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ASTROMETRIC POSITIONING OF GEOSTATIONARY SATELLITES (PASAGE)

T. López Moratalla,[1] F. J. Montojo,[1] C. Abad,[2] J. Pizarro,[3] J. L. Muiños,[1] J. Palacio,[1] and P. Galindo[3]

RESUMEN

El principal objetivo del proyecto PASAGE es utilizar observaciones astrométricas desde tierra para obtener efemérides precisas de satélites geoestacionarios y determinar sus órbitas. Este uso de la astrometría es bastante distinto del habitual y requiere el desarrollo de técnicas y algoritmos especiales para reducir las observaciones.

ABSTRACT

The PASAGE project major goal is to use earth-based astrometric observations to calculate precise ephemeris of geostationary satellites and for orbital determination of these satellites. This special use of astrometry is quite different from classical one and has required the development of the necessary techniques and algorithms for processing the observations.

Key Words: astrometry — ephemerides — space vehicles

1. INTRODUCTION

Precise ephemerides of geosynchronous satellites available at any time is a key point for satellite's station keeping routines, both for planning maneuvers and for checking out the results of these maneuvers.

The major goal of PASAGE project is to use earth-based astrometric observations both for obtaining precise ephemeris of geosynchronous satellites and for orbit determination of these satellites. It requires the development of the necessary techniques and algorithms to process the observations. Nevertheless, optical observations depends on atmospheric conditions and, therefore, this technique must operate together with other alternatives.

Optical observation of objects in geostationary ring, including space debris, is also used by other groups with several purposes; see for instance Alby et al. (2004), Beutler et al. (2005), Sabol & Culp (2001), and Schildknecht et al. (2004).

Topocentric equatorial coordinates of the satellite can be obtained using one single telescope and, when having a sufficient number of observations, these can be used for orbit determination purposes. The Gautier astrographic telescope of the Real Instituto y Observatorio de la Armada (ROA) is an adequate instrument for doing the task. The improvement of the telescope's performances by a CCD device has supposed the recovery of this telescope. An Apogee Alta U9 CCD camera has been bought and fitted to the telescope for this purpose.

The project also involves the telescopes of the Observatorio Astronómico Nacional de Venezuela (OAN). By means of astrometric observations taken from San Fernando and Venezuela, the parallax can be derived and a better determination of the satellite position can be achieved. Some previous results of the project are presented in Abad et al. (2007).

A better satellite position can be computed when astrometric observations are combined with the "Two Way Satellite Time and Frequency Transfer" system (TWSTFT). This technique is used at the San Fernando Time Laboratory for synchronizing with other laboratories. Range measures can be obtained with this procedure and, in fact, both techniques could be mutually validated. This method can only be applied to geostationary satellites which support TWSTFT; in our case INTELSAT 707.

2. GEOSTATIONARY APPARENT MOTION

An ideal geostationary satellite should remain at rest when observed from the Earth. So, its local hour angle will be nearly fixed, whereas stars are deriving with sidereal time. This obvious fact is determinant when designing the observational technique.

Satellites reflect the light of the Sun and their visibility will depend on the phase angle between satellite and Sun. Then, only a fraction of the orbit can be observer every day, longer while closer is the satellite nominal longitude to the observer meridian.

Geostationary satellites maximum brightness in a night depends on physical characteristic of the plat-

[1]Real Instituto y Observatorio de la Armada, San Fernando (Cádiz), Spain (teodoro.lopez@roa.es).
[2]Centro de Investigaciones de Astronomía, Mérida, Venezuela.
[3]Grupo de Sistemas Inteligentes de Computación, Universidad de Cádiz, Spain.

form and it varies along the year. The brightest magnitudes are reached nearly equinoxes (5V or 6V can be expected) and the faintest ones are around the solstices (they can oscillate between 11V and 14V). Eclipses of satellites are also produced around the equinoxes, with seventy minutes of maximum time of occultation, approximately; more details can be found in Soop.

3. OBSERVATIONAL TECHNIQUE

Three possible observational techniques were investigated: observations in TDI mode, standard astrometric observations (telescope with sidereal movement) and observations with the telescope in stationary mode (without sidereal movement).

The last one showed to be more suitable and we concluded that observations must be performed with the telescope in stationary mode, pointing to the satellite nominal orbital location. Stars appear as tracks in the background of the images so generated, while satellites appear as points; tracks length is proportional to exposure time.

It should be pointed out that the acknowledgment of the accurate time of observation is a critical aspect of these observations. It is not an issue in standard astrometric plates, but when dealing with geostationary satellite an error of a tenth of a second in time supposes one and a half arc seconds of error in satellite hour angle, which is unacceptable. So all the images are time tagged by the controlling computer that is synchronized by using the NTP protocol to the ROA Stratum 1 NTP Server. Another NTP Server have been mounted by ROA at OAN in Venezuela.

By the moment, most of the observations have been made with the Gautier astrograph. Observations with OAN telescopes have not yet been conclusive. But recently the double astrograph has been first activated from its installation more than 30 years ago; this instrument has not automatic pointing system, which makes it useless for standard observations. On the contrary, it is suitable for stationary observations. In fact first plates are going forward.

4. REDUCTION TECHNIQUE

Satellite coordinates are computed from star tracks appearing in the plates. These tracks need a special processing in order to determine x and y plate coordinates corresponding to the middle of the track.

A preliminary selection of tracks is made. y coordinate is accurate computed by a Gaussian fit to the

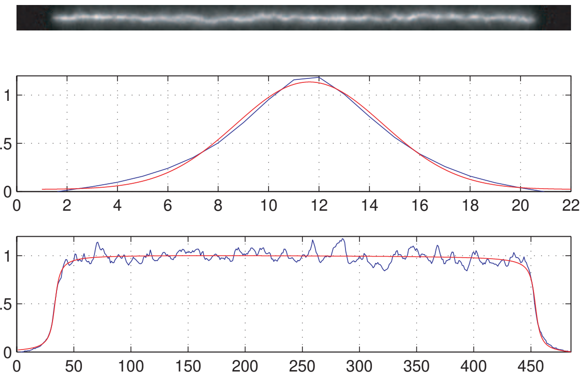

Fig. 1. Example of reduction. Up: detail of a track as appear in the plate; oscillations are ought to San Fernando seeing. Center: Gaussian fit to the y profile. Down: tepuy fit to the x profile.

profile resulting by adding pixels in the same row. For x coordinate the problem is not trivial. We can get the coordinate of the center of the track by convolution of the x profile with an unit pulse of width equal to length of track. If the x profile were a perfect pulse, the result would be a triangle which vertex defining the track center. Unfortunately the x profile is deformed by seeing (specially at San Fernando location) and the x coordinate so computed is only a good approximation to the actual value. We get a much better value by adjusting a "tepuy function" (Abad et al. 2003) to the profile, which center is the looked one for. An example is shown in Figure 1

An astrometric fit to a reference catalogue (Tycho-2 in our case) provides the telescope shot and satellites coordinates with an accuracy of tenths of arc seconds, which is an order of magnitude better than traditional angular observations techniques used by spatial agencies.

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