Terrestrial Data Analysis and SINEX Generation

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Abstract. This position paper focuses on the computation of local ties between co-located space geodetic instruments using terrestrial data, and on SINEX generation. We address also some important aspects related to the Reference Point (RP) definition for the various instrument types, i.e. VLBI, SLR, GPS and DORIS. The main issue is related to the data analysis of the terrestrial data, and to the generation of the final SINEX files, which should contain the full variance covariance matrix for the local ties. Finally, we provide recommendations regarding local tie determination and the documentation of the results.

1 Introduction

Co-locations and local ties (intra-site vectors) between the space geodetic instruments are a key element for integrating the reference frame results from the different techniques, such as VLBI, SLR, GPS and DORIS. Both, the current situation regarding distribution of co-location sites and accuracy of local ties is not satisfying. Furthermore, the ITRF2000 results indicate that there are a number of dubious or erroneous local ties (Altamimi et al., 2002, Altamimi, 2005). Discrepancies between local ties and the space geodetic solutions were also identified at DGFI using the results of TRF computations (Angermann et al., 2004, Krügel and Angermann, 2005). An interpretation of the existing discrepancies is difficult since various factors have to be considered, such as systematic biases between space geodetic solutions, local site dependent effects, errors in local ties, remaining inconsistencies related to the datum definition. Regarding a better separation of these effects and to identify still remaining technique-specific systematic biases, the local ties between co-located instruments should be determined with the highest possible accuracy. This is also very important to fully exploit the unique capabilities and the individual strengths of the different space techniques.

To achieve this high accuracy requirement for the local ties various issues need to be addressed, including the design of the local network, the instrumentation and technical equipment, the surveying methodology, the realization of the reference points for the various instrument types, computational and software-related aspects, transformation of the local network into the global frame, documentation of local surveys and representation of final results in SINEX format.

This position paper concentrates on issues related to the data analysis and the SINEX generation, the other topics mentioned above are primarily addressed in other sessions of this workshop. A key issue in precise local tie determination is the definition and realisation of the reference point for the different instrument types, which is addressed in Chapter 2. In Chapter 3 some specific observational aspects are presented. Computational issues (software, estimation models, analysis strategy), including the generation of a complete correlation matrix corresponding to the intra-site vector are addressed in Chapter 4. Finally, the documentation and representation of local tie results in SINEX format are presented in Chapter 5.

2 Aspects related to Reference Point definition

A fundamental aspect that must be taken into account when performing a local tie determination is the physical definition of the Reference Point (RP) of each space geodetic technique. In principle, there are two different types of instruments, those with mechanically moving parts to control the direction of data acquisition (VLBI and SLR), and those with radio-frequency antennas simultaneously sensitive to signals from all directions (GPS and DORIS).

VLBI: The RP is defined as the intersection of the fixed axis with the orthogonal plane to it, containing the moving axis (Ma 1978). This definition takes into account the possible presence of an offset and applies to all kinds of VLBI telescopes. Nevertheless, it isn't general enough because it does not take into account the possible presence of a fixed skew angle (i.e.: a lack of orthogonality between the fixed and the moving axis): in this case, the plane containing the moving axis does not exist. The RP is generally defined as the point on the fixed axis having minimum distance from the moving axis.

In practice, the observations performed to several calibrating radio sources at different frequencies, allow the estimates of eight parameters that are related to the general telescope orientation and to its deformation due to gravitational and other loading effects. These parameters have an impact on the azimuth and elevation pointing angles. In this case, also the skew error is taken into account. Its estimated value at different observing frequency can change considerably (up to 0.03 gon) while, in principle, it should remain constant. Terrestrial observations of the VLBI telescope aiming to RP determination might have an impact on the determination of some of these relevant parameters and would therefore represent a precious source of information offering the possibility to constraint their values.

