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MODEL FOR NAVIGATION SATELLITE AVAILABILITY ON VARIOUS ORBITS ANALYSIS

While facing different tasks in space, the necessity to create a reliable way of navigation in space is required. The model is developed to analyze the availability of the navigation satellites in space.

Introduction

Determination of the coordinates of spacecraft in near-Earth space is required when executing a number of tasks that are relevant in the present time (docking, movement to desired orbit), or that would be relevant in the near future (with the removal of large orbit space debris). Satellite navigation systems are most effective on the Earth's surface so far. According to the interface control documents

and Compass systems when entered in operation would work in the same range.

Availability of navigation satellites is determined using almanac data of GPS, GLONASS, Galileo, Compass, as well as data about the location of the object (latitude, longitude, altitude), and parameters of radiating pattern of antenna satellites.

Model initial data and assumptions

Definition of coordinates, velocity and time of satellite navigation systems in the near-Earth space is performed in the radio navigation field, which is formed by radio signals emitted by satellites. To determine the coordinates in three-dimensional space it is necessary to simultaneously receive signals from at least four satellites.

GPS and GLONASS almanacs were obtained experimentally. Almanacs for Galileo and Compass are formed according to the interface control documents for the systems of orbital constellation of 27 satellites and 30 satellites respectively.

For satellites above the horizon plane beam width is set in the range ± 23°, for satellites below the horizon plane (the back side of the Earth), the radiation pattern in the range of ± 13,8 ° to ± 23 °.

The radiating patterns of satellite antenna systems form radio navigation field in the limits of main lobe. The measured radiation pattern of the GPS satellite is shown on fig. 1.

Model of availability was programmed in MatLab and operates as follows. After loading the almanac satellite navigation object coordinates, date, time interval and observation modes (above the horizon, below or above the horizon and below the horizon) the visible satellites from the object and a time interval during which there is the necessary number of satellites for navigation are calculated. The simulation results are illustrated by graphs.

Model operates to assess the availability of each satellite navigation system alone or any combination between them.

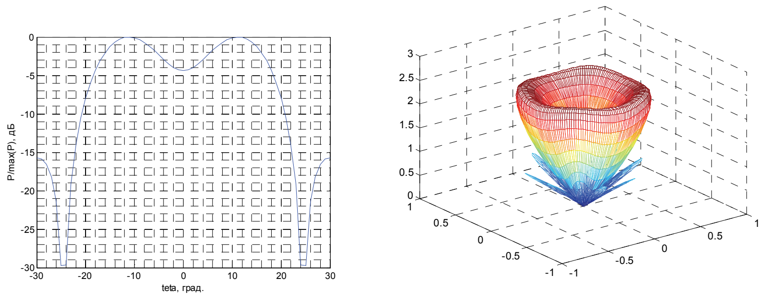

Fig 1. Radiating pattern of GPS satellite

The axis of radiating pattern passes through the phase center of antenna and is directed into the center of mass of Earth. In the center of radiating pattern there exists a specially formed "gap", which is used to align the field on Earth's surface.

The radiating patterns of GPS and Galileo satellites can be found on fig. 2 [1].

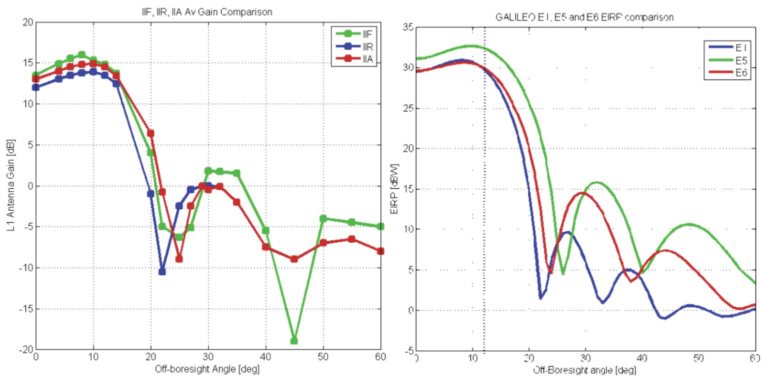

Fig. 2. Radiating pattern of GPS and Galileo

If the distance of the object from the Earth's surface is over 2000 km to GLONASS and 3000 km to GPS, we can talk about unstable radio navigation field, which means that we can not simultaneously receive signals from four satellites of one navigation system.

