Legacy Waveforms on Software Defined Radios: Benefits of Advanced Digital Signal Processing

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Report Documentation Page

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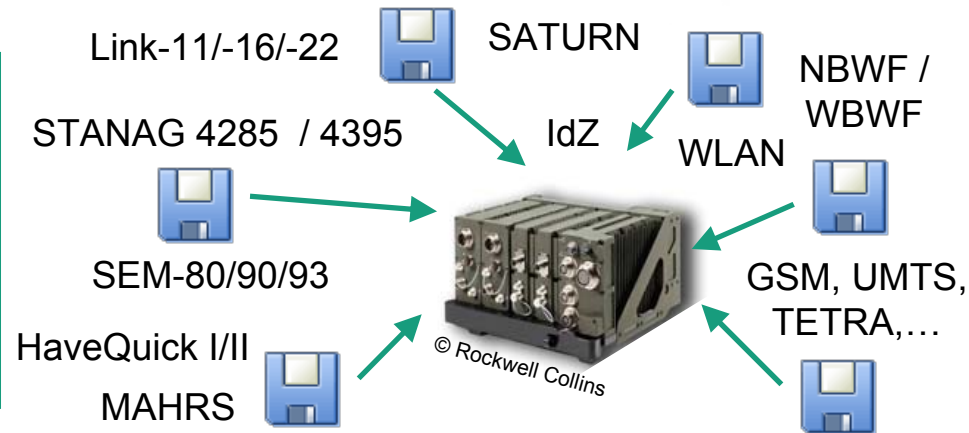| 16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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Conventional Radio Equipment vs. Software Defined Radio

- **Conventional Radios**

  - limited interoperability

  - new system specification ↔ new radio equipment

  - high service & maintenance costs

SEM-93

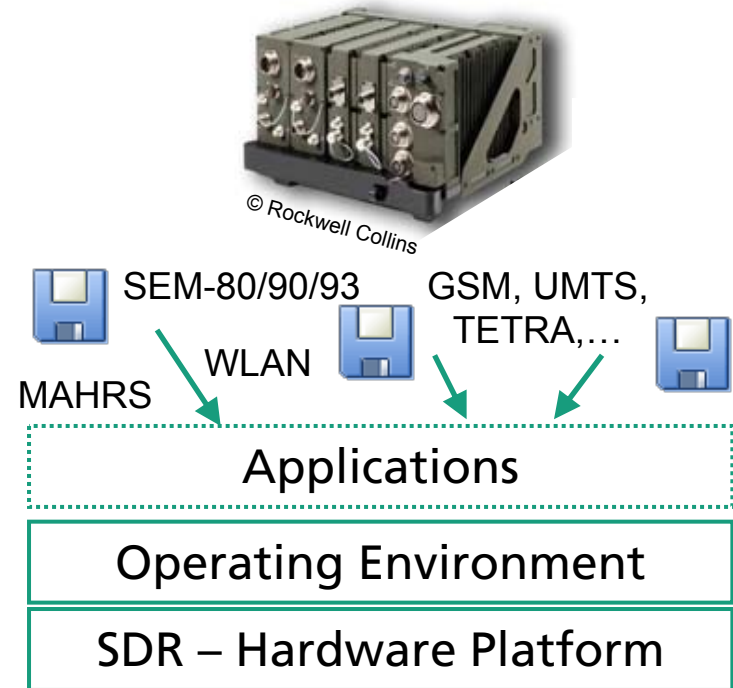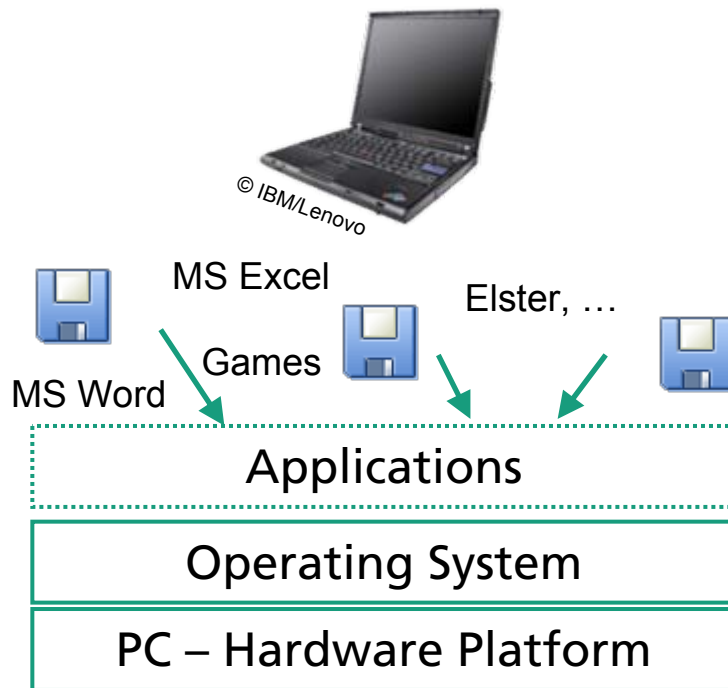© Thales Def. Deu

MIDS/Link16

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TETRA

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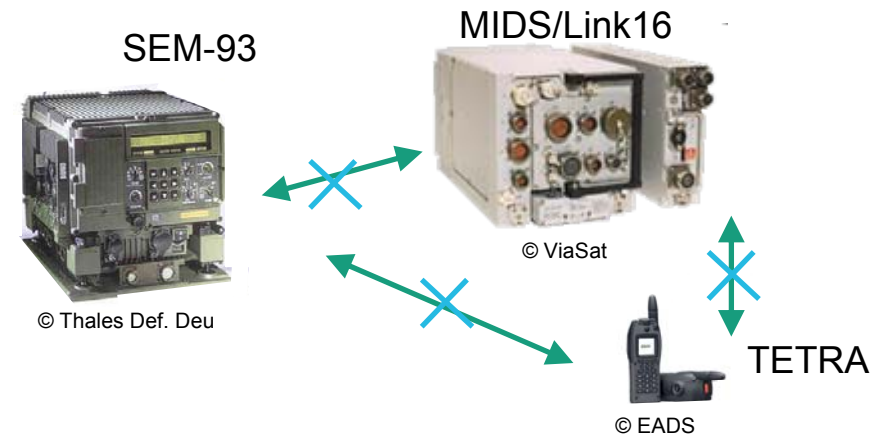
- **Software Defined Radio**

  Considerable parts of signal processing are realized as software programms on programmable and/or reconfigurable hardware.