There are practically three different approaches that are currently used for recovering the position of the VLBI RP:

1. Direct approach: on some VLBI telescopes the RP is materialized using a target and it is observed as all the other points that form the local network. The RP is therefore estimated straightforwardly in the terrestrial data adjustment. It is clear that, using this so-called "direct" approach, no information related to the telescope orientation/deformation can be recovered. Furthermore, since the materialized point is not connected to the physics of observations, it is unlikely that it is identical to the real RP.
2. Hybrid approach: it is represented by the physical materialisation of the rotational axes using appropriate targets (Nothnagel et al., 2002). Observations of these targets during rotational sequences allow the determination of the RP provided that they represent the rotational axes. With this "hybrid" approach no information on the fixed axis and moving axis orientation will be available. Furthermore, no information on VLBI antenna deformation can be recovered (but, at the same time, deformations will most likely not affect the measurements). The accuracy of other relevant unknown VLBI telescope's structure characteristics (e.g. skew angle, offset, tilt angle) will depend on how accurately the elevation axis is materialized and represented by the targets.
3. Indirect approach: it is based on the definition of the axes (i.e.: the RP) through the observation of rotational sequences of targets widely and opportunely installed on the antenna structure (Dawson and Johnston, 1999; Sarti et al., 2000). This "indirect" approach uses geometrical considerations to constraint the positions of the targets and will be heavily affected by gravitational deformations of the radio telescope structure, and consequently aims at realising the physical definition of the RP from

terrestrial measurements techniques. At the same time it is very flexible, offering the possibility to estimate the tilt of the fixed axis, the skew angle and other desired parameters. In principle, there is the possibility to superimpose a finite element deformation model of the antenna structure to the target positions estimate for a more accurate determination of the sought VLBI RP.

The need of investigating the structural antenna models and the delay corrections introduced in VLBI data analysis is a very important subject that must be studied and possibly linked to terrestrial data analysis in order to ensure a reasonable, efficient and consistent computation of the RP based on terrestrial observations.

SLR-LLR: the RP is defined, similarly to the VLBI case, as the intersection of the two axes of the telescope: the fixed axis and the moving axis. The RP definition is, for the indirect methodology mentioned above, equivalent to the VLBI one. It is therefore possible to apply this approach to SLR-LLR telescopes with no major changes. The hybrid methodology could, in principle, be applied too. The materialisation of the axes would in this case be more dependent on the design of the telescope. There is no possibility of applying the direct methodology at SLR-LLR telescopes because the RP is inaccessible.

GPS and **DORIS**: for these two techniques, the RP is a physical point in the antenna such as the bottom of the amplifier housing of the ground plane, the so-called Antenna Reference Point (ARP). In principle, the RP definition for GPS and DORIS is equivalent and it is based on the external structure of the antenna. The ARP may directly be the tracking point of the system or may be related to a physically materialized geodetic marker using an eccentricity vector. The survey of DORIS and GPS ARP can be performed using an indirect approach, triangulating the external shape of the antenna (Sarti et al. 2004). This approach requires no removal of the antenna and is particularly useful in permanent networks where the tracking point has been chosen to be the ARP itself. Simple geometrical considerations are chosen and applied for ARP computation. If the tracking point is an external geodetic marker, a direct approach is used: a target is linked to the marker and observed. A combination of the two approaches allows the precise determination of the *intra-technique eccentricity* (i.e. the eccentricity between the technique-related geodetic marker and the RP) which, for almost all GPS sites, is expected to remain stable in time. This is not the case for most of the DORIS tracking systems, where the antenna is placed on a mast and the geodetic marker can be missing.

Recommendation 1: A clear definition of RPs should be developed by the analysis communities for each space geodetic technique.

Recommendation 2: An external geodetic marker exists for each technique. An accurate intra-technique eccentricity should be re-estimated every time the local tie survey is performed regardless the RP coincides with the tracking point or not.

Recommendation 3: The space geodetic analysis and local tie analysis community (e.g. the newly created IERS working group on local ties, all local survey groups) should develop new local tie products for use in analysis (e.g.: skew angle, tilt angle, wobble, structural deformations).

3 Ground observations

Taking into account the high accuracy requirement of 1 mm for local tie determination, the issues related to site surveys for co-locations are extremely important, including the design of the local network, planning and strategies for ground observations, site monumentation and local control networks, monitoring local site stability, surveying methods and technical equipment. All these issues are addressed in session 2 “Site Surveys” of this workshop.

