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Autonomous Navigation of Service Spacecrafts on Geostationary Orbit Using GNSS Signals

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Abstract—In this paper we consider the possibilities of navigation of spacecrafts designed to service artificial Earth satellites on the geostationary orbit and of space debris removal in the near-Earth space using the signals of Global Navigation Satellite Systems. We have formulated the methodology for estimation of the signals availability of navigation satellites on the geostationary orbit through the utilization of almanac of GPS and GLONASS. It has been demonstrated that in the case of reception of navigation signals, which are radiated by the antenna system within the limits of main lobe of the radiation pattern (RP), the availability of satellite navigation signals on the geostationary orbit is very low even if we utilize GPS and GLONASS simultaneously. We present the simulation results of the received on the geostationary orbit navigation satellites using the signals radiated in the main lobes in the range from ±13.8 to ±23.5° for the L1 frequency, from ±13.8 to ±26° for the L2/L5 frequencies and in the side lobes in the range from ±30 to ±60° of RP of the satellite antennas. The simulation of the navigation satellites available on the geostationary orbit is given on the 24-hour time interval. Presented results are illustrated by the calculations of number of visible satellites and by the geometric factor.

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1. INTRODUCTION

Space has always many people for reasons of scientific curiosity, as well as economical ones. For example, 152 spacecraft have been launched in 2015 [1]. Robust autonomous navigation is one of the necessary tools for the exploration of space.

Why does one need an autonomous navigation in space? The navigation of spacecrafts is a complicated and specific scientific-technical problem [2]. For its solution we require terrestrial means of navigation field monitoring (NFM) and highly sensitive on-board systems. NFM problem with the utilization of terrestrial means requires the development of a wide hardware infrastructure, which is often not feasible for a company or a country, that has launched the spacecraft, due to the high cost of a network of terrestrial stations or to the fundamental impossibility of positioning in the required location. On-board equipment of a spacecraft is exposed to other problems, namely to the influence of solar activity, deterioration of accuracy of the coordinates determination in time, a long period of accumulation and filtration of navigation signals.

The idea of using the global navigation satellite system (GNSS) for autonomous navigation of spacecrafts at large distances from the Earth was considered in [3]. GNSS was developed for the needs of users at or near the Earth's surface. It is known that GPS provides a robust radionavigation field for heights up to 3000 km above the Earth's surface, and GLONASS has the robust field for heights up to 2000 km [4]. This covers the requirements of space users on low orbits and allows active utilization of GNSS for low-orbit tasks. Necessary specifications for implementation of autonomous navigation on high Earth orbits are not yet mentioned in technical documentation. In particular, this refers to the application of signals of the side-lobes of satellite antennas, since these signals were considered as parasitic ones until the introduction of the space service volume.

The life cycle of artificial Earth satellites (AES), which are utilized for communications, remote sensing, navigation, scientific and other applications, is limited. Taking into account high cost of their production and launch, there occurs a need for the extension of AES lifetime by means of service spacecrafts. For the geostationary orbit there are two main reasons for the removal of AES to the disposal orbit, namely these are irreparable breakdown of the components and the depletion of fuel in the engine [5].

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