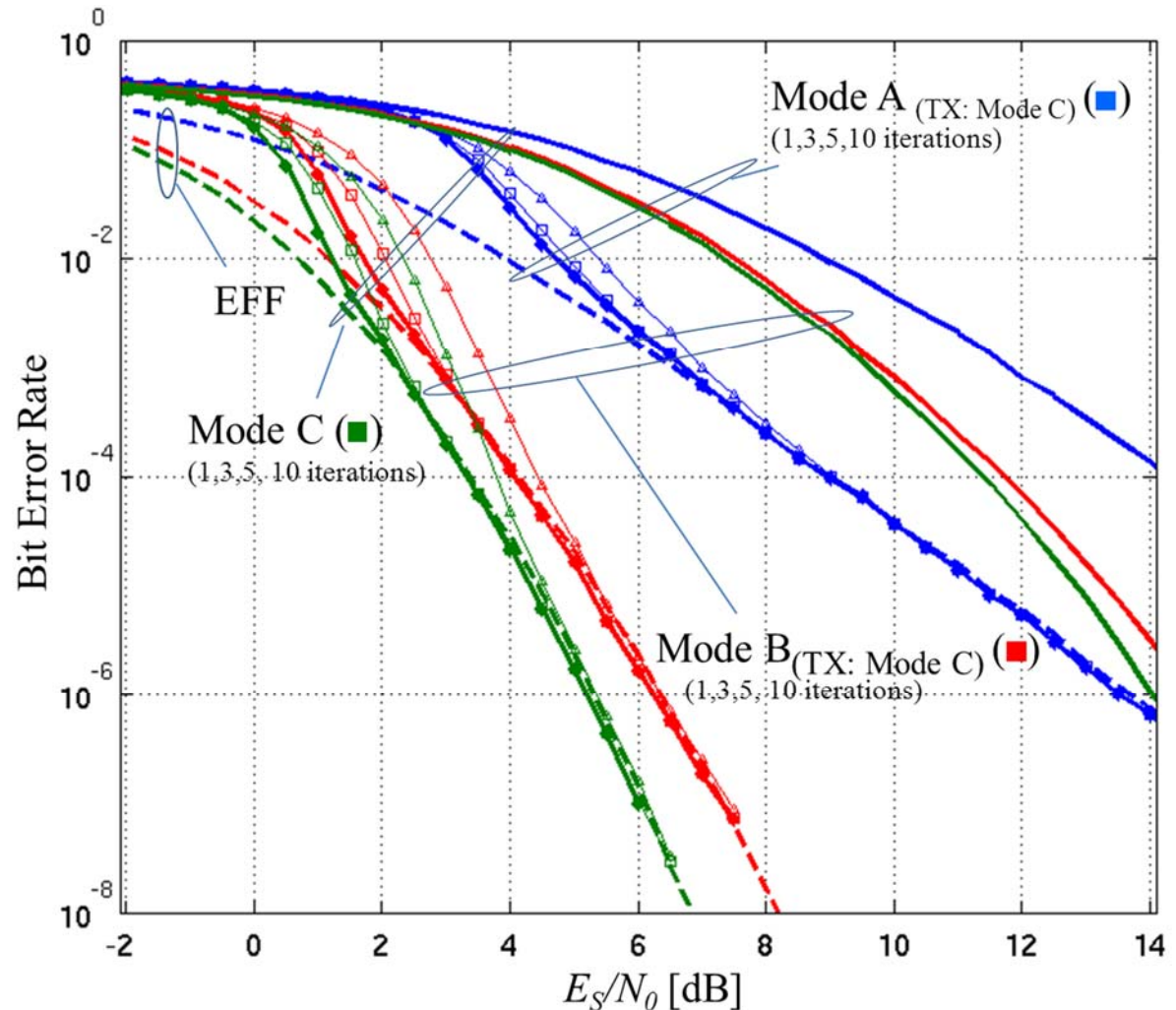
Simulation Results for Hierarchical BICM-ID Schemes



## ■ Key Result

- BER performance loss is considerable when a straightforward approach is used

Does it help  
to relax some of the  
Design Constraints ?

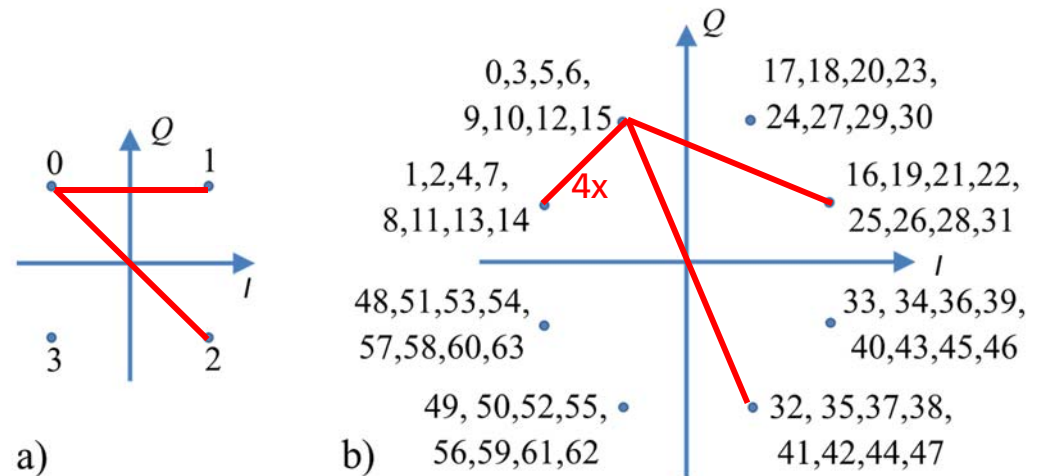


# Hierarchical BICM-ID System

*Relaxing some Design Constraints*

- Relaxing the following constraints
  - instead of considering the three Modes A, B, and C focus on the two Modes A and C only
  - instead of a classic 64-QAM scheme with one bit label per signal constellation point each, use an 8-PSK scheme with eight bit labels per point

