SINEX File Implementation in the VLBI Calc/Solve Analysis System

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Overview

The original design of the SINEX (Solution INdependent Exchange) format was for combining several GPS solutions. However, later this format evolved toward a common machine-readable form of solution listings for other space geodesy techniques, for example, VLBI and SLR. This process of evolution is not yet completed, therefore, different software systems implement different options for the Sinex format.

The solution listing in SINEX 2.10 format produced by Solve contains information about stations, sources, estimates of the parameters, their covariance matrix, the constraint equations, the right-hand side of constraint equations and weight matrix of constraint equations. In addition to these results, a portion of the decomposed normal matrix and normal vector can be included in the listing as well. A user has control over which blocks should be included in the listing. The current implementation of the SINEX format allows one to include in the listing the most important parameters, for example, station positions, source positions, and Earth orientation parameters. However, a user has control over which parameters among the parameters of the supported type are to be included or not included in the listing. A description of the SINEX implementation in VLBI analysis at GSFC is given in <[1]>.

Differences from the SINEX 1.00 standard

In Sinex 2.10 format, eight new blocks were added to the list of blocks of Sinex 1.00

- SOLUTION/CONSTRAINT_EQUATION_INFO
- SOLUTION/CONSTRAINT_EQUATION_MATRIX
- SOLUTION/CONSTRAINT_EQUATION_VECTOR
- SOLUTION/CONSTRAINT_WEIGHT_MATRIX

The purpose of these four blocks is to overcome problems in the original design of Sinex format and provide complete information about all constraints used in the VLBI solution.

- SOLUTION/DECOMPOSED_NORMAL_MATRIX **D**ii
- SOLUTION/DECOMPOSED_NORMAL_VECTOR **d**i

The purpose of these blocks is to provide information about the transformed normal equations before applying constraints. NB: one of the three items: covariance matrix, constraint equations and decomposed normal equations is redundant: having two of them one can derive the third one.

- NUTATION/DATA
- PRECESSION/DATA

The purpose of this section is to provide information about used nutation/precession model and to define parameter “estimates of nutation angles”.

[1] http://gemini.gsfc.nasa.gov/solve_root/help/sinex.html

SOLUTION/STATISTICS block has new items:

- WEIGHTED SQUARE SUM OF O–C
  $\sum_{obs} y^T W y$
- WRMS OF POSTFIT RESIDUALS
  $\sum_{obs} [(Nx-y)^T W (Nx-y) / Tr(W)$

where y = the difference between the observed time delay and theoretical, N = normal matrix, x = vector of the parameter, adjustments, and W = weight matrix.

Summing is done over all observations used in parameter estimation. Comment: field WEIGHTED SQUARE SUM OF O–C is not computed in global mode.

The BLOCKS which keep elements of matrices do not have fields "Second Matrix Element" and "Third Matrix Element".

The purpose of this change is to facilitate the process of creation of the listing and to reduce significantly the probability of errors.

SOLUTION/MATRIX_APRIORI is not provided. The reason is that Solve does not use an apriori covariance matrix. It uses singular constraints that cannot be reduced to the form of an apriori covariance matrix. Full information about constraints is provided in other blocks.

Definitions

Let the normal matrix **N** and the normal vector **n** be partitioned in two blocks, i (included parameters) and e (excluded parameters). Let the matrix of constraints **C** be added to **N**. Let $\mathbf{C_{ii}} = 0$ and $\mathbf{C_{ei}} = 0$. If the matrix $\mathbf{N_{ee}} + \mathbf{C_{ee}}$ is not singular, then there exists a matrix **M** such that

$$M \begin{pmatrix} N_{ii} & N_{ie} \\ N_{ei} & N_{ee} + C_{ee} \end{pmatrix} = \begin{pmatrix} D_{ii} & 0 \\ 0 & D_{ee} \end{pmatrix}$$

$$M \begin{pmatrix} n_i \\ n_e \end{pmatrix} = \begin{pmatrix} d_i \\ d_e \end{pmatrix}$$

The matrix $\mathbf{D_{ii}}$ is called the *decomposed normal matrix* and the vector $\mathbf{d_i}$ is called the *decomposed normal vector*. The matrix is partitioned to keep the parameters of interest in the i-block and the excluded parameters in the e-block.

The decomposed normal matrix $\mathbf{D_{ii}}$ can be computed from the blocks of the covariance matrix of the constrained (least squares) LSQ solution. Assuming that the normal matrix of constraint has blocks $\mathbf{C_{ei}} = 0$, we can express the covariance matrix **V** of the constrained LSQ solution as

$$\left(\begin{pmatrix} N_{ii} & N_{ie} \\ N_{ei} & N_{ee} \end{pmatrix} + \begin{pmatrix} C_{ii} & 0 \\ 0 & C_{ee} \end{pmatrix} \right)^{-1} = \begin{pmatrix} V_{ii} & V_{ie} \\ V_{ei} & V_{ee} \end{pmatrix}$$

In this case, the decomposed normal matrix $\mathbf{D_{ii}}$ and the decomposed normal vector $\mathbf{d_i}$ can be expressed as

$$D_{ii} = V_{ii}^{-1} - C_{ii}$$
$$d_i = D_{ii} x_i$$

where $\mathbf{x_i}$ is the i-block of the vector of estimates from the LSQ constrained solution.

SINEX file listing for a global solution

Parameters included in the listing:

- site positions (global)
- site velocities (global)
- radio source positions (global)

Parameters NOT included in the Sinex file:

- Antenna axis offsets (global)
- X pole, Y pole, UT1 and their rates
- Daily nutation offsets
- Clock function
- Baseline dependent clock offsets
- Atmosphere path delay
- Atmosphere gradients

Examples:

WEB pages <[1],[2]>

Source positions were not included in this listing. The solution description is in <[3]>.

SINEX file listing of daily solutions

Parameters included in the listing:

- daily site positions
- X pole, Y pole, UT1 and their rates
- Daily nutation offsets

Parameters NOT included in the Sinex listing

- clock function
- baseline-dependendent clock offsets
- atmosphere path delay
- atmosphere gradients

A collection of 3400 sinex files of daily solutions is in <[4]>.

The solution description is in <[5]>.

A new file is added within 24 hours after the correlation of each new 24-hour experiment session.

[1] http://gemini.gsfc.nasa.gov/solutions/2002c/2002c_all.snx
[2] http://gemini.gsfc.nasa.gov/solutions/2002c/2002c_trf.snx
[3] http://gemini.gsfc.nasa.gov/solutions/2002c/2002c_trf.snx
[4] ftp://cddisa.gsfc.nasa.gov/pub/vlbi/ivsproducts/daily_sinex/gsfd0001/
[5] ftp://cddisa.gsfc.nasa.gov/pub/vlbi/ivsproducts/daily_sinex/gsfd0001.dsnx.txt