References:

1. Kaplan E D. Understanding GPS: principles and application [M]. Boston: Artech House, 2006.
2. WANG Jun, SUI Xin. Carrier tracking loop with improved frequency discrimination and its performance analysis [J]. Systems engineering and electronic technology, 2012, 34(12): 2438-2443.
3. E H Satorius, Z Ye, T Ely. Carrier Acquisition and Tracking Requirements for Doppler Navigation[C].Aerospace Conference, 2003, 4:4_1631-4_1638.
4. WANG Wei, CHEN Hui. Principle and Simulation of carrier recovery in high speed data transmission [J]. Radio Engineering, 2005, 35(5): 43-44.
5. XIE Yan-hua. Estimation and compensation of Doppler frequency shift based on satellite mobile communication system [D]. Dalian: Dalian University, 2013: 21-22.

A STRUCTURE OF EXPERIMENT ON PROCESSING SIGNALS RECEIVED FROM SHIP NAVIGATION EQUIPMENT BY MEANS OF “S-AIS” PAYLOAD

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Abstract. The study focuses on the idea of experiment on processing signals received from ship navigation equipment by means of “S-AIS” payload.

Keywords: small spacecraft, nanosatellite, picosatellite, platform, cubesat, onboard communication system, ais

The term “nanosatellite” is applied to ultra-small spacecraft (USSC) with a mass less than 10 kg and the volume of basic unit smaller than 1 m^3. Construction of USSC has become clearly possible according to electronic components, which enables us to create spacecraft with mentioned sizes. During the last 15 years, hundreds of spacecraft have been launched, and a large number of them have been successfully exploited. The main problem of USSC construction refers to the question how to achieve the rational relation between quality, cost and efficiency indexes. These characteristics are accomplished only by considering the major physical and technical performance factors. The most significant advantage of USSC lies in the fact that it can be designed and constructed by a small group of researchers.

Development in micro-electronics has facilitated rapid progress in USSC area, which became a flexible instrument for conducting scientific, technological and educational experiments in space. On the other hand, these spacecraft have not yet made their way from student projects to full-fledged players on space service market: until now, there is a perception that this area is purely entertaining activities (PR for space technology), or these products might be used as testing stands for developing and/or demonstrating various technology solutions (ideas, conceptions, etc.). There are several reasons behind this. Firstly, because of the very conception of USSC: small production cycle, lack of support by classical standards of aerospace industry, inexperience of researcher team and modest financing. Secondly, the reliability indicators are low because initially non-specialized electronic components of the class "industrial" are used. Finally, the space field has generally been too conservative. In order to overcome these mentioned barriers, it is reasonable to carry out a series of experiments based on USSC for addressing principal scientific and technological problems.

The aim of this study is to conduct scientific and technical experiments in space by means of nanosatellite developed in the laboratory "Space communication technologies" of Peter the Great St. Petersburg Polytechnic University.

The automatic identification system (AIS) is an automatic system designed to identify ships, their sizes, GPS position, course, speed and other ships' information, which are transmitted to terrestrial base station by using VHF band radio signals. As being a terrestrial-based system, the AIS has its limitation in territorial attachment of operating range to the coasts, where the ground transmitter stations are located. One way to deal with the situation is receiving and retransmitting AIS signals from LEO spacecraft. In the long term, global marine surveillance can be accomplished by deploying inexpensive orbital groups of existing or specially constructed AIS spacecraft.

The central issue of space-based AIS is message collision, which occurs when the spacecraft receives simultaneously messages from different ships from close TDMA cells. The amount of lost information in space-based AIS could reach 90%.

The shipborne mobile station AIS broadcasts static, dynamic, voyage information, and also safety messages periodically. Static data (ship IMO number, name, type, etc.) is entered in installation stage. Dynamic data (position, time, course, speed, etc.) is determined by ship measuring equipment. Voyage data (destination, cargo type, waypoints, etc.) is registered before the trip. The safety message is a short text. The AIS equipment broadcasts messages within different time periods depending on the type of information and the ship moving mode.

The operational principle of AIS is shown in fig. 1. AIS carrying ships, situated on the open seas or coastal areas, automatically broadcast standard messages containing ship information in the radio band of marine mobile service. Received AIS information is decoded and visualized on the computer of ships or coastguard, then represented on the digital maps of the sea surface.

Due to the fact that coastal AIS stations cannot receive signals from ships, which are located farther than 75–80 km from the coast, it was suggested to use LEO micro and nanosatellites as the AIS receiver-retransmitters (fig. 2). To date, more than 20 AIS micro and nanosatellites have been launched.

The first obvious problem is low energy of radio channel “ship-satellite”, which imposes a restriction on signal reception procedure. Moreover, radiation pattern (RP) of ship antenna allows the connection with spacecraft only by the side lobes. However, that is not a big problem because the low speed of information transmission (9.6 kbit/s) and the narrow bandwidth of GMSK signal ensure a high enough signal-to-noise ratio for reliable reception of information from all ships in the field of view of low-gain antenna on microsatellite. The essential problem is overlapping messages from different ships (collision), which is considered as intersystem interference.

