Coherent Combining of Subframes in Interoperable L1 Band GNSS Signals

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Introduction

- Coherent combining
  - Adding the symbols of successive blocks of noisy signal.
  - Improves the Eb/No of the signal.
  - Useful in low SNR conditions.
  - Information of the signal should remain constant for the duration of combining.

\[
y_1 \ y_2 \ \ldots \ \ldots \ \ldots \ y_n
\]

\[
y_{m} \ - \ \text{symbol of the noisy signal}\]
\[
m = 1,2,3,\ldots,n
\]

- Energy per bit of each block is Eb.
- On combining \( k \) blocks coherently, the energy per bit of combined block will be \( k\text{Eb} \).
Why in L1 GNSS?

• Core navigation data
  - Satellite clock and ephemeris (CED) parameters
  - Position calculation
  - Accurate

• Low SNR condition scenario
  - Semi-indoor
  - Foliage
  - Subframe block discarded due to CRC failure

L1 signals
  - CED data in subframe 2
  - Data remain constant until data cut over
  - Systems: GPS, Beidou, NavIC, QZSS
Frame structure of L1 signals

**GPS L1C**
- Each frame contains three subframes.
- FEC used in SF2 is LDPC.

**BeiDou B1C**
- Each frame contains three subframes.
- FEC used in SF2 is NB-LDPC.

**NavIC L1C**
- Each frame contains three subframes.
- FEC used in SF2 is LDPC.
Coherent Combining in L1 GNSS

Frame 1
- SF 1
- De-interleave
- SF 1
- SF 2
- SF 3
- SF 2

Frame 2
- SF 1
- De-interleave
- SF 1
- SF 2
- SF 3
- SF 2

Frame k
- SF 1
- De-interleave
- SF 1
- SF 2
- SF 3
- SF 2

Coherent Combining
Simulation flow

1. **Noisy Signal**
   - Without coherent combining
   - With coherent combining

2. **Step A**
   - Collect the SF-2 blocks
   - Go to Step A
   - FER calculation
   - Valid SF-2 block

3. **BPSK demodulation**
4. **LDPC decoder**
5. **CRC check**
6. **FER calculation**

Flowchart:
- If CRC pass:
  - LDPC decoder
- If CRC fail:
  - BPSK demodulation
### Simulation results

**Target FER = 1e-3**

Table 1. FER of SF2 without coherent combining

<table>
<thead>
<tr>
<th>Eb/No (dB)</th>
<th>FER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1e-3</td>
</tr>
</tbody>
</table>

Table 2. FER of SF2 with coherent combining

<table>
<thead>
<tr>
<th>Eb/No (dB)</th>
<th>FER (w/o coherent combining)</th>
<th>No. of blocks combined</th>
<th>FER (with coherent combining)</th>
<th>Coherent combining gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>0.92</td>
<td>3</td>
<td>1e-3</td>
<td>5 dB</td>
</tr>
<tr>
<td>-6</td>
<td>0.9</td>
<td>6</td>
<td>1e-3</td>
<td>8 dB</td>
</tr>
<tr>
<td>-8</td>
<td>0.87</td>
<td>10</td>
<td>1e-3</td>
<td>10 dB</td>
</tr>
</tbody>
</table>

![Graph showing FER vs. No. of blocks combined for different Eb/No ratios](image)
Summary

• In low SNR conditions, due to failure of CRC, subframe discarded.

• By coherent combining, Eb/No of the subframe block can be increased, resulting in improvement in FER, hence availability of navigation data is improved.

• Tracking thresholds are at low level for low SNR conditions, the corresponding data demodulation thresholds can also be lowered by using this technique.

• In addition to AWGN channel, simulations is being further extended to fading channels.
Thank You