A few specific remarks related to ground observations and network design are provided below:

- Technical aspects: It is important that properly calibrated high precision instrumentation and high precision devices should be extensively used in order to ensure accurate results.
- Design of local network: This is a very important aspect since the design of the network directly influences the correlation matrix associated to the eccentricity vector estimate. Different choices operated on the geometry of the observations considerably affect the correlations between the components of the space geodesy RP techniques (Sarti et al. 2004).
- Terrestrial observations: The measurements of angles and distances, along with height differences, are used to adjust the local network and estimate target positions. The relevant corrections that must be taken into consideration for an accurate terrestrial data processing are refraction and geoid undulation.

Recommendation 4: High precision instrumentation and devices should always be adopted. Minimum requirements on instrumentation and measurement redundancy should be set.

Recommendation 5: A priori simulations of terrestrial observations should be undertaken so as to assess the impact of different survey designs.

4 Computation

This chapter concentrates on several aspects related to the adjustment of the local networks in order to provide accurate local tie results. This topic was the major focus of this session “Analysis and SINEX” of this workshop. Examples of site surveying and eccentricity vector estimation at different co-location sites were presented during this workshop (see e.g. Dawson et al., 2005; Johnston et al., 2005; Michel et al., 2005; Schlüter et al., 2005; Vittuari et al., 2005). These examples provide an overview of the wide spectrum of this topic, which is demonstrated also by other publications (e.g. Kanao et al., 1995; Dawson and Johnston, 1999; Johnston et al., 2000; Long and Bosworth, 2000; Sarti et al., 2000; Tomasi et al., 2001; Nothnagel et al., 2002). Thus, it is obvious that the situation regarding site surveys and computation of local ties is very much dependent on the specific approach applied when measuring the RP and on specific conditions at a co-location site, and it is not therefore easy to provide general guidelines and recommendations. Furthermore, it should be considered, that there are various groups involved in site surveys, using a wide variety of software for adjusting the local networks (e.g. Microsearch Geolab, STAR*NET, PANDA, CREMER, …), and applying different computation methodologies. This clearly shows that there are (at present) no common standards or recommended procedures for computing local ties.

The idea of this position paper is to address some aspects related to this topic in order to stimulate discussions between the relevant groups, and to make some recommendations for future improvements:

- An important question is the realization of the Reference Point for different space geodetic instrument types. In particular, there is no unique choice that can be operated on the geometrical constraints applied in the indirect approach. They will most probably have an effect on the final estimate and the associated correlation matrix. It is therefore important to plan an *ad hoc* survey at a representative co-location site and measure the eccentricity vectors. The data should be collected with the intention of producing a common dataset on which all the available post-processing software based on the indirect methodology can run and estimate the surveyed eccentricities. The same considerations apply to the hybrid survey approach, where the axis are materialized: different procedures should be compared;

- A sufficiently sophisticated modelling of relevant effects must be ensured: it has to be possible to take into account refraction and deviation of the vertical and therefore produce an accurate estimate of the positions of surveyed targets;
- A number of questions related to the computation methodology (e.g. weighting of different observation types, transformation of local network into the global frame, datum definition of the local ties) need to be studied;
- A survey of software used for the local network adjustment should be initiated.

The issues mentioned above should be addresses by the recently created IERS working group on co-locations in cooperation with other relevant groups, i.e. the ITRF combination centres, analysis and technique centres of the different space techniques, etc.

Recommendation 6: Survey and comparison of different software systems used for the adjustment of local networks (definition of a suitable pilot project) should be performed.

Recommendation 7: A common data set on a representative co-location site should be provided to compare the direct, hybrid and indirect approaches to RP determination.

5 Documentation and SINEX generation

The topic of local survey documentation was addressed in session 4 "reporting" of this workshop. A draft version of a standard documentation called "Local surveys document for co-located space geodetic techniques within the International Terrestrial Reference Frame" was discussed concerning content, the level of detail, the organization and the format (see contributions of session 4, this volume).

