Improving DVB-S2 Performance Through Constellation Shaping and Iterative Demapping

Xingyu Xiang, Dr. Matthew C. Valenti
West Virginia University
MILCOM – Nov. 10, 2011
Outline

– Introduction

– Constellation Shaping

– Implementation

– Conclusion
Outline

– Introduction

– Constellation Shaping

– Implementation

– Conclusion
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

(*) Source rate control may be directly applied to source(s) or locally at the GTW input, or via Network Traffic Control.
System Design Methodology

Constellation Shaping[10]

BICM-ID System[12,13]

DVB-S2 Standard with LDPC code and uniform APSK modulation [1]

Performance improvement (Shaping Gain)

Optimized Parameters [6]

References:


Outline

– Introduction

– Constellation Shaping

– Implementation

– Conclusion
- **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.
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
The grouping of the sub-constellations is based on the symbol energy and labeling.
- The shaping encoder maps K bits to N bits codeword, which has more zeros than ones. One example is (K=3, N=5):

<table>
<thead>
<tr>
<th>3 Input data bits</th>
<th>5 output codeword bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>00000</td>
</tr>
<tr>
<td>001</td>
<td>00001</td>
</tr>
<tr>
<td>010</td>
<td>00010</td>
</tr>
<tr>
<td>011</td>
<td>00100</td>
</tr>
<tr>
<td>100</td>
<td>01000</td>
</tr>
<tr>
<td>101</td>
<td>10000</td>
</tr>
<tr>
<td>110</td>
<td>00111</td>
</tr>
<tr>
<td>111</td>
<td>10100</td>
</tr>
</tbody>
</table>

- $p_0$: the probability of 0 in the codeword table, ($p_0 = 31/40$ above)
- $p_1$: the probability of 1 in the codeword table, ($p_1 = 9/40$ above)
The block P/S is a Bit Separation, whose outputs are with different length bit streams.
The block P/S is a Bit Separation, whose outputs are with different length bit streams.
The block P/S is a Bit Separation, whose outputs are with different length bit streams.
The non-uniform capacity value is generated with respect to different $P_0$, i.e., different probability distribution of sub-constellations.
Outline

– Introduction

– Constellation Shaping

– Implementation

– Conclusion
– 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 finds 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

<table>
<thead>
<tr>
<th>γ</th>
<th>R</th>
<th>Rc</th>
<th>Rs</th>
<th>$\xi_b/N_0$ (Capacity Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>{2.64, 4.64}</td>
<td>3</td>
<td>3/5 (38880/64800)</td>
<td>1</td>
<td>4.029 dB</td>
</tr>
<tr>
<td></td>
<td>2/3</td>
<td>2/3 (43200/64800)</td>
<td>1/2</td>
<td>3.829 dB</td>
</tr>
</tbody>
</table>

![Graph showing BER curves for different modulation schemes.](image)

- **BICM Uniform**
- **BICM-ID Uniform**
- **Shaping (4,2)**
- **Shaping (6,3)**
- **Shaping (12,6)**
BER curves For Rayleigh fading channel

<table>
<thead>
<tr>
<th>$\gamma$</th>
<th>R</th>
<th>$R_c$</th>
<th>$R_s$</th>
<th>$\xi_b/N_0$ (Capacity Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.64, 4.64</td>
<td>3</td>
<td>3/5 (38880/64800)</td>
<td>1</td>
<td>6.259 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2/3 (43200/64800)</td>
<td>1/2</td>
<td>6.099 dB</td>
</tr>
</tbody>
</table>

![BER curves graph](image)
Outline

– Introduction

– Constellation Shaping

– Implementation

– Conclusion
Conclusion

– 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