Link-11/-16/-22

SATURN

NBWF / WBWF

STANAG 4285 / 4395

IdZ

WLAN

SEM-80/90/93

GSM, UMTS, TETRA,…

HaveQuick I/II

MAHRS

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Analogies: PCs vs. Software Defined Radio

■ On first glance …

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MS Excel

Games

Elster, …

MS Word

Applications

Operating System

PC – Hardware Platform

SEM-80/90/93

WLAN

MAHRS

GSM, UMTS, TETRA,…

Applications

Operating Environment

SDR – Hardware Platform

… but, SDRs are much more complex !!!

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Motivation (1/2)

- Before new wideband networking waveforms are available
- Key challenge

Concepts for Porting Legacy Waveforms to Software Defined Radios

Portability [IEEE]

the ease with which a system or component can be transferred from one hardware or software environment to another

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Legacy Radio

Software Defined Radio

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Motivation (2/2)

- **Different concepts**

  - one-to-one porting of signal processing → guaranteed interoperability

  - introduce novel receiver signal processing → keep interoperability

  - introduce novel transceiver signal processing
    → no interoperability to legacy radios, but to other SDRs

Legacy Radio

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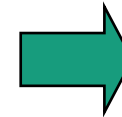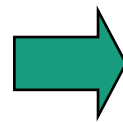
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Software Defined Radio

  - Example: MIL-STD-188-110B Serial Single Tone Waveform

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MIL-STD-188-110B Serial Single Tone

