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DILUTION OF PRECISION FOR MULTI-GNSS

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The geometric factor (DOP) relates the errors in determining pseudo-ranges to satellites with the errors in estimating the position and time of the user using GNSS. DOP values depend on the geometric location of the navigation satellites relative to the user's position. In [1], the behavior of DOP multi-GNSS was studied for combinations of a limited number of satellites of four systems. Each of the four systems has its own system time. Depending on the number of systems, the covariance matrix through which DOP is determined has an order of 4 (for one system) to 7 (for four systems) elements. If we assume that all systems operate on the same system time, then the covariance matrix would always be of order 4 elements. From a computational point of view, this is beneficial, because it reduces the number of operations when inverting the matrix for multiple systems. The purpose of this work is to study DOP multi-GNSS when individual systems operate in a single and separate system time with the same geometric arrangement of satellites. The row of the geometry matrix for the i satellite has the form:

$$G_i = \left[\cos Az_i \cos El_i \quad \sin Az_i \cos El_i \quad \sin El_i \quad \alpha_i^1 \quad \alpha_i^2 \quad \alpha_i^3 \quad \alpha_i^4\right], \tag{1}$$

where Az_i - azimuth of i satellite,

El_i - elevation angle of i satellite.

For parameters, the upper index is the system number, the lower index is the line number:

$$\left[\alpha_i^1 \quad \alpha_i^2 \quad \alpha_i^3 \quad \alpha_i^4\right] = \left[1 \quad 0 \quad 0 \quad 0\right],$$
$$\left[\alpha_i^1 \quad \alpha_i^2 \quad \alpha_i^3 \quad \alpha_i^4\right] = \left[0 \quad 1 \quad 0 \quad 0\right],$$
$$\left[\alpha_i^1 \quad \alpha_i^2 \quad \alpha_i^3 \quad \alpha_i^4\right] = \left[0 \quad 0 \quad 1 \quad 0\right],$$
$$\left[\alpha_i^1 \quad \alpha_i^2 \quad \alpha_i^3 \quad \alpha_i^4\right] = \left[0 \quad 0 \quad 0 \quad 1\right].$$

If all satellites belong to the same system or operate in the same system time, then (1) takes the form:

$$G_i = \left[\cos Az_i \cos El_i \quad \sin Az_i \cos El_i \quad \sin El_i \quad 1\right] \tag{2}$$

DOP values are calculated through the diagonal elements of the matrix [1]

$$H = [G^T \cdot G]^{-1} \tag{3}$$

Using equations (1-3), DOP was calculated when the elevation angles changed from -20° to 30°. Azimuth angles were selected from the interval 0°-360°. On Fig.1 - Fig. 3 showing DOP simulation results for two, three and four systems, using equations (1) and the same systems using (2). In both cases, the geometry of the satellites (Sv) is the same.

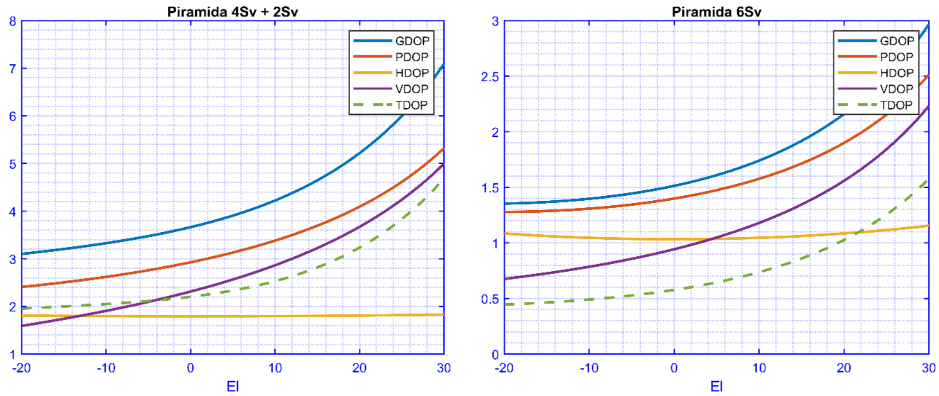

Fig.1. DOP simulation results for two systems

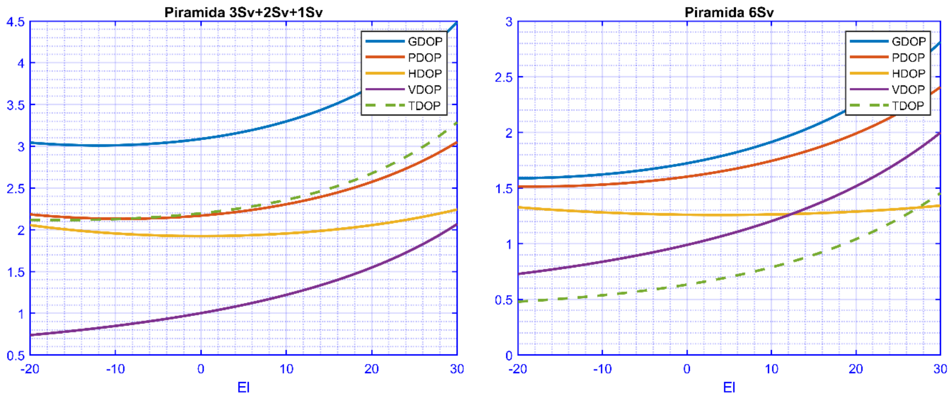

Fig.2. DOP simulation results for three systems

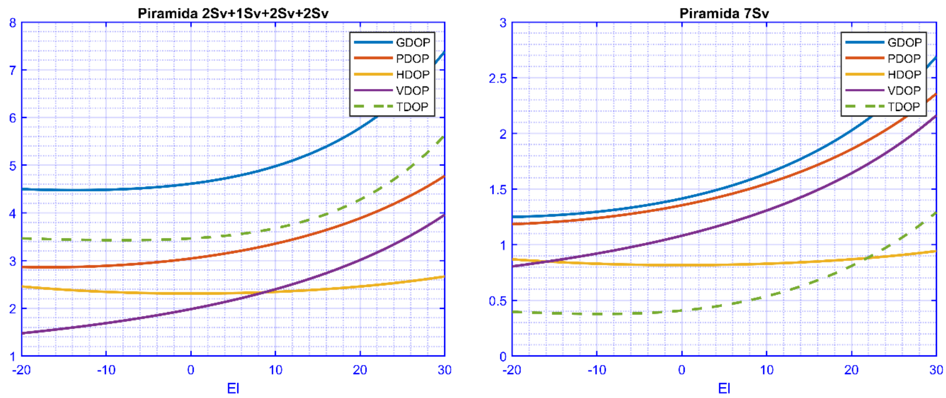

Рис.3. DOP simulation results for four systems

From the analysis of the results obtained, we can conclude that with the same geometric arrangement of satellites belonging to different systems, the results of DOP calculations, under the assumption that the systems operate in a single system time, are underestimated.

References

1. Konin, V., Pogurelskiy, O., Prykhodko, I., Maliutenko, T., Sushych, O., Ishchenko, O. (2023). Multi-GNSS in Limited Navigation Satellite Availability. In: Ostroumov, I., Zaliskyi, M. (eds) Proceedings of the International Workshop on Advances in Civil Aviation Systems Development. ACASD 2023. Lecture Notes in Networks and Systems, vol 736. Springer, Cham. https://doi.org/10.1007/978-3-031-38082-2_10.