Parameterization of the Solar Radiation Pressure model for GPS satellites

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The treatment of solar radiation pressure (SRP) effect until now is the main problem in precise modeling of GPS satellite orbits. Especially it concerns periods when satellites pass through the Earth shadow.

The standard SRP models based on design features of GPS satellites do not provide the accuracy required today for the scientific applications. In spite of the fact that the shape and reflecting properties of satellites practically do not vary, and the shadow boundaries are determined accurately, the parameters of models can not be adopted as constants. It is mainly due to changes in the orientation regime of eclipsing satellites [1]. When the precise information on these changes is not available the appropriate influence on orbit can be modeled only empirically.

This results in necessity of numerical experiments aimed to find the optimal structure of SRP model in order to reduce orbit errors. The urgency of similar experiments is stipulated also in relation with significant increase of interest to a shared use of GPS and GLONASS satellites. At the same time, we have no reliable radiation pressure model for GLONASS satellites in the scientific literature.

The problem posed above has been solved within the framework of activities on creation of a software package GRAPE [2] for processing phase observations of the global GPS network. While the basis of the dynamic model for this package is the same as for LAGEOS-type satellites, the special investigation has been carried out to improve the empirical SRP model for GPS satellites. For this purpose the processing of the pseudo–observations (precise ephemeris produced by International GPS Service) on the 240–day time span has been performed.

In general, finding of the best structure of empirical SRP model has not unambiguous solution. The solution depends on criteria under which the optimization is carried out.

First, the search of the high accuracy model structure has been implemented using the following two criteria:

– minimum RMS of fitting to IGS precise orbits;

– accuracy of the recovered Earth rotation parameters, which have been used in producing the precise orbits.

In the best complete model we obtained under these conditions the force components along X, Y, Z axes of the satellite fixed coordinate system are presented in the form

$$X = C \sum_{k=0}^{3} X_{2k+1} \sin[(2k+1)(B+\Delta B)] + X_{2s} \sin 2(u - u_0),$$
$$Z = C \sum_{k=0}^{2} Z_{2k+1} \cos[(2k+1)(B+\Delta B)] + Z_{2c} \cos 2(u - u_0),$$
$$Y = Y_0 + Y_{2s} \sin 2(u - u_0) + Y_{2c} \cos 2(u - u_0),$$

where B — sun-satellite-Earth angle; u, u_0 — arguments of latitude of the satellite and sun; X_{2k+1}, Z_{2k+1} — coefficients of standard T20 and T30 models as given in IERS Conventions; $C, \Delta B, X_{2s}, Z_{2c}, Y_0, Y_{2s}, Y_{2c}$ — the empirical model parameters.

In practice, however, all seven parameters of the empirical model cannot be confidently determined from phase observations. Therefore we were interested to obtain model of an optimum structure satisfying the following conditions:

– the number of parameters which are determined from phase observations should be as small as possible;

– parameters, which are determined beforehand from pseudo–observations and are fixed when processing the phase measurements, should be sufficiently stationary.

From analysis of numerous evaluations under all the above mentioned criteria four parameters have been selected for the empirical model of an optimal structure: $C, \Delta B, Y_0, X_{2s}$. Therewith, two of them $\Delta B, X_{2s}$ can be fixed without noticeable deterioration of accuracy and only C, Y_0 can be determined directly from phase observations. The results of calculations are presented in the paper.

References

1. Bar-Sever Y. E. A new model for GPS yaw attitude. Special Topics and New Directions, Workshop Proc., Potsdam, 1995, 128–140.

2. Gayazov I. S., Keshin M. O, Fominov A. M. GRAPE software for GPS data processing: first results of ERP determination. In: Proc. IGS Network Workshop – 2000, Oslo, 2000, extended abstracts.