■ US DoD *"Interoperability and Performance Standards for Data Modems"*

```
     ↓
┌─────────┐
│   FEC   │
└─────────┘
     ↓
┌─────────┐
│    π    │
└─────────┘
     ↓
┌─────────┐
│Modulator│
└─────────┘
     ↓
┌ ─ ─ ─ ─ ─ ─ ─ ┐
  Physical Channel,
│ Equalization… │
└ ─ ─ ─ ─ ─ ─ ─ ┘
     ↓
┌──────────┐
│Demodulator│
└──────────┘
     ↓
┌─────────┐
│  π⁻¹    │
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     ↓
┌─────────┐
│ Log-MAP │
└─────────┘
     ↓
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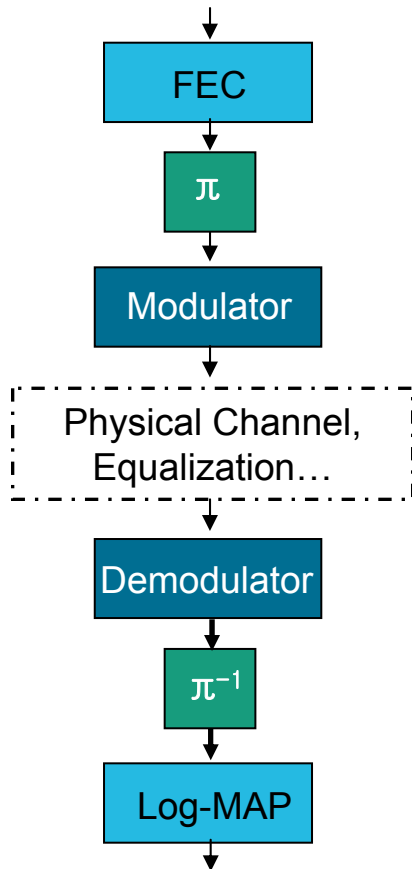
■ Some details

■ this mode was specified in 1991(MIL-STD-188-110A)

■ configurations:

Datarate (bps)	Method for achieving the code rate	Modulation
4800	No coding	8-PSK
2400	**G(171,133), r = ½**	**8-PSK**
1200	G(171,133), r = ½	QPSK
600	G(171,133), r = ½	BPSK
300	G(171,133), r = ½ repeated 2 times	BPSK
150	G(171,133), r = ½ repeated 4 times	BPSK
75	G(171,133), r = ½ plus 8 Walsh-code	BPSK

