Methods of improving efficiency of interference suppression GNSS anti-jam receivers.

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Block diagram of the multi-antenna GNSS receiver
Block diagram of the multi-antenna GNSS receiver
Nullformer

\[ w_{opt} = R_{ZZ}^{-1} r_{ZE} \]

\[ R_{ZZ} = \langle Z^H Z \rangle \]

\[ r_{ZE} = \langle Z^H E \rangle \]

Output signal:

\[ Y = E - Z w_{opt} \]

\[ Z = (Z_1, Z_2, \ldots, Z_N) \]

\( E \) – reference channel signal

\( Z_i \) – \( i \)-th adjusting channel
DoA Estimation by Capon method

\[
R_{XX} = \langle X^H X \rangle \quad X = (E, Z)
\]

\[
P_{\text{CAP}}(\theta, \phi) = \frac{1}{a(\theta, \phi)^H R_{XX}^{-1} a(\theta, \phi)}
\]
Interference-free subspace:

\[ R_{xx} = UAU^H \]

\[ U = (\hat{U}, \hat{\bar{U}}) \]

\[ Y = X \cdot (\hat{U}, \hat{\bar{U}}) = (\hat{Y}, \hat{\bar{Y}}) \]

\[ (\hat{Y}, \hat{\bar{Y}}) \cdot (\hat{U}^H, \hat{\bar{U}}^H) = \hat{X} + \hat{\bar{X}} \]

\[ A = \text{diag}(\lambda_1, \lambda_2, ..., \lambda_N) \quad \lambda_1 \leq \lambda_2 \leq ... \leq \lambda_N \]

Interference-free subspace:

\[ \hat{U} = (u_1, ..., u_{N-J}) \]

Interference subspace:

\[ \bar{U} = (u_{N-J+1}, ..., u_N) \]

\[ \hat{X} \quad \text{- interference-free signal} \]

\[ \bar{X} \quad \text{- interference signal} \]

\[ \lambda_{th} = v_0 + P_s \]

\[ P_s \quad \text{- maximum power of GNSS signals} \]
DoA Estimation by MUSIC

\[ P_{MUS}(\theta, \phi) = \frac{1}{a(\theta, \phi)^H \hat{U} \hat{U}^H a(\theta, \phi)} \]
Block diagram of the multi-antenna GNSS receiver
Beamforming

\[ S = X \Phi_{SV} \star U U^H \]
Factors affecting the efficiency of anti-jam devices base on spatial selection signals

- Dynamic range ADC
- Channel non-identity
- Multipath interference
Dynamic range (cutoff)

Interference is Gaussian noise: $C_{\text{max}} = 20 \log_{10} \left( \frac{2\uparrow D}{3} \right)$
Channel identity (calibration)
Channel identity (narrowband processing for broadband signals)

\[ \Psi(\tau) * H\downarrow 1 + \Psi(\tau) * H\downarrow 2 + ... \\
+ \Psi(\tau) * H\downarrow P = \\
\Psi(\tau) * \sum_{p=1}^{P} H\downarrow p \Rightarrow \\
\sum_{p=1}^{P} H\downarrow p = \delta \]
Multipath interference (STAP)

\[ X_1(t_i) \]

\[ X_K(t_i) \]
Increase of computational affinity of matrix inversion by systolic array

\[ R_{XX} = QR \]

BC – Boundary Cell
IC – Internal Cell
Increase of computational affinity of EVD

PE- Processor Element
Anti-jam receiver

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNSS Systems</td>
<td>Glonass/GPS</td>
</tr>
<tr>
<td>Antenna</td>
<td>4-element CRPA</td>
</tr>
<tr>
<td>Tracking and navigation channels</td>
<td>48</td>
</tr>
<tr>
<td>Position accuracy (1σ)</td>
<td>V: 3 m</td>
</tr>
<tr>
<td></td>
<td>H: 5 m</td>
</tr>
<tr>
<td>Velocity (1σ)</td>
<td>0,05 m/s</td>
</tr>
<tr>
<td>Temperature range</td>
<td>from -60 to +85°C</td>
</tr>
<tr>
<td>Size/Volume</td>
<td>115x115x50 mm</td>
</tr>
<tr>
<td>Power</td>
<td>14 W</td>
</tr>
<tr>
<td>Weight</td>
<td>1,3 kg</td>
</tr>
</tbody>
</table>
Conclusions:

• Describes the basic methods of building GNSS anti-jam receiver;
• Basic factors affecting anti-jam technology are considered, such as:
  - dynamic range
  - channel non-identity
  - Multipath interference
• Basic ways of suppression of these factors are reviewed;
• Ability to use systolic arrays for improving computational efficiency, including for the purposes:
  - QR-decomposition
  - EVD-decomposition
• All reviewed solutions are implemented in serial GNSS anti-jam receivers of MDB «Compas».
Thank for your attention

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