In this position paper we focus on the representation and documentation of the final local tie results, which should be done in the Solution INdependent EXchange format (SINEX) for space geodesy. A consistent format description for all space geodetic techniques is available, i.e. SINEX 2.00[1]. Examples for local tie SINEX files are also available, i.e. the local ties used for ITRF2000 computation[2], and local survey results of the Australian Surveying and Land Information Group, AUSLIG (see attached SINEX file for the co-location site Yaragadee as an example). The local survey results for all co-location sites should be available in SINEX format. In addition, also the exchange of local survey terrestrial observations is of great importance for promoting a comparison of different software. Datasets containing the terrestrial observations should be available for computation and processing by all the groups interested in estimating eccentricity vectors. For this purpose clearly stated standards are needed.

[1] see http://alpha.fesg.tu-muenchen.de/iers/sinex/format
[2] see ftp://lareg.ensg.ign.fr/ pub/itrf/itrf2000/tiesnx/*.SNX

Concerning the final generation of local tie SINEX files there are remaining open issues, which need to be addressed within the space geodesy community and in particular within the recently created IERS working group on site co-locations. Important aspects include:

- Contents of the SINEX files: It should contain the largest amount of information concerning the local network in order to compare the stability of the site from one local survey to the other. The full variance covariance matrix should be available, also the submission of unconstrained normal equations is recommended. It should be agreed, which SINEX blocks are mandatory.
- Reference frame for local tie results: In principle, the results could be provided in an arbitrary local frame, or it is possible to exchange the coordinates in a global frame (e.g. ITRF). How the mapping in the global frame should be done is an open issue. GPS observations should provide a reliable and (sub-millimetre) accurate orientation via the IGS satellite orbits. The scale of the local network should be defined precisely by the terrestrial observations and GPS. How the reference frame should be defined also depends on the way data are used afterwards. Important is, that any constraints applied to the local network adjustments will be completely reported in the SINEX files.
- Time stability of local ties: Control measurements at co-location sites are important to detect any changes in the local ties, i.e. after a large earthquake in the vicinity of a co-location site (e.g. Arequipa, Peru) a re-survey of the local ties is mandatory. A major question regarding the documentation of local tie results is, how possible site depending effects should be considered in the SINEX files, i.e. constant local ties for a defined time period, or even time dependent local ties.

Recommendation 8: Standards on raw terrestrial data archiving and sharing must be developed.

Recommendation 9: There should be an agreement on the type and number of stations to be included in SINEX.

Recommendation 10: There should be an agreement on the reference frame in which the local ties are expressed and how they are mapped into this reference frame.

Recommendation 11: There should be an agreement on the generation of SINEX files: (e.g.: which blocks should be mandatory, the submission of unconstrained normal equations is recommended).

References

Altamimi Z., P. Sillard, C. Boucher (2002): ITRF2000: A New Release of the International Terrestrial Reference Frame for Earth Science Applications, J. Geophysical Res., 107 (B10), 2214, doi: 10.1029/2001JB000561.

Altamimi Z. (2005): ITRF and Co-location Sites, this volume.

Angermann D., H. Drewes, M. Gerstl, R. Kelm, M. Krügel, B. Meisel (2004): ITRF Combination – Status and Recommendations for the Future, presented at IUGG 2003 (in press).

Dawson J. and G. Johnston (1999): The determination of the Intersection of axes. Internal Report, Australian Surveying and Land Information Group (AUSLIG).

Dawson J., G. Johnston, B. Twilley (2005): The determination of telescope and antenna Invariant Point (IVP), this volume.

Johnston G., J. Dawson, B. Twilley, P. Digney (2000): Accurate Survey Connections between Co-located Space Geodesy Techniques at Australian Fundamental Geodetic Observatories. Tech Rep 3. AUSLIG Geodesy, Australia

Johnston G., J. Dawson, B. Twilley (2005): Precision surveys at Australian geodetic observatories, this volume.

Kanao M., K. Shibuya, K. Watanabe, S. Fujiwara, H. Ikeda, K. Okano (1995): A Note on Geodetic Ties among Several Reference Points by Different Space Geodetic Techniques at Syowa Station, Antarctica. J of Geod Soc of Japan 41(4): 357–364

Krügel M. and D. Angermann (2005): Analysis of local ties from multi-years solutions of different techniques, this volume.