Blocktype-Interleaver: short l_S=2880 bits & long l_L=23040 bits

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BICM-ID: Basic Concept

- *Bit Interleaved Coded Modulation with Iterative Decoding*
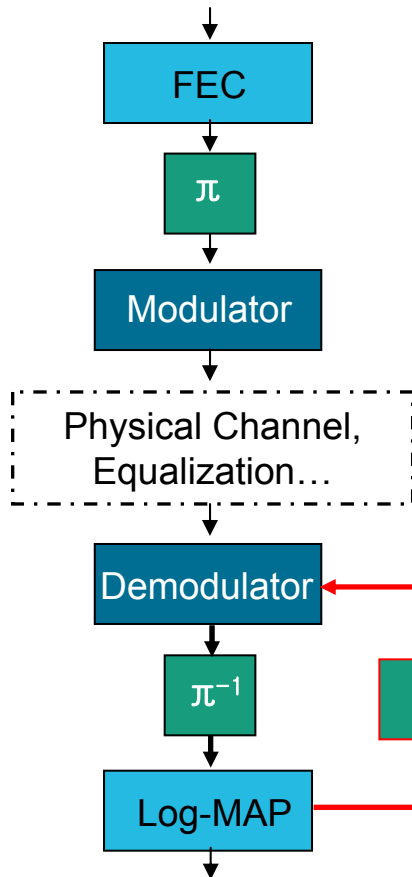
- **Transmitter**
  - connects coded bits, originally far apart in the sequence, to one channel symbol
  - coded bits forming one symbol are mutually independent

- **Receiver**
  - demodulator and decoder exploit reliabilities using soft-input-soft-output (SISO) techniques
  - new: iterative feedback of extrinsic information

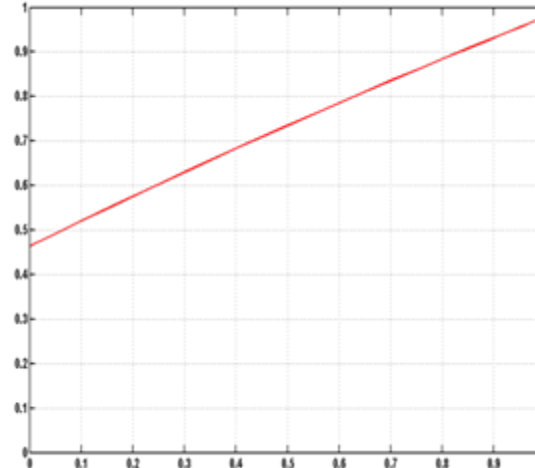# EXIT-Charts: Basic Concept
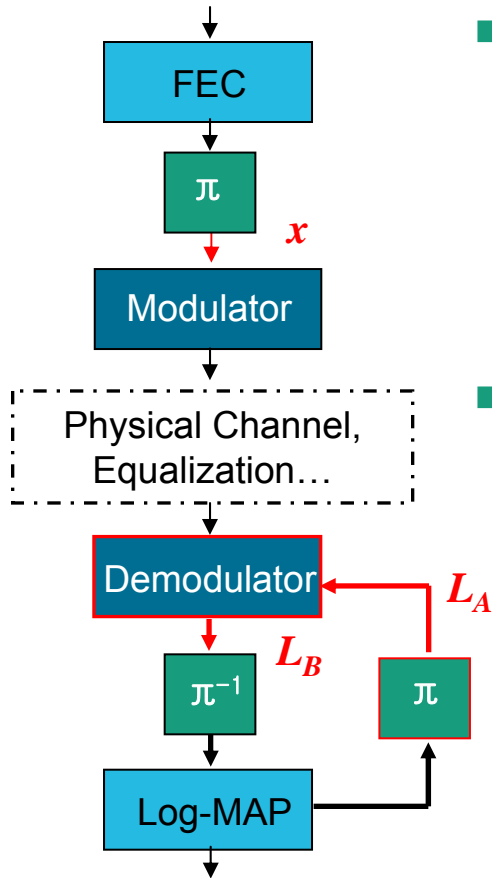
■ *Extrinsic Information Transfer Charts*

■ EXIT-Charts

  ■ visualize extrinsic information transfer from the extrinsic input of a SISO decoder to the extrinsic output

  ■ help to understand the convergence behavior

■ Example

$\text{I}(L_B\,;\,x)$