- Symbol labelling in a Hierarchical BICM-ID System with Relaxed Constraints



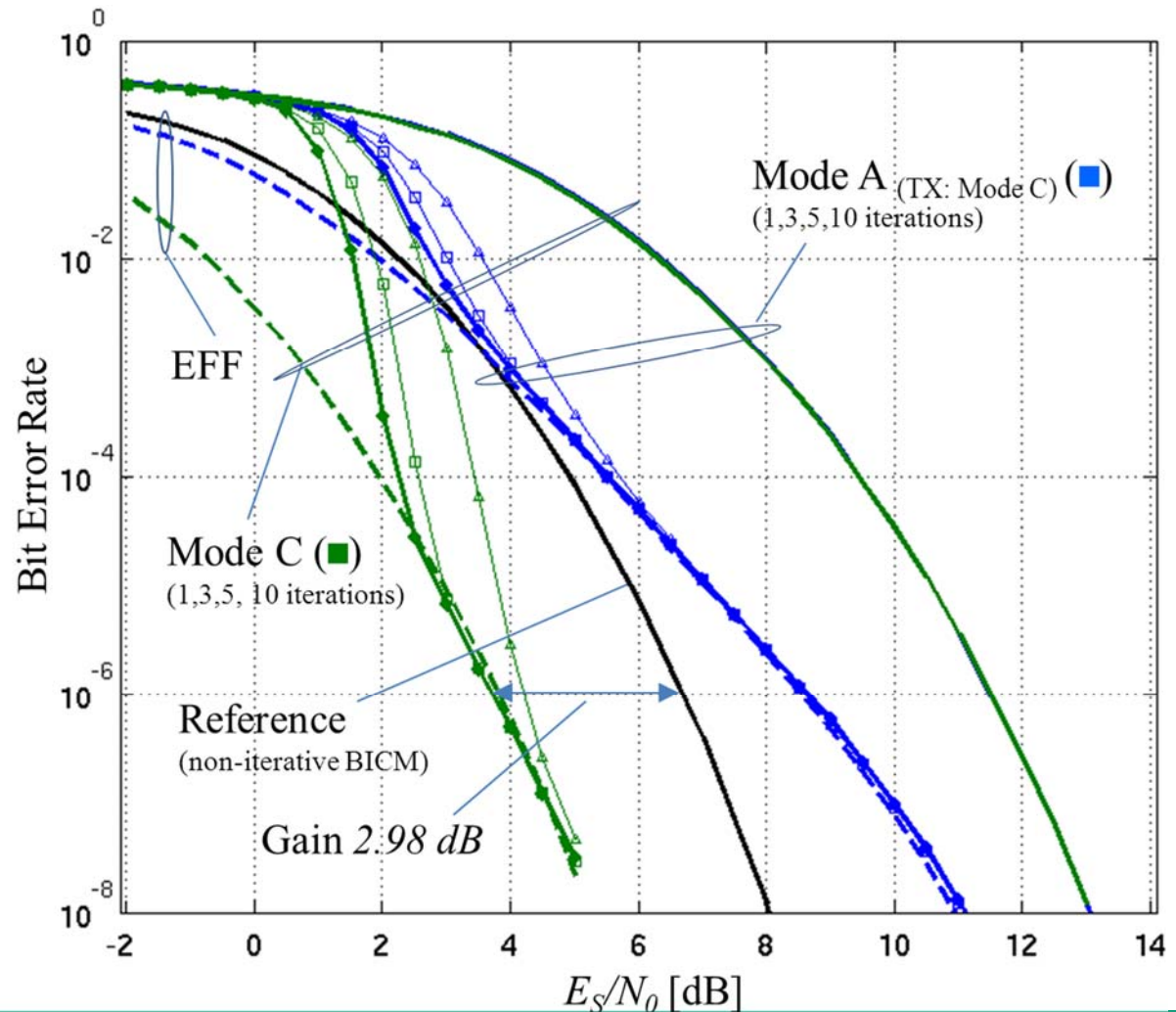


# Hierarchical BICM-ID System

*Simulation Results for a Hierarchical BICM-ID Scheme w. Relaxed Constraints*

## ■ Key Result

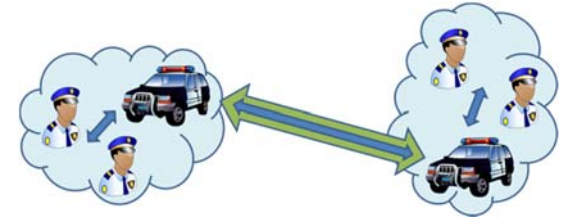
- considerable parts of the performance loss can be compensated with the relaxed constraints





# Conclusions

## Hierarchical BICM-ID Systems



- Objective: Design a hierarchical BICM-ID system which allows
  - decoding a single transmit signal by receivers of different capabilities
- Results
  - in non-hierarchical BICM-ID systems, a stronger error protection can overcompensate the loss of a more sensitive modulation scheme
  - a straightforward approach to hierarchical BICM-ID suffers considerably from the additional constraints on the Modulation Symbol Label Design
  - relaxing some constraints offers significant improvements

# Thanks for your attention !