UTILIZATION OF SATELLITE COMMUNICATION SYSTEMS FOR THE RAPID EXCHANGE OF DATA FOR THE LOW-ALTITUDE SPACECRAFT: EXPERIMENT "KONTAKT-MKA" ON THE SMALL SPACECRAFT "AIST-2"

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Nowadays it is actively developing and implementing the technologies of LEO satellite communications systems (LSCS) to enable communication between moving objects on the Earth. The problem of the use of such satellite communication systems for objects, moving on a low Earth orbit, becomes increasingly relevant. This is due to the fact that the carrying out of complex experiments or other operations with the use spacecraft (SC) constellations often requires a communication channel to provide receiving data from board of the SC and transmission commands to SC in real time independently of their location within radio line of sight the Mission Control Center (MCC). Furthermore, there may be used effectively Internet, providing data transmission from the gateway to the user.

Traditional means of communication with SC require location of SC within radio line of sight of the MCC transceiver antenna, which is possible only in a certain range of latitudes. Using modern LSCS allows rapid and low-cost access to the processes occurring on the orbit by using advanced IT-technologies. In 2005 there was first carried out an experiment on the organization of data transmission via Globalstar LSCS on nanosatellite TNS-0 /1/ [1].

In this work was carried out the analysis of the possibility of communication sessions by using Globalstar LSCS, the duration of communication sessions and the possible volume of transmitting data were estimated. For simulation of spacecraft motion and evolution of Globalstar satellites have been used the equations of motion of the center of mass of spacecraft in absolute geocentric coordinate system, which take into account the non-central gravitational field of the Earth and influence of atmosphere braking. Simulation of the evolution of Globalstar satellites carried out without taking into account the influence of the atmosphere [2].

For transmission of data from SC to the MCC requires to transmit data on one of the Globalstar satellites, which transmits the data through a gateway. Further data from the SC available for user via the Internet. Thus, for data transmission it is required carrying out the condition of simultaneously visibility of SC with one of the satellites Globalstar LSCS, which should be in radio line of sight of one of the gateway (Figure 1). The equations (1) and (2) determine the moments of time of entering within radio line of sight and exit from it:

$$\Phi_{CS-GW} = \bar{r}_{CS-GW}\bar{r}_{GW} - \bar{r}_{CS-GW}R_E \sin\gamma_{\min}, \tag{1}$$

$$\Phi_{CS-SC} = \bar{r}_{CS-SC}\bar{r}_{SC} - \bar{r}_{CS-SC}R_{SC} \sin\gamma_{\min}, \tag{2}$$

where $\gamma_{\min}$ – minimum elevation angle; $\bar{r}_{GW}$ – radius vector of the gateway; $\bar{r}_{CS-GW}$ – range vector from the gateway to the Globalstar satellite; R_E – Earth radius; $\bar{r}_{SC}$ – radius vector of the SC; $\bar{r}_{CS-SC}$ – range vector from the SC to the Globalstar satellite; R_{SC} – radius of the orbit of SC.

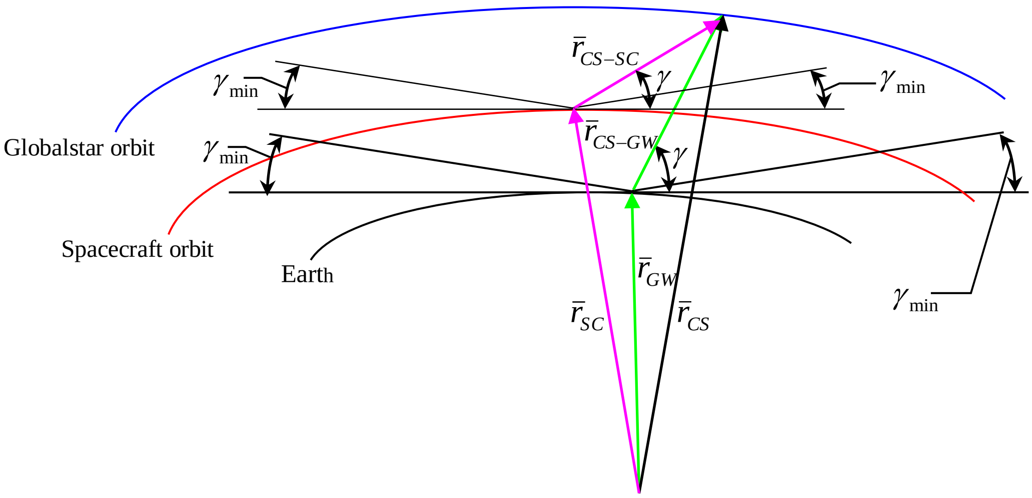

Fig. 1 – Determination of the mutual radio line of sight of the Globalstar satellite, gateway and SC.