The radio navigation field is superposition of electromagnetic waves emitted by all navigation satellites within the main lobe of the satellite antenna pattern. The structure of the radio navigation field formation can be seen on fig 3.

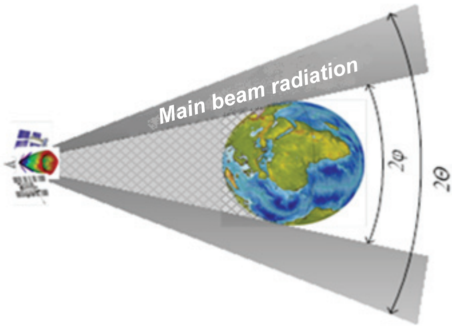

Fig. 3. Radio navigation field formation

Experimental data

The experimental data of the model is illustrated in the graphical form and produces three figures.

The satellites which can be seen above the horizon plane for 3000 km are shown on fig, 4.

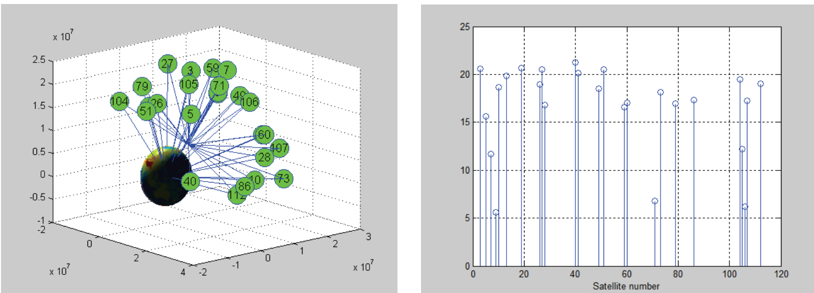

Fig. 4. GNSS satellites geometrically available for an object on altitude 3000 km

The sky plot of the available satellites can be seen on fig. 5.

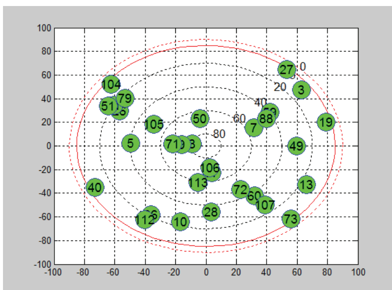

Fig. 5. Sky plot of available GNSS satellites

It is often impossible to use only satellites above the horizon for higher altitudes, therefore satellites below the horizon should be used. The example of available satellites on 20 000 km altitude can be seen on fig. 6.

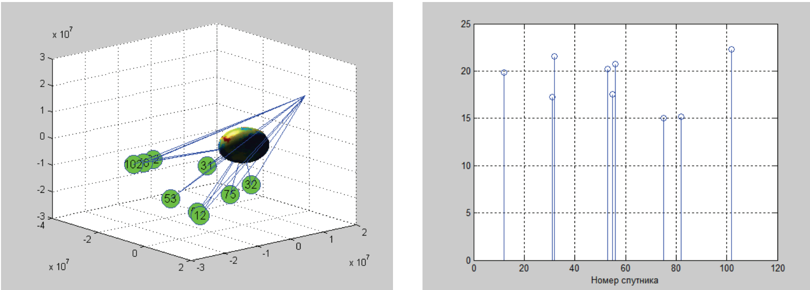

Fig. 6. Satellites geometrically available for an object on altitude 20000 km

Conclusion

The model allows to estimate the navigation field performances on various orbits with heights ranging from 800 km (Low Earth Orbit) to 36 000 km (Geostationary orbit). The model includes satellite constellations of both existing systems (GPS, GLONASS) and systems under development (Galileo, Compass).

References

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