UDC 530.122.1

Beglik V. V., Ohrymenko I. P., Kolchevskay I. N., Kolchevsky N. N.

GRAVITY DETECTOR BASED ON CONSTELLATION OF SATELLITES

A. N. Sevchenko Institute of Applied Physical Problems of Belarusian State University, Minsk, Belarus

On today's date, there are 3 observatories operating worldwide for the detection of gravitational waves, with 67 events registered. A space-based gravitational wave measurement system called "S-LIGO-NxR-zy" has been proposed. Software has been developed for calculating the kinematic characteristics of S-LIGO using RAD Studio version 10.4.2 and the Delphi programming language. The system with different configurations of satellites based on Platonic bodies has been studied.

In 2017, the Nobel Prize in Physics was awarded for the observation of gravitational waves. The 2019 and 2020 Nobel Prizes in Physics also relate to astrophysics, and have given rise to new directions in astrophysical science, such as "black hole demographics." There are a large number of satellite systems operating in near-Earth space, including GPS, Galileo, GLONASS, Starlink, and others. In 2018, the Belarusian State University launched its own nanosatellite, which became the third satellite of Belarus. On August 31, 2020, the President of the Republic of Belarus signed a decree on the launch of a second scientific and educational satellite of the Belarusian State University.

It has been proposed to investigate a model of a space-based gravitational wave detector using an artificial satellite measurement system. The configurations of the satellites are based on polyhedra, such as Platonic solids. Platonic solids have a geometric symmetry that can improve the detector's sensitivity to gravitational waves, allowing the detection of gravitational waves with higher precision and resolution than existing detectors.

The software development was carried out in the RAD Studio 10.4 development environment using the Delphi programming language. The program interface was developed using the VCL (Visual Component Library) component and function library. The TeeChart library was used for visualization of calculation results, graphing, and visual analysis. The created 3D model was built using the GlScene visualizer. This software has various functions, such as setting up satellites and calculating their coordinates, setting the direction of satellite movement, altitude, and other important parameters.

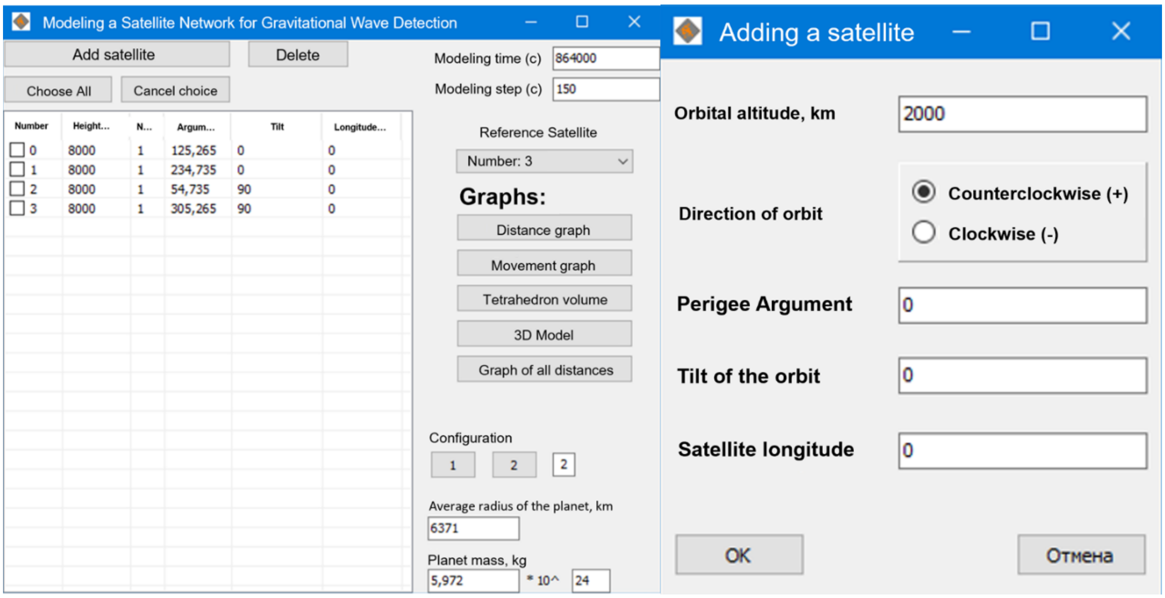

Figure 1 – Main program window, satellite addition window.

