Time stability of the K-band catalog sources

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Outline

• K-band in ICRF3
• Brief review on how to use the Allan variance to determine noise floor of source time series
• Noise floor of the latest GSFC K-band time series solution and comparison with the latest GSFC S/X time series solution on 3 different sets
K-band

K-band in ICRF3


This paper: Study of the latest GSFC time series solutions for K and S/X.

<table>
<thead>
<tr>
<th></th>
<th>K solution</th>
<th>S/X solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source #</td>
<td>906</td>
<td>4775</td>
</tr>
<tr>
<td>Session #</td>
<td>65</td>
<td>6271</td>
</tr>
<tr>
<td>Source # (≥10 sessions)</td>
<td>354</td>
<td>788</td>
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</tbody>
</table>

310 common sources

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K-band and S/X-band
Position time series examples

Different ways to look at these time series:

- Standard deviation => static quantity;
- Noise floor determined with the Allan variance => takes into account the time variable.
Using the Allan variance to determine noise floor (1/2)

• The Allan variance is a statistical tool that gives the level and type of noise of time series.
• If \( \left( x_i \right)_{i=1,n} \) are the measurements and \( \tau \) the sampling time, the Allan variance is:

\[
\sigma^2(\tau) = \frac{1}{2} \left\langle \left( \overline{x_{i+1}} - \overline{x_i} \right)^2 \right\rangle
\]

• Type of noise determined by the slope of the curve: 

\[
\log_{10} \left( \sigma^2 \right) = f \left( \log_{10} (\tau) \right)
\]
Real data: sources not observed regularly => difficulties in statistical determination due to gaps in between observations, number of observations,...

Preprocessing of the time series.

- **Step 1**: Keep sources with 10 or more observations.
- **Step 2**: Averaging (yearly and monthly) and interpolation. Threshold cut-off when interpolating.
- **Step 3**: Allan variance processing for each source, each coordinate, each averaged time series.
- **Step 4**: Noise floor determination for each source and each coordinate. We look at the noise type determined by the slope of the Allan variance curve:
  - White noise or flicker noise: the noise floor is the lowest Allan variance value.
  - Random walk: source rejected.
Comparison 1/3
310 common sources – Period 1979-now

Noise floor determined by the Allan variance

The K noise floors tend to be smaller than the S/X noise floors.

Standard deviation
Comparison 1/3
310 common sources – Period 1979-now

Noise floor comparison in 10° declination bands

RAcos(DEC)

Source noise floor (µas)

S/X noise floor
K noise floor

DEC

Source noise floor (µas)

S/X noise floor
K noise floor

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Focus on same period of observation:

November 2016 to November 2018.

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<tr>
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<th>S/X solution</th>
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<tbody>
<tr>
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<td>254</td>
<td>431</td>
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</table>
Comparison 2/3
87 common sources – Period 11/2016-11/2018

RAcosDEC (mas)
0552+398
S/X Standard dev: 0.347
K Standard dev: 0.158

RAcosDEC (mas)
3C120
S/X Standard dev: 0.319
K Standard dev: 0.183

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87 common sources – Period 11/2016-11/2018

The S/X noise floors tend to be smaller than the K noise floors.

Noise floor determined by the Allan variance

Standard deviation
Noise floor comparison in $10^\circ$ declination bands
• UD sessions: 24-hour VLBA sessions at K-band.

• UF001 and UG002 sessions: 24-hour VLBA sessions at S/X band. Goals: improving the precision of ICRF3, ICRF3 maintenance, and future updates of the ICRF at radio frequencies. Approximately 3300 of the weakest ICRF3 sources will be re-observed during these sessions.

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<tr>
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<th>S/X solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source #</td>
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<td>Session #</td>
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<tr>
<td>Source # (≥10 sessions)</td>
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<td>132</td>
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</table>

31 common sources

RAcosDEC (mas)
0552+398

K Standard dev: 0.150

S/X Standard dev: 0.214

S/X Standard dev: 0.209

S/X Standard dev: 0.209

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The K noise floors and the S/X noise floors seem to be equivalent.

Noise floor determined by the Allan variance

Standard deviation
Noise floor comparison in 10° declination bands

![Graphs showing noise floor comparison in 10° declination bands.]

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Conclusions

• **K-band time stability**
  • The K-band observations have reached a level of stability equivalent to the level of current S/X observations.
  • The strength of the S/X data set is in its broad diversity of baselines and sessions.
  • We need to continue monitoring the K-band observations and comparing the stability of the frame realized by the K-band observations with the S/X frame.

• Thanks to the VLBA, K-band observations have increased greatly in the past two years, prompting many studies. At the 2019 EVGA:
  • Benedikt Soja: “Ionospheric calibration for K-band celestial reference frames”.
  • Hana Krásná: “Earth orientation parameters estimated from K-band VLBA measurements”.
  • Aletha de Witt: “The K-band (24 GHz) Celestial Reference Frame”.

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Thank you
Structure, proper motion?

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Noise floor comparison
Individual sources

Noise floor determined by the Allan variance

Standard deviation

(157/142 sources) Entire period (310 sources)

(24/28 sources) 2-yr period (87 sources)

(74 sources) VLBA sessions (31 sources)

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