$\text{I}(\,L_A\,;\,x)$

EXIT-Charts: Basic Concept
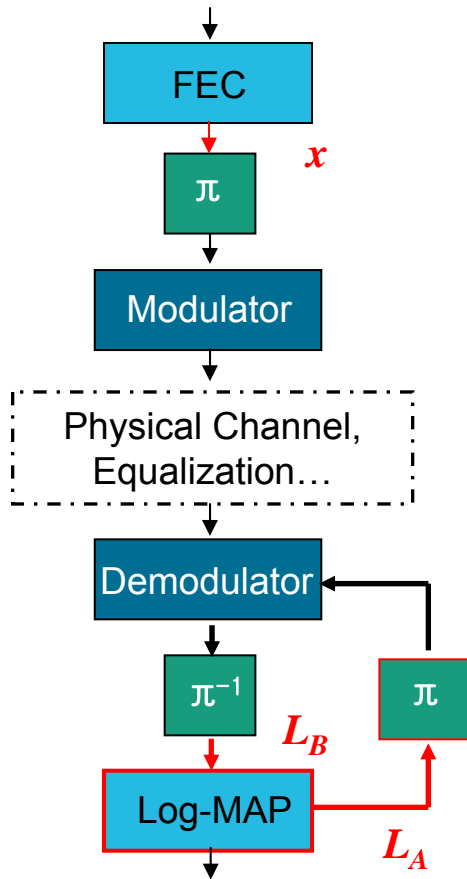
- *Extrinsic Information Transfer Charts*

FEC

x

π

Modulator

Physical Channel, Equalization…

Demodulator

π^{-1} π

L_B L_A

Log-MAP

- EXIT-Charts

  - visualize extrinsic information transfer from the extrinsic input of a SISO decoder to the extrinsic output

  - help to understand the convergence behavior

- Example

$I(L_B\,;\,x)$

$I(\,L_A\,;\,x)$

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EXIT-Charts: Basic Concept

- *Extrinsic Information Transfer Charts*

- EXIT-Charts

  - visualize extrinsic information transfer from the extrinsic input of a SISO decoder to the extrinsic output

  - help to understand the convergence behavior

- Example

$I(L_B ; x)$

n. Iteration

2. Iteration

1. Iteration

0. Iteration

$I(L_A ; x)$
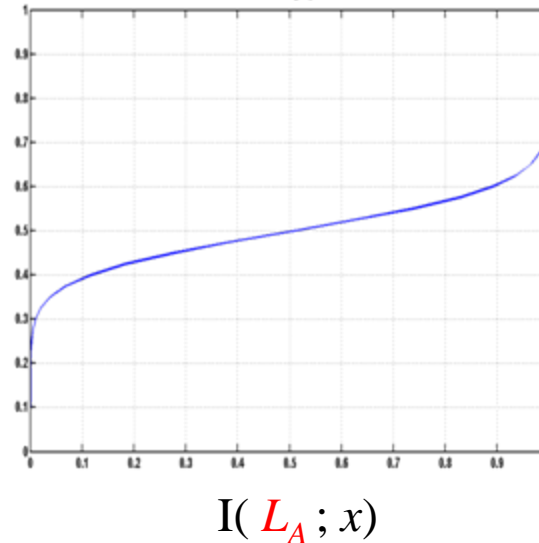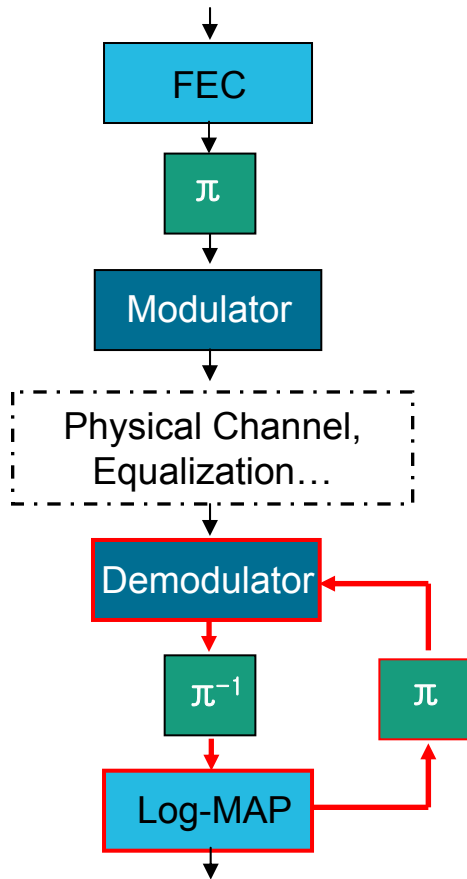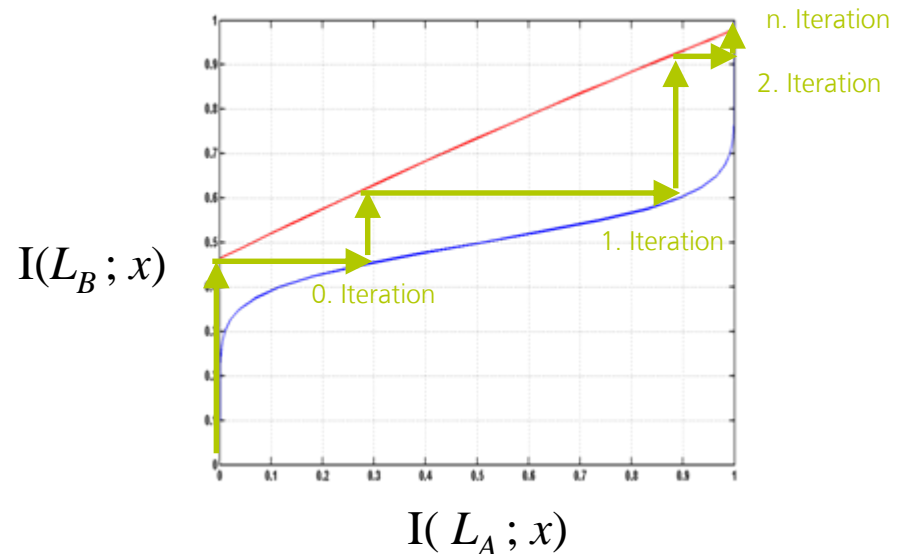