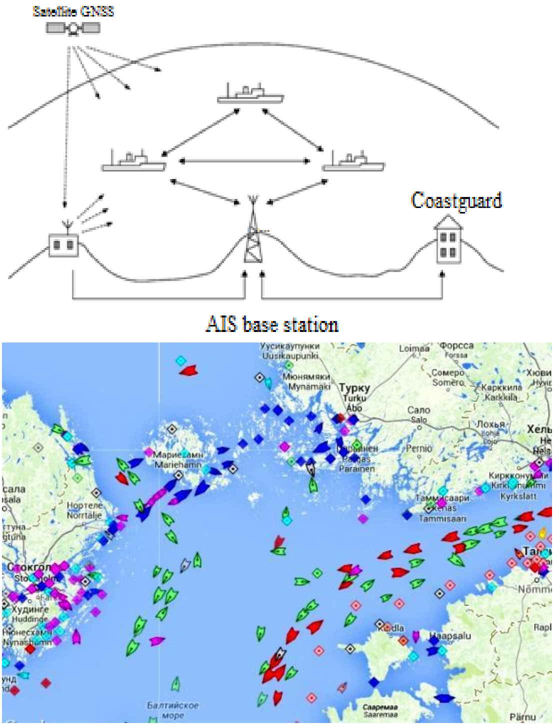

Fig. 1. The operational principle of AIS and the visualization result.

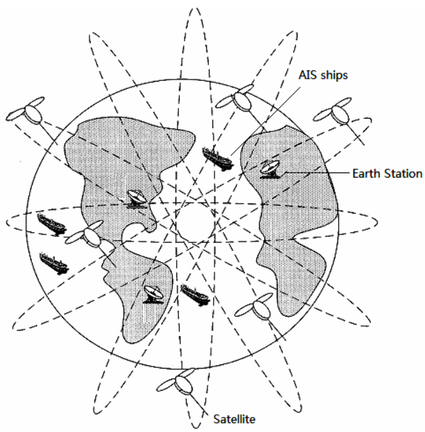

Fig. 2. The principle of retransmission AIS signals from satellites.

When using on ground AIS equipment, the radius of the cell, in which the algorithm SOTDMA operates to prevent message collision [1], does not exceed 75 km. In space-based AIS systems, field of view of the satellite is significantly higher and there is a possibility of overlapping messages from different ships of several cells. Obviously, the more cells covered by the field of view of microsatellite, the higher possibility of collision is. Thus, the main advantage of satellite signal retransmission in S-AIS, expansion of the field of view and increase in the number of physically "be seen" ships, eventually becomes its disadvantage: signals collide and get distorted. As a result, rejection and loss of position and service information (up to 90%) take place in on-board receiver.

On-board Doppler filtering can be used as an alternative way to deal with the collision. By applying narrow-band filter to linear path of satellite AIS receiver, only signals from ships, which are located in traversable band of the filter, can be caught by receiver though the filter bandwidth (fig. 4).

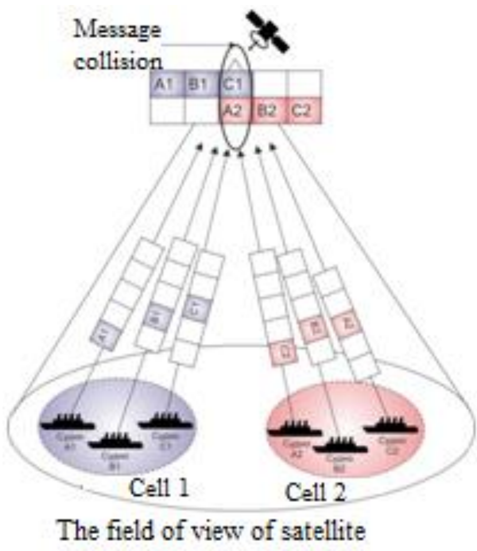

Fig. 3. Package collisions in signal reception in S-AIS.

Signals from other ships in the same field of view are not able to reach linear path, since their carriers are above or below central frequency of filter bandwidth. In this way, the number of interfering signals decreases significantly. Unlike practical narrowing radiation pattern beam, in this case, the field of view remains wide. Spacecraft, flying on the orbit and shifting the traversable band by its way, can ensure a covering zone inside the “footprint” of the on-board antenna. The possibility that ships, located inside the traversable band from the same inclined distance to spacecraft, simultaneously send their messages in the same time slot is close to zero. Therefore, the problem with collision can be solved. The filtered signal can be processed on-board by AIS receiver. Then, the result is sent to the ground reception station by low-speed channel 9.6 kbit/s.

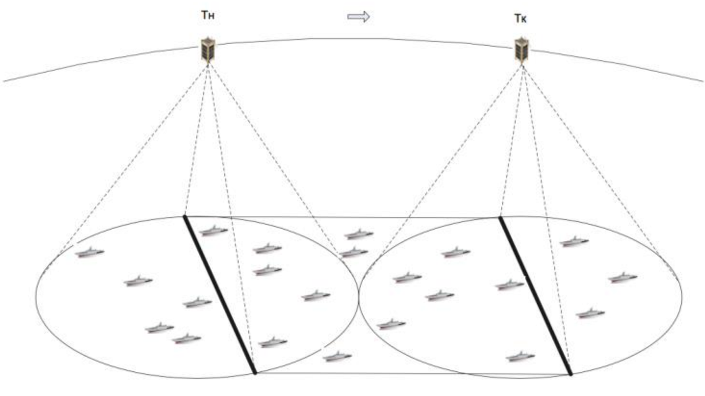

Fig. 4. The operating principle of S-AIS by using Doppler filtering.

References

1. Space-Based AIS: Contributing to Global Safety and Security. J.S. Cain, E. Meger / ISU 13th Annual Symposium – “Space for a Safe and Secure World”.
2. Establishment And Simulation of the Model for Space-Based AIS. Liu Chang, Cao Ming-zh. Advances in information Sciences and Service Sciences, vol.3, no.22.– pp. 589-596