Thus, to perform mutual radio line of sight "SC - Globalstar satellite - gateway" the condition should be satisfied:

$$\left.\begin{array}{l}\Phi_{CS-GW} \geq 0 \\ \Phi_{CS-SC} \geq 0\end{array}\right\} \quad (3)$$

In the case of using LSCS with inter-satellite communication satisfying of the simultaneous mutual radio line of sight LSCS satellites and gateway condition is not required.

It was performed the multiparametric research of the duration of communication session with SC via Globalstar LSCS depending on the height of SC orbit at different inclinations i and different values of the orbital plane displacement ΔΩ relatively of the orbit planes of Globalstar satellites.

The simulation results show that the communication time with the SC via Globalstar LSCS on the interval of multiplicity of repetition of relative configuration LSCS and the position of SC in orbit about 19 hours can range from 80 to 300 minutes and the volume of transmitted data from 5 to more than 20 MB without the use of global roaming service, depending on the height of the orbit, its inclination and longitude of the ascending node. The use of the global roaming service can increase the total communication time and the volume of transmitting data more than 3 times.

Performed a numerical research of principal possibility of transmission data between two SC via Globalstar LSCS resources and specially designed experimental equipment "Kontakt" within the project of small spacecraft "AIST-2." Creating of a communication channel between two SC is possible if it is satisfied the conditions of mutual radio line of sight, at those times when the satellites Globalstar LSCS are within radio line of sight of ground gateway and two SC. The condition mutual radio line of sight, under which data can be transmitted between two spacecraft:

$$\left.\begin{array}{l}\Phi_{CS-GW} \geq 0 \\ \Phi_{CS-SC_1} \geq 0 \\ \Phi_{CS-SC_2} \geq 0\end{array}\right\} \quad (4)$$

It was performed the modeling for the cases of absence and the presence of global roaming. Modeling was performed for two SC moving in orbits with the same parameters - height of 510 km and an inclination of 97,3° on the range of multiplicity of mutual initial position. In the result of the modeling it was defined that for different values of the relative displacement ΔΩ of the two SC orbital planes relative to each other and the angular distance between two SC Δθ, not exceeding 25 °, it is possible to carry out from 8 to 12 communication sessions duration from 5 minutes in the absence of a global roaming, as well as from 22 to 37 communication sessions duration of more than 5 minutes in the presence of global roaming on the same interval repeatability of relative configuration. At the same time, with increasing values of the ΔΩ and Δθ number of short sessions increases and the number of long sessions decreases (Figure 2 -11).

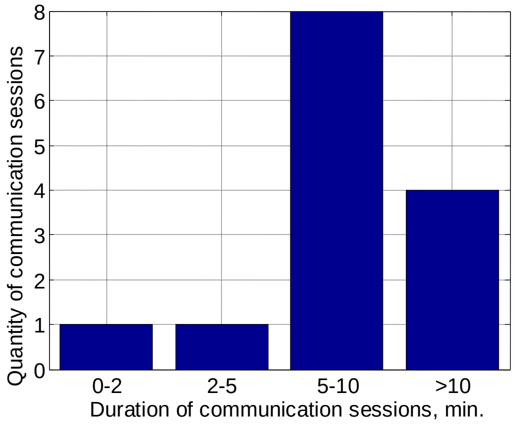

Fig. 2 – Quantity of communication sessions between two SC when Δθ=5° and ΔΩ=0° (Local roaming)