Long J. and J. Bosworth (2000): The Importance of Local Surveys for Tying Techniques Together. In: Vandenberg N, Baver K (eds.) International VLBI Service for Geodesy and Astrometry 2000, General Meeting Proc NASA/CP-2000-209893

Ma C. (1978): Very Long Baseline Interferometry applied to Polar Motion, Relativity and Geodesy, NASA Tech. Memorandum 79582, Greenbelt (MD).

Michel V., G. Roesch, J. Long (2005): Hartebeesthoek Co-location Survey, this volume.

Nothnagel A., D. Behrend, S. Bergstrand, B. Binnenbruck, R. Haas, C. Steinforth (2002): Local Survey Ties at VLBI Observatories, ed. J. Campbell, R. Haas, A. Nothnagel, TMR Network, FMRX-CT96-0071 Scientific Report 1996–2001, Bonn, 62–97.

Sarti P., P. Sillard, L. Vittuari (2004): Surveying co-located Space Geodetic Instruments for ITRF computation, J Geodesy 78 (3), 210–222.

Sarti P., L. Vittuari, P. Tomasi (2000): GPS and classical survey of the VLBI antenna in Medicina: invariant point determination, Proceedings 14th Working Meeting on European VLBI for Geodesy and Astrometry, Castel San Pietro Terme (Bologna), Italia, 8–9 Settembre, pp. 67–72.

Schlüter W., R. Zernecke, S. Becker, T. Klügel, D. Thaller (2005): Local ties between the reference points at the Fundamentalstation Wettzell, this volume.

Tomasi P., P. Sarti, M.J. Rioja (2001) The determination of the Invariant Point of the VLBI antenna in Ny Ålesund. Mem. of National Institute of Polar Research 54, 319–330.

Vittuari L., P. Sarti, P. Sillard, P. Tomasi, M. Negusini (2005): Surveying the GPS-VLBI eccentricity at Medicina: methodological aspects and practicalities, this volume.

Appendix: SINEX file of local ties at co-location site Yaragadee, provided by the Australian Surveying and Land Information Group (AUSLIG)

```
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*-------------------------------------------------------------------------------
* SOLUTION INDEPENDANT EXCHANGE FORMAT (SINEX) FOR SPACE GEODESY.
* - SINEX VERSION 1.00
* - FILE CREATED BY PROGRAM SINEX_LT V1.0
* - TECHNIQUE IS COMBINED GPS AND TERRESTRIAL (C) - LOCAL TIE SURVEY
* - SINEX FILE FOR LOCAL TIE SURVEY AT YARAGADEE SLR STATION
* - SOLUTION COMMENTS
*-------------------------------------------------------------------------------
+FILE/REFERENCE
 DESCRIPTION        Australian Surveying and Land Information Group
 OUTPUT             AUSLIG LOCAL TIE SURVEYS
 CONTACT            jimsteed@auslig.gov.au
 SOFTWARE           SINEX_LT V1.0
 HARDWARE           HP 735
-FILE/REFERENCE
*-------------------------------------------------------------------------------
+FILE/COMMENT
-FILE/COMMENT
*-------------------------------------------------------------------------------
+INPUT/HISTORY
*O_FM VER_ AGY TIME_STAMP__ DAT DATA_START__ DATA_END____ T PARAM C TYPE________
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-INPUT/HISTORY
*-------------------------------------------------------------------------------
+INPUT/FILES
*AGY TIME_STAMP__ FILE_NAME____________________ DESCRIPTION_____________________
 AUS 00:102:00000 AUS00C04.SNX                  YARAGADEE LOCAL TIE SINEX FILE
-INPUT/FILES
*-------------------------------------------------------------------------------
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ APP_H_
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 YARR  A 50107M006 C Yaragadee, IGEX GPS    115 20 49.1 -29 02 47.7  241.4
 YARA  A 50107S006 C Yaragadee, DORIS       115 20 48.0 -29 02 46.9  243.4
 7090  A 50107M001 C Yaragadee, SLR Gd Mk   115 20 48.2 -29 02 47.3  241.4
 YIVP  A 50107S007 C Yaragadee, SLR         115 20 48.2 -29 02 47.3  244.5
 YARB  A 50107S010 C Yaragadee, DORIS       115 20 48.0 -29 02 46.9  243.7
-SITE/ID
*-------------------------------------------------------------------------------
+SOLUTION/EPOCHS
*CODE PT SOLN T _DATA_START_ __DATA_END__ _MEAN_EPOCH_
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 YARR  A    1 C 98:234:00000 98:237:00000 98:236:00000
 YARA  A    1 C 98:234:00000 98:237:00000 98:236:00000
 7090  A    1 C 98:234:00000 98:237:00000 98:236:00000
 YIVP  A    1 C 98:234:00000 98:237:00000 98:236:00000
 YARB  A    1 C 98:234:00000 98:237:00000 98:236:00000
-SOLUTION/EPOCHS
*-------------------------------------------------------------------------------
+SOLUTION/STATISTICS
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 NUMBER OF OBSERVATIONS         1153
 NUMBER OF UNKNOWNS             957
 NUMBER OF DEGREES OF FREEDOM   196
-SOLUTION/STATISTICS
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
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```