To perform calculations, it is necessary to set the characteristics of the orbit along which the satellites move. To specify the parameters and orientation of the orbit in space for an Earth orbiting satellite, six Keplerian elements or orbital elements should be specified:

- The semi-major axis "a" - the average distance between the Earth and the satellite.
- The inclination of the orbit "i" to the equatorial plane of the Earth.
- The right ascension of the ascending node (RAAN).
- The eccentricity "e".
- The mean anomaly "M0".
- The argument of perigee "ω".

Since this work investigates the motion of satellites in circular or near-circular orbits, the height of the satellite above the Earth's surface (h) was used instead of the semi-major axis. The eccentricity of a circular orbit is equal to 1, so this parameter is not introduced when specifying the orbit parameters (see figure 1). The software provides various functions, such as setting up satellites and calculating their coordinates, specifying the direction of satellite movement, altitude, and other important parameters. It also allows for plotting graphs of the satellite system's motion in the XY, XZ, and ZY coordinate projections, graphing satellite distances, evaluating the quality of tetrahedron formation, 3D modeling of satellites with visualization of faces and orbits, adding/deleting configurations, and importing/exporting satellite configurations. The software is compatible with Windows 7 and later versions.

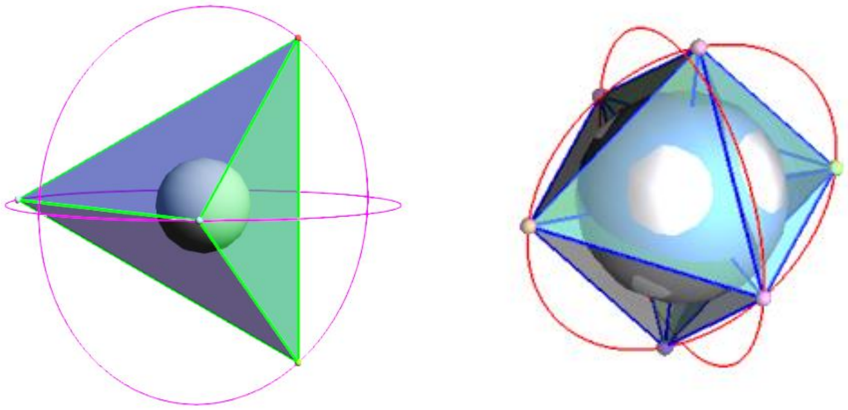

Figure 2 – Configurations of gravitational systems based on Platonic solids.

The idea is to use multiple platonic solids connected to each other to create a spatial structure that is sensitive to gravitational waves. When waves pass through this structure, they cause a deformation of its shape, which can be detected and measured. The use of platonic solids can allow for the creation of many different detector configurations that can be optimized for detecting specific types of gravitational waves. This could broaden the range of sources of gravitational waves that can be detected and studied. Software has been developed for calculating the kinematic characteristics of S-LIGO, which allows for the design and investigation of various satellite systems (Figure 1). The software runs on the Windows platform and enables the user to define satellite configurations and dynamically compute the distances between satellites, 3D shape parameters with visualization of facets, and satellite orbit parameters.

Reference

1. Abbot, B. P.// Exploring the sensitivity of next generation gravitational wave detectors / B. P. Abbott [et al.] // Class. Quantum Grav.2017.

2. Abbot B. P., Abbot R., Abbot T. D.// Observation of Gravitational Waves from a Binary Black Hole Merger Phys. Rev. Let.2016.

3. Weber J.//Gravitational-wave-detector events. Physical Review Letters.1968.

4. LIGO NEWS: LIGO Suspends Third Observing Run [Electronic resource] URL: https://www.ligo.caltech.edu/news/ligo20200326.