Simulation Results

■ *Classic Approach - Straight forward implementation without BICM-ID*
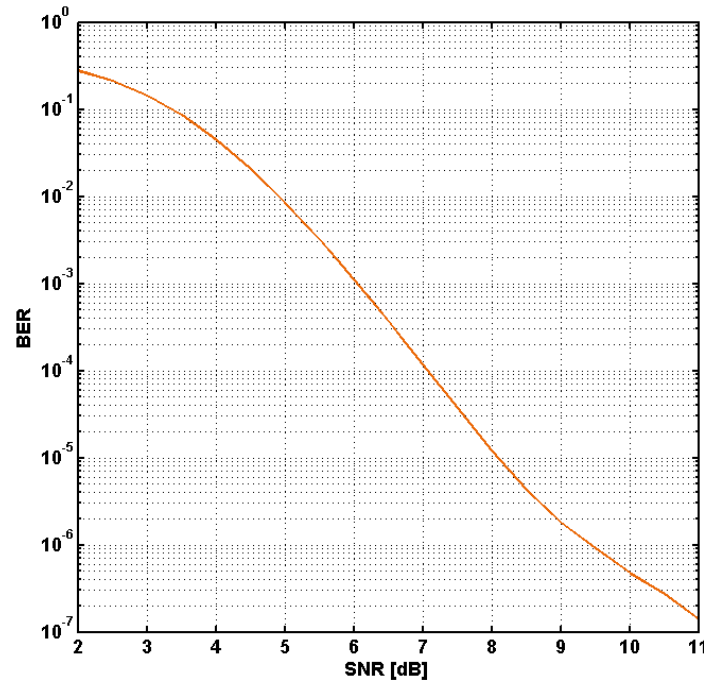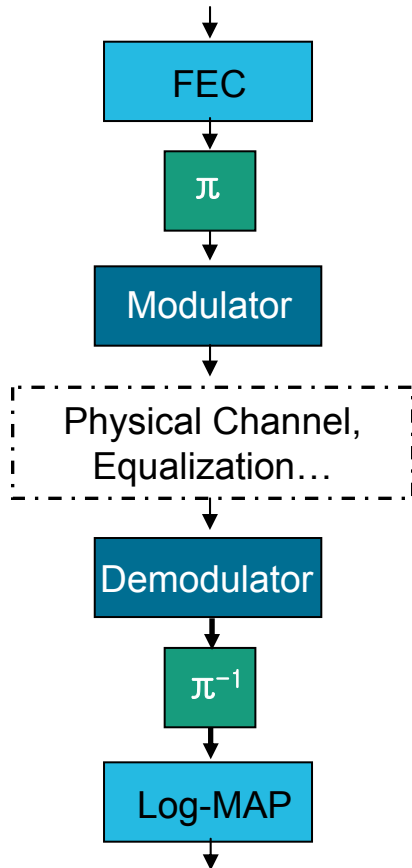
Simulation Results

■ *Enhanced Approach - Implementation with BICM-ID*
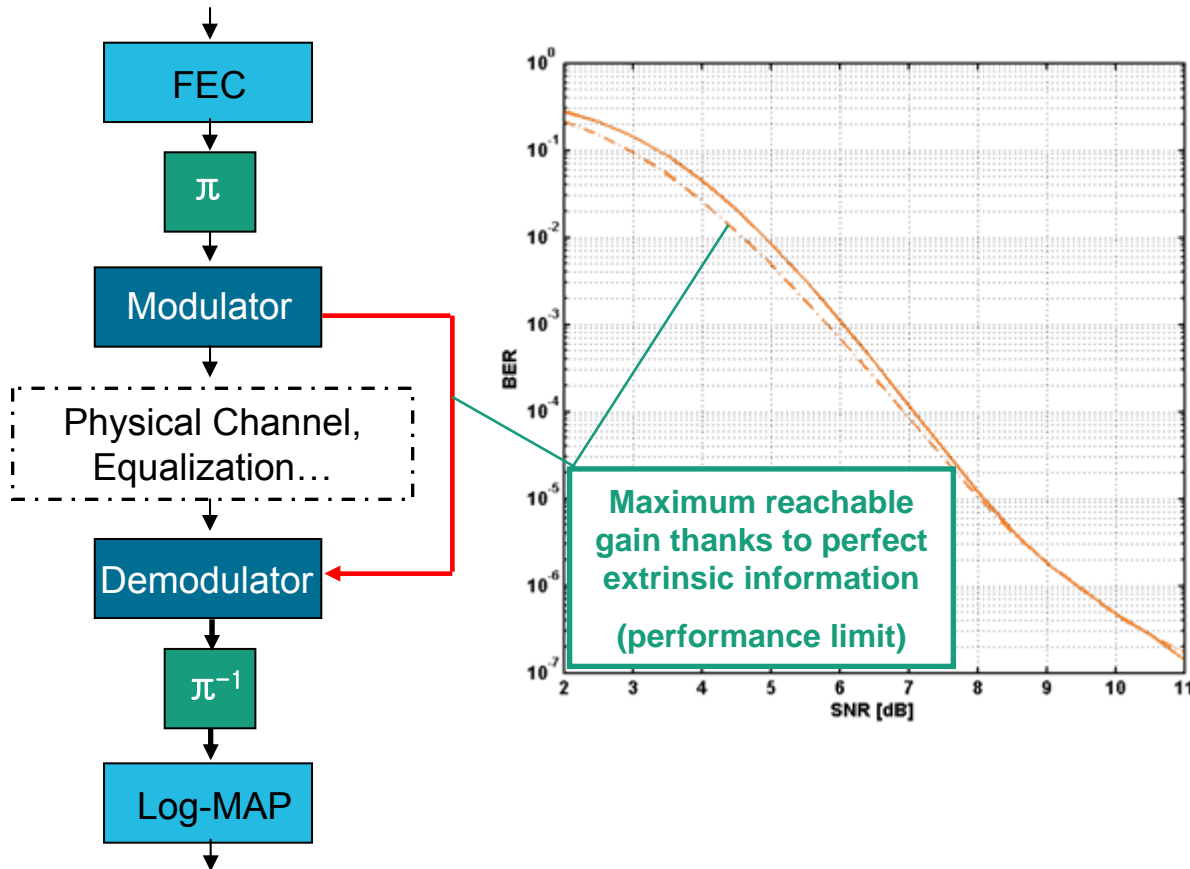
Simulation Results

- *Enhanced Approach - Implementation with BICM-ID*
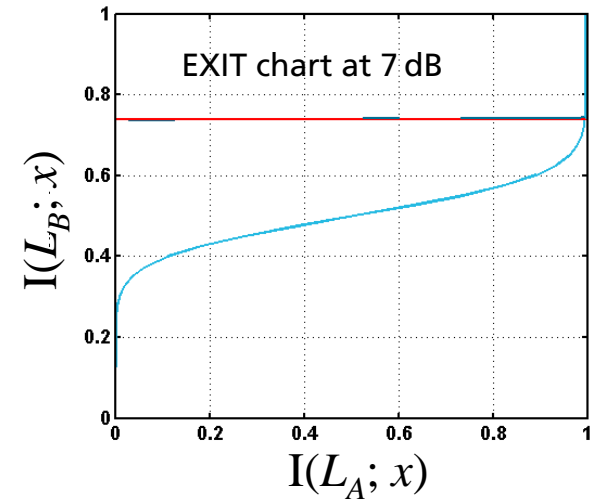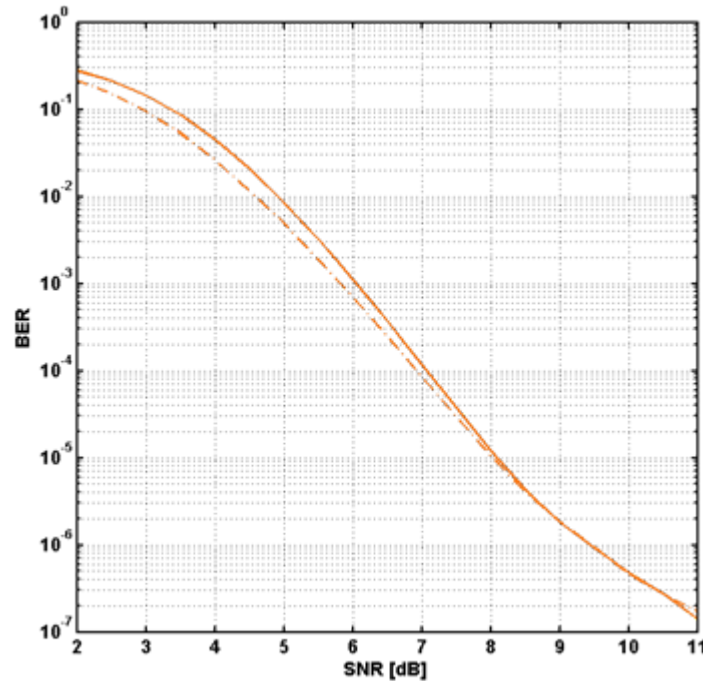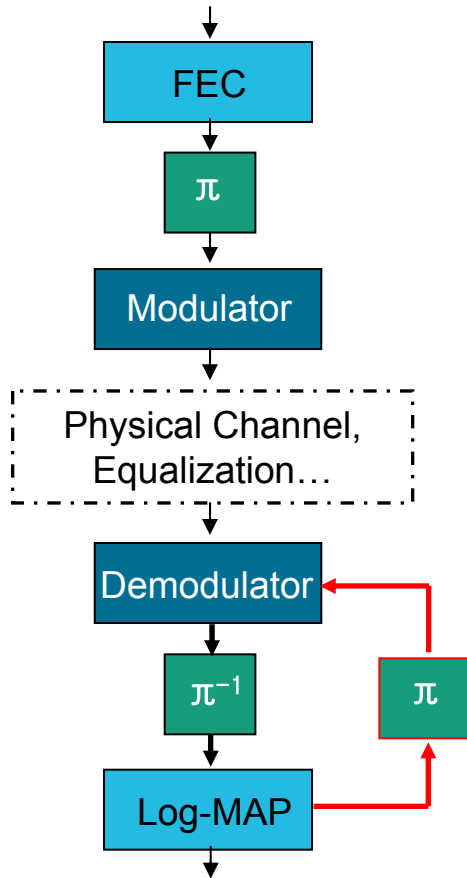
Standard compliant implementation offers only small gains using BICM-ID

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Proposed SDR-Modes
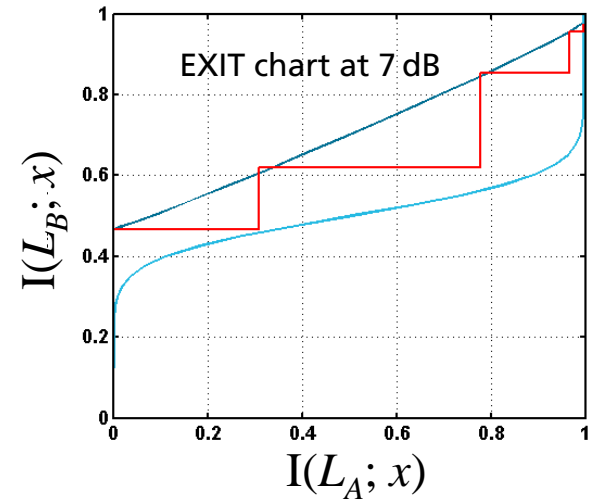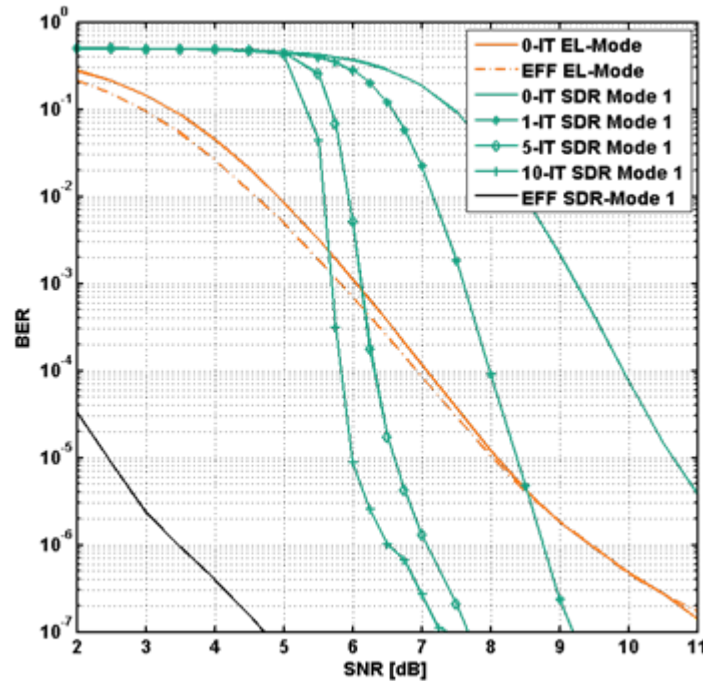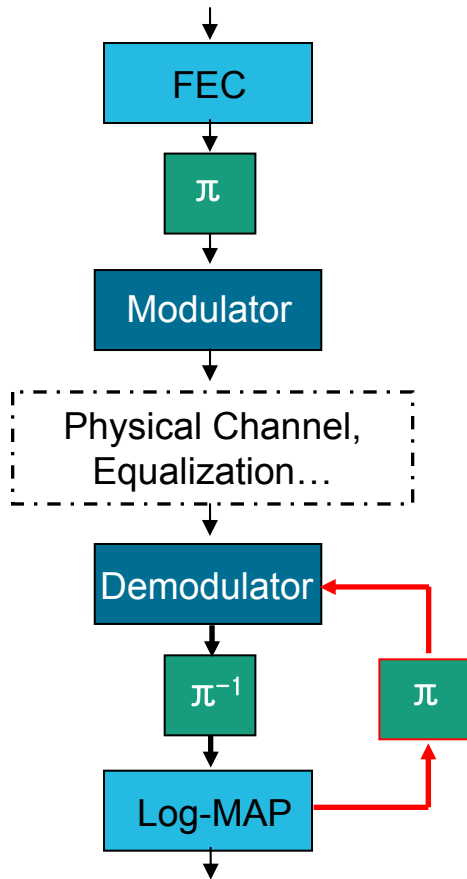
■ *Small modification offers substantial performance improvements*

■ Proposed modification

  ■ change mapping from Modified Gray-coding to Semi-Set Partitioning

