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

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

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Standard Form 298 (Rev. 8-98)  Prescribed by ANSI Std Z39-18
Conventional Radio Equipment vs. Software Defined Radio

- Conventional Radios
  - limited interoperability
  - new system specification ↔ new radio equipment
  - high service & maintenance costs

- Software Defined Radio
  Considerable parts of signal processing are realized as software programms on programmable and/or reconfigurable hardware.
Analogies: PCs vs. Software Defined Radio

- On first glance ...

... but, SDRs are much more complex !!!
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
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

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

US DoD “Interoperability and Performance Standards for Data Modems”

Some details

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

<table>
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<th>Datarate (bps)</th>
<th>Method for achieving the code rate</th>
<th>Modulation</th>
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<td>4800</td>
<td>No coding</td>
<td>8-PSK</td>
</tr>
<tr>
<td>2400</td>
<td>G(171,133), r = ½</td>
<td>8-PSK</td>
</tr>
<tr>
<td>1200</td>
<td>G(171,133), r = ½</td>
<td>QPSK</td>
</tr>
<tr>
<td>600</td>
<td>G(171,133), r = ½</td>
<td>BPSK</td>
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<tr>
<td>300</td>
<td>G(171,133), r = ½ repeated 2 times</td>
<td>BPSK</td>
</tr>
<tr>
<td>150</td>
<td>G(171,133), r = ½ repeated 4 times</td>
<td>BPSK</td>
</tr>
<tr>
<td>75</td>
<td>G(171,133), r = ½ plus 8 Walsh-code</td>
<td>BPSK</td>
</tr>
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Blocktype-Interleaver: short \( l_s = 2880 \) bits & long \( l_L = 23040 \) bits
**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

![EXIT-Charts Diagram](image_url)
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**

  ![EXIT-Charts Diagram](chart.png)

  \[ I(L_B; x) \]

  \[ I(L_A; x) \]
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**

![EXIT-Charts Diagram]

\[
I(L_B ; x) \\
I(L_A ; x)
\]
Simulation Results

- **Classic Approach** - Straight forward implementation without BICM-ID

```
FEC
π
Modulator
Physical Channel, Equalization...
π⁻¹
Demodulator
Log-MAP
```

![Graph showing BER vs. SNR](image-url)

© Fraunhofer FKIE
Simulation Results

- **Enhanced Approach - Implementation with BICM-ID**

![Diagram]

- Maximum reachable gain thanks to perfect extrinsic information (performance limit)
Simulation Results

- Enhanced Approach - Implementation with BICM-ID

Standard compliant implementation offers only small gains using BICM-ID
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
Simulation Results

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

![Diagram of communication system components]

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

EXIT chart at 7 dB
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 not always appropriate, minor changes can reveal major performance gains!
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.