```
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     3 STAZ   YAR1  A    1 97:001:00000 m    0 -.307853075150000E+07 .999761E-04
     4 STAX   YARR  A    1 97:001:00000 m    2 -.238902449710000E+07 .240133E-03
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*-------------------------------------------------------------------------------
+SOLUTION/APRIORI
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    12 STAZ   7090  A    1 97:001:00000 m    2 0.307852491100000E+07 .000000E+00
    13 STAX   YIVP  A    1 97:001:00000 m    2 -.238900812440000E+07 .000000E+00
    14 STAY   YIVP  A    1 97:001:00000 m    2 0.504333185350000E+07 .000000E+00
    15 STAZ   YIVP  A    1 97:001:00000 m    2 0.307852646190000E+07 .000000E+00
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*-------------------------------------------------------------------------------
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     3    15  0.99952292928151E-08  0.65976496385168E-09  0.16732432461969E-09
     3    18  0.96796601566017E-08
     4     4  0.57663718733818E-07 -0.69339609527378E-07  0.40497988502278E-07
     4     7  0.10754823058586E-07  0.16148811492324E-08  0.18590251867944E-08
     4    10  0.14970237042238E-07  0.44327683542601E-08  0.29189917036896E-08
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     5    11  0.12335851927706E-07  0.39489189026108E-08  0.17068267059642E-10
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     5    17  0.11510122421147E-07  0.53189575558663E-08
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    10    13  0.10014718352023E-07 -0.31039234255058E-10  0.19081847097157E-10
    10    16  0.53318707390152E-07 -0.41911935808965E-08 -0.40630973092586E-07
    11    11  0.18039157017326E-06 -0.69516164908292E-07  0.17169732130307E-10
    11    14  0.99636896261264E-08  0.22297514459718E-10 -0.24296005975307E-07
    11    17  0.14057792654436E-07  0.25110340239799E-07
    12    12  0.13536701931872E-06 -0.18277628257240E-11  0.38960815712452E-11
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    14    17  0.97276550737121E-08  0.52131777419854E-09
    15    15  0.12445853060369E-05  0.65976496384522E-09  0.16732432463000E-09
    15    18  0.96796601566024E-08
    16    16  0.26136946171794E-06 -0.86585708316172E-07 -0.58789214044583E-07
    17    17  0.19863269594678E-06 -0.27134015587172E-07
    18    18  0.22972797582782E-06
-SOLUTION/MATRIX_ESTIMATE U COVA
*-------------------------------------------------------------------------------
+SOLUTION/MATRIX_APRIORI U COVA
*PARA1 PARA2 ____PARA2+0__________ ____PARA2+1__________ _____PARA2+2_________
     1     1  0.10000000000000E-07
     2     2  0.10000000000000E-07
     3     3  0.10000000000000E-07
-SOLUTION/MATRIX_APRIORI U COVA
*-------------------------------------------------------------------------------
%ENDSNX
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