재밍 환경에서의 FHSS 위성 통신 링크의 성능 분석

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Satellite Link

- Simple Bent-Pipe Transponder (BPT)
- Intentional Jamming and interceptor
- FFSS communication system
Introduction

- **Sysmte Block Diagram**

- **Consideration**
  - The performance improvement according to inner and outer interleaver
  - Soft and Hard Viterbi decoding in jamming environment
Channel Coding

- **RS Code**
  - Non-binary BCH Code with \(q(2^m)\)-ary alphabet
  - \((n_r, k_r, d_r)\) code
    - \(n_r\): the length of code word
    - \(k_r\): the length of information symbol word
    - \(d_r\): the minimum distance
  - Code Rate \(R_{\text{out}} = \frac{k_r}{n_r}\)

- **Convolutional Code**
  - Constraint length (K)
  - \((n_c, k_c)\) code
    - \(n_c\): output coded bits in shift register
    - \(k_c\): input information bits in shift register
  - Code Rate \(R_{\text{in}} = \frac{k_c}{n_c}\)
Serial Concatenated Code
- If Viterbi decoder is incorrectly decoded, a burst error would be occurred.
- A burst of errors in the 8 bits results in inner code is only one q-ary symbol error in outer code (q=256)

Inner Interleaver
- Make Slow-FHSS system to FHSS system
- Bit interleaving
- Avoid burst of bit errors
- Improve the performance of inner code

Outer Interleaver
- Symbol interleaving
- Avoid bursts of q-ary symbol errors
System Modeling

- Channel Model
  - Full and Partial band jamming
  - Partial overlap of the jammer with the hop bandwidth is ignored
  - AWGN noise is ignored ($N_J \gg N_0$)

- System Model
  - SFH/4FSK with non-coherent detection
  - Channel coding
    - Shortened RS code with Symbol $q=256(2^8)$
    - Binary Convolutional Code with constraint length $K=9$
    - Soft / Hard decision Viterbi decoder
    - Interleaver
System Modeling

- System parameter
  - Code parameter

<table>
<thead>
<tr>
<th>Case</th>
<th>RS code</th>
<th>Conv. Code</th>
<th>Code Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>(29,25)</td>
<td>1/2</td>
<td>25/58(1/2.3)</td>
</tr>
<tr>
<td>Case 2</td>
<td>(19,13)</td>
<td>1/3</td>
<td>13/57(1/4.4)</td>
</tr>
<tr>
<td>Case 3</td>
<td>(14,8)</td>
<td>1/4</td>
<td>1/7</td>
</tr>
</tbody>
</table>

- Interleaver size

<table>
<thead>
<tr>
<th>Case</th>
<th>Outer Inter. (Symbol)</th>
<th>Inner Inter. (Bit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>28 x 8</td>
<td>480 x 8</td>
</tr>
<tr>
<td>Case 2</td>
<td>19 x 8</td>
<td>480 x 8</td>
</tr>
<tr>
<td>Case 3</td>
<td>14 x 8</td>
<td>480 x 8</td>
</tr>
</tbody>
</table>
Simulation Result 1

- Full band jamming without any Interleaver

![Graph showing performance of FH/4FSK system with channel coding (without any interleaver)]
Simulation Result 1

- Full band jamming with only inner interleaver
Simulation Result 1

- Full band jamming with both interleavers
Partial band jamming
With inner interleaver
Without outer interleaver
Hard decision Viterbi decoding
Simulation Result 2

Performance of FH/4FSK System with Channel Coding (Case 2)

Performance of FH/4FSK System with Channel Coding (Case 3)
Simulation Result 3

- Partial band jamming
- With inner interleaver
- With outer interleaver
- Hard decision Viterbi decoding
Simulation Result 3

Performance of FH/4FSK System with Channel Coding (Case 2)

Performance of FH/4FSK System with Channel Coding (Case 3)
Simulation Result 4

- Partial band jamming
- With inner interleaver
- With outer interleaver
- Soft decision Viterbi decoding

![Graph showing the performance of FH/4FSK system with channel coding (Case 1). The graph plots BER (Bit Error Rate) against $E_b/N_0$ (Energy per bit to noise power spectral density) for different values of $\rho$. The legend indicates different cases with $\rho = 0.1, 0.3, 0.5,$ and $0.7$. The curves show the improvement in BER with increasing $E_b/N_0$.](image)
Simulation Result 4
Conclusion

- The performance of satellite communication system is improved by using inner and outer interleavers.

- The performance of channel coding (BER=10⁻⁵)

<table>
<thead>
<tr>
<th></th>
<th>Result 1</th>
<th>Result 2</th>
<th>Result 3</th>
<th>Result 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best</td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 2</td>
<td>Case 1</td>
</tr>
<tr>
<td>Worst</td>
<td>Case 3</td>
<td>Case 1</td>
<td>Case 1</td>
<td>Case 3</td>
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