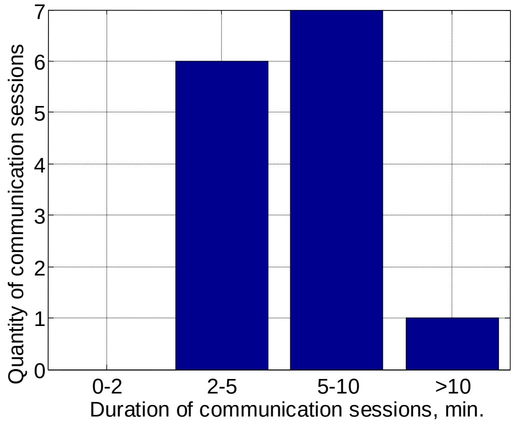

Fig. 3 – Quantity of communication sessions between two SC when Δθ=25° and ΔΩ=0° (Local roaming)

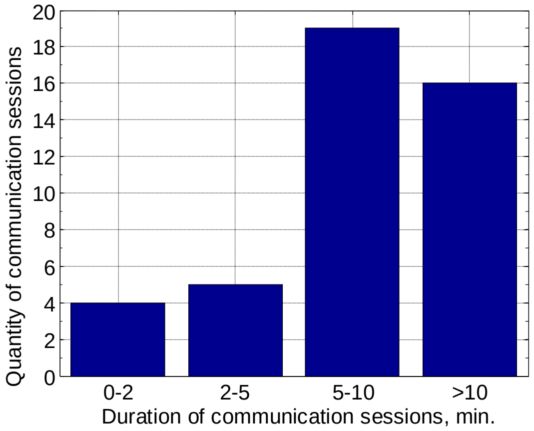

Fig. 4 – Quantity of communication sessions between two SC when Δθ=5° and ΔΩ=0° (Global roaming)

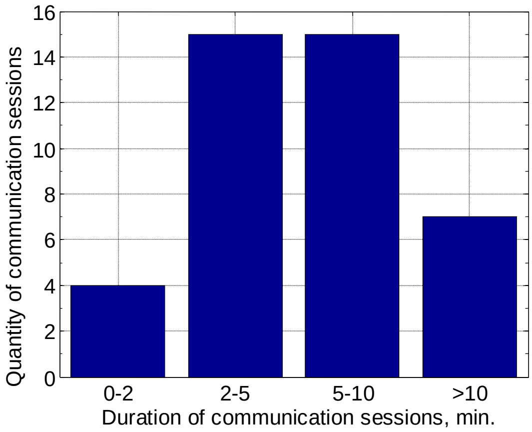

Fig. 5 – Quantity of communication sessions between two SC when Δθ=25° and ΔΩ=0° (Global roaming)

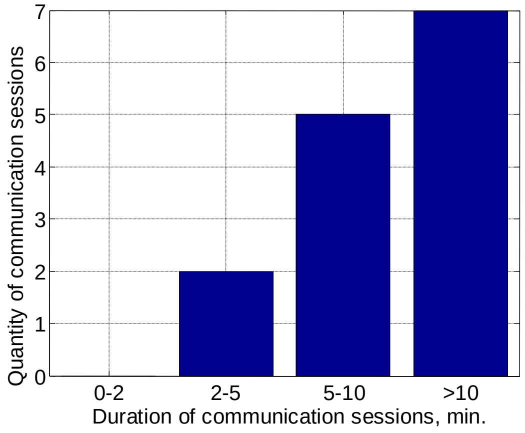

Fig. 6 – Quantity of communication sessions between two SC when ΔΩ=5°and Δθ=0° (Local roaming)

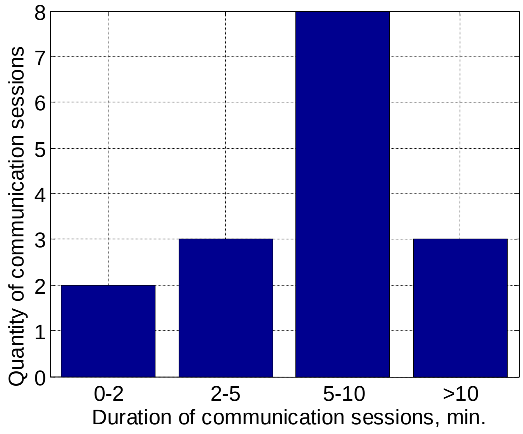

Fig. 7 – Quantity of communication sessions between two SC when ΔΩ = 25 ° and Δθ = 0° (Local roaming)