  ■ neighboring signal constellation points are as dissimilar as possible

  ■ usually, only a single line of software code needs to be changed
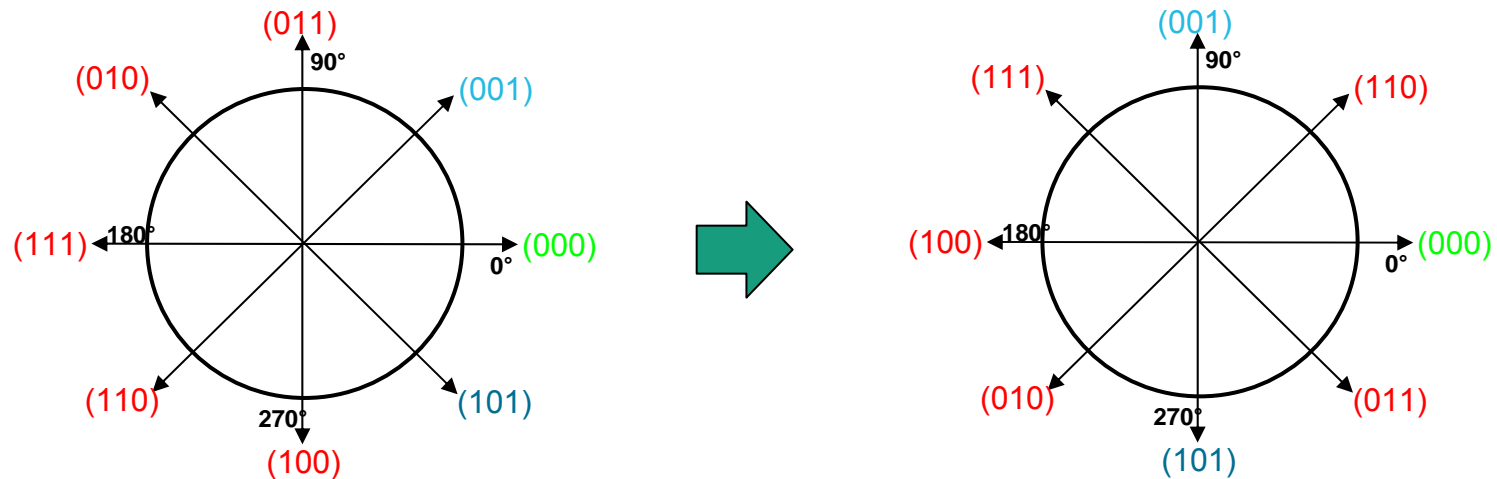
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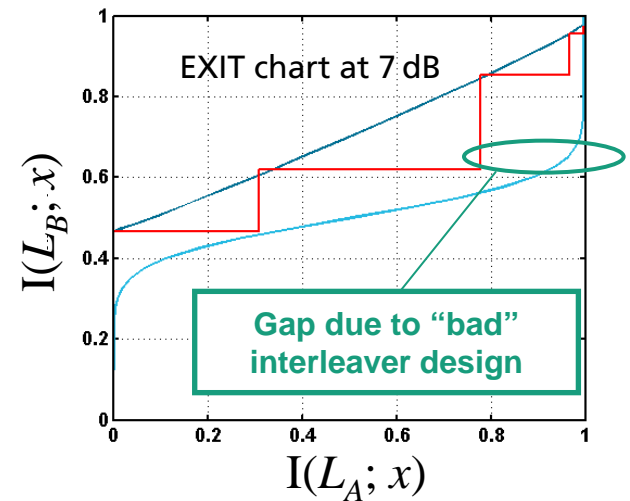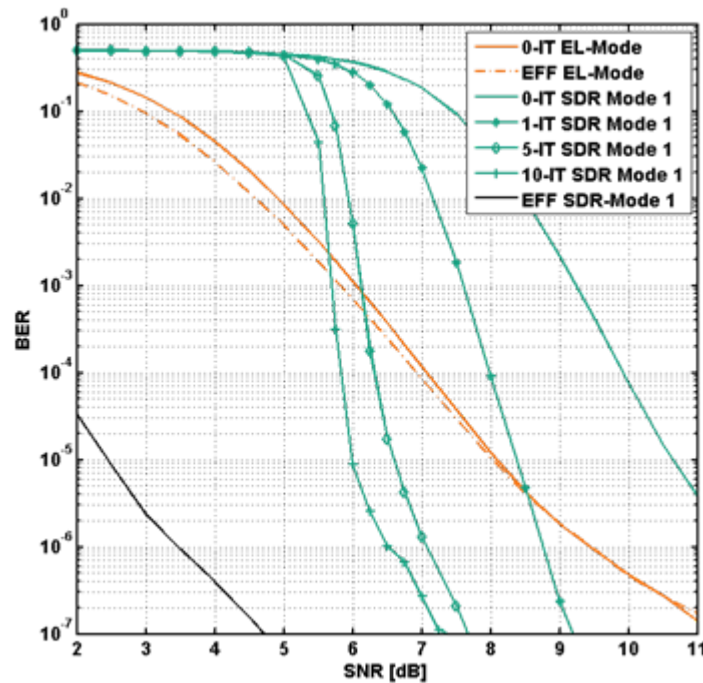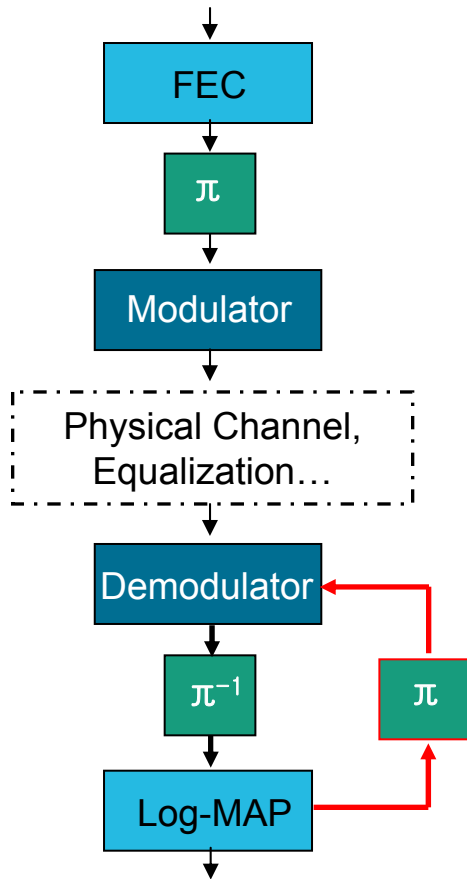
Simulation Results

- *Proposed SDR-Mode with BICM-ID and SSP Labeling*

Proposed SDR-Mode (change of labels) **offers significant gains using BICM-ID**

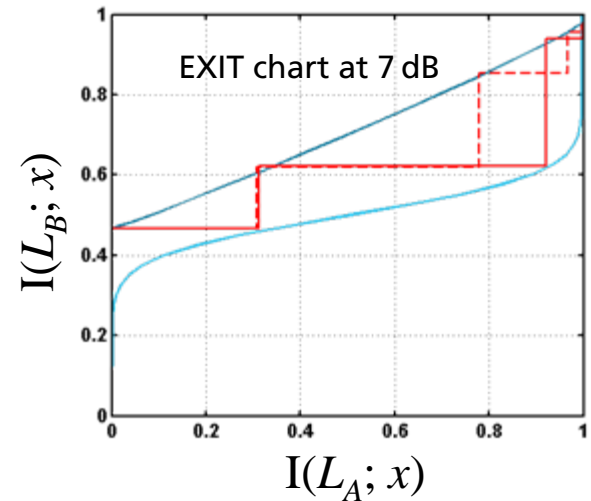# Simulation Results
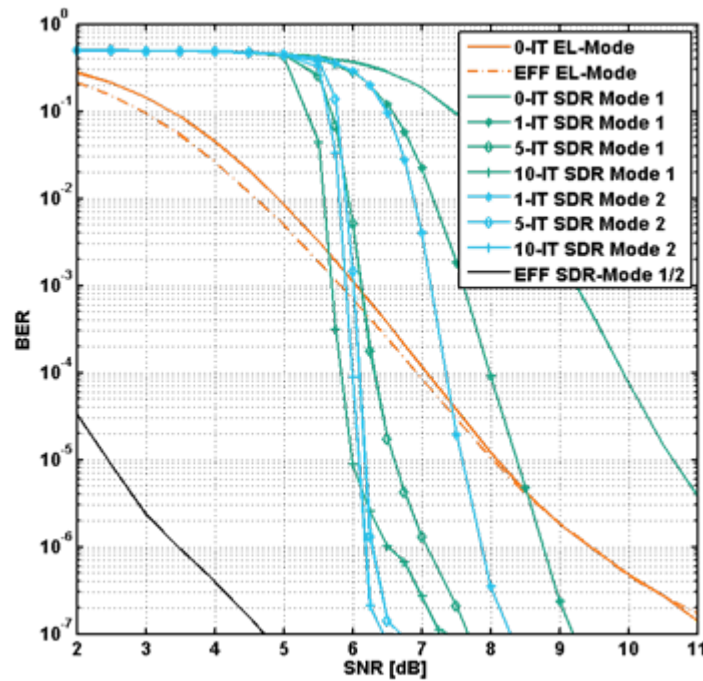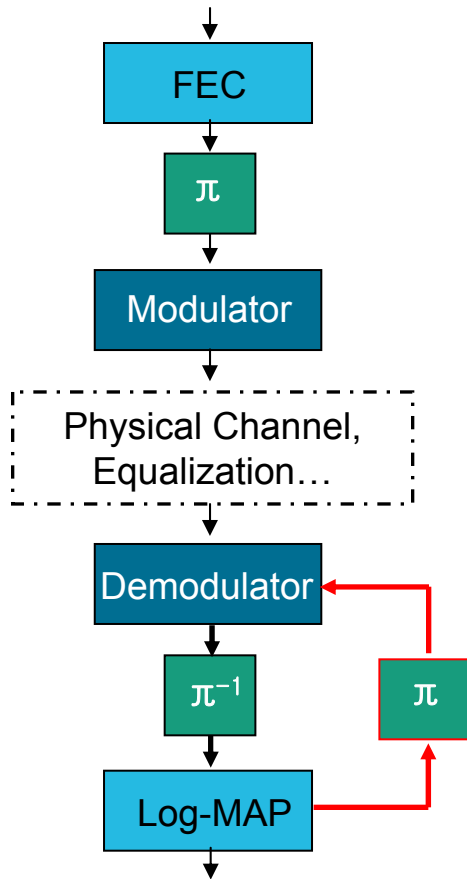
- *Proposed SDR-Mode with BICM-ID and SSP Labeling*

Proposed SDR-Mode (change of labels) **offers significant gains using BICM-ID**

Simulation Results

■ *Proposed SDR-Mode with BICM-ID, SSP Labeling and S-Rand Interleaver*


Change of interleaver design offers additional gains using BICM-ID

Conclusion

Do recent advances in digital receiver design reveal benefits ?

- A waveforms error robustness can be increased significantly, if novel signal processing is applied

- New SDR platforms are able to offer increased processing demands

- Straight-forward implementation of BICM-ID offers only small gains

- New SDR-Modes are not interoperable to the legacy WF on the air interface, but can perform significantly better
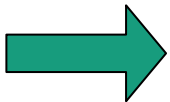
➡ **Yes, porting the PHY-functionalities in a one-to-one manner is <u>not always</u> appropriate, minor changes can reveal major performance gains!**

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Thanks for your Attention!

Questions or Comments?

Interleaver Influence

■ The Interleaver preserves independence of the concatenated decoders and spreads therewith the sources of extrinsic information

Original

1st C1   1st C2   2nd C1   2nd C2   10th C2

S-Random