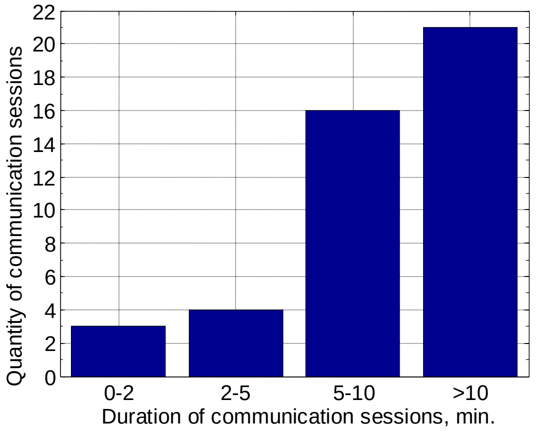

Fig.e 8 – Quantity of communication sessions between two SC when ΔΩ=5° and Δθ=0° (Global roaming)

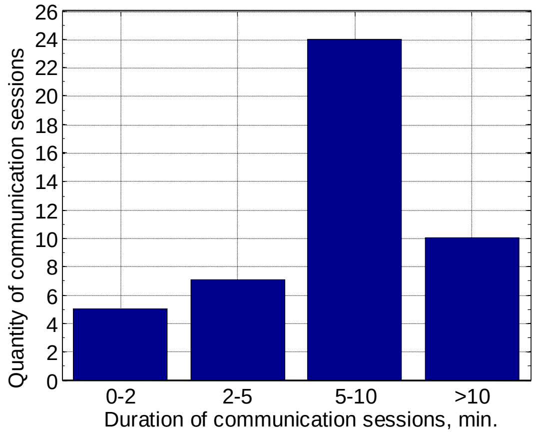

Fig. 9 – Quantity of communication sessions between two SC when ΔΩ=25° and Δθ=0° (Global roaming)

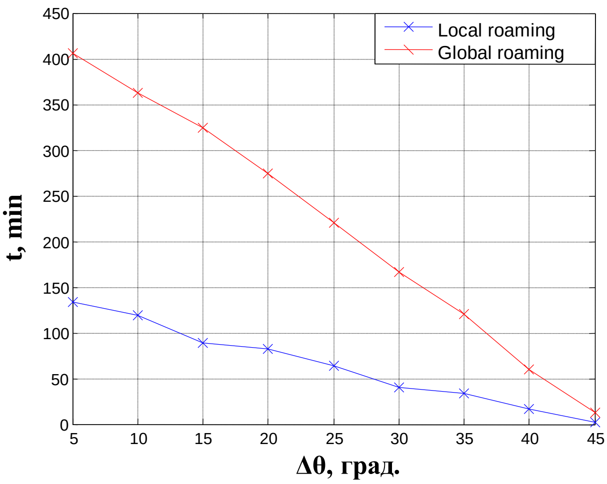

Fig. 10 – The total communication time via Globalstar in depending on the angular distance between the spacecraft when ΔΩ=0°

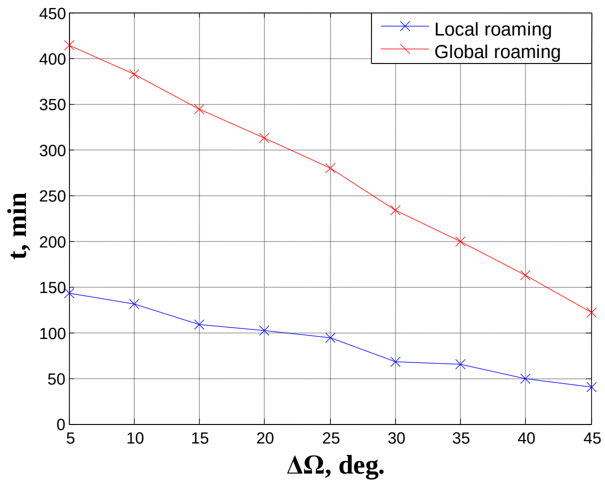

Fig. 11 – The total communication time via Globalstar in depending on the spacecraft orbital planes displacement when Δθ=0°

Described data transmission technology via Globalstar LSCS will be checked during the flight small spacecraft "AIST-2", which is scheduled in 2015, for data transmission to MCC as well as on the scientific SC "Lomonosov", which will be launched at the same time.

In this work carried out investigations of optimal planning communication sessions, taking into account the relative motion of two satellites in the case of local roaming.

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