ABSTRACT

The presented article describes hard- and- software of the nanosatellite TNS-0, developed by the FSUE “RISDE”. The primary goal of the nanosatellite is an experimental check of a possibility to use the channel given by general-purpose satellite communications system "GLOBALSTAR” as the "on-board/Earth” duplex data transfer channel. For attacking the given problem the bearing structure (platform) provided with a passive magnetic system of orientation and a passive temperature control system has been developed on the basis of a balance between the radiated and absorbed solar energy, the following hardware is installed on the platform: a system controller, a set of sensors, the "GLOBALSTAR" modem with antenna system, radio beacon of the "COSPAS" system with an antenna system, and a power supply battery. The installed equipment provides the satellite operating modes control, acquisition of the TM data and data exchange with a Mission Control Centre. The system controller developed on the basis of the C8051F022 microcontroller of the Silicon Laboratories Company which carries out: acquisition of the telemetry information, data exchange with the "GLOBALSTAR" modem, power supply control. The built-in software is developed in C. The used algorithms should provide the satellite controllability during all term of active life in conditions of guarantee-free information exchange with the Mission Control Center and the limited energy storage of power supplies.

1. INTRODUCTION

An actual problem for small-sized satellites is a possibility to use the global communications systems of the common usage as the channel for transmission of command and telemetry information, the data capacity doesn’t require the essential rates.

At the beginning of 2005 the FSUE “RISDE” schedules the launch of the technological nanosatellite TNS-0 [1], designed for experimental investigation of a capability of using such a channel as the satellite communication system “GLOBALSTAR”. The satellite launch is planned to perform from the International Space Station by the cosmonaut during the spacewalks.

The space segment of "GLOBALSTAR” communication system consists of 48 LEO satellites (the repeaters) providing an access of subscribers to the ground exchange stations. The communication services (duplex data transmission with a rate of 9600bit/s) are normally rendered to the ground users through the “GLOBALSTAR” modem. Installations of the user’s modem on LEO satellite change considerably the
conditions of setting up and supporting a user’s communication channel with a satellite-repeater. It is obvious, that the communication quality during the arbitrary point of time will be defined by the relative positioning of the TNS-0 and satellites of "GLOBALSTAR" system (relative orientation of velocity vectors) which will set a direction of antenna patterns and values of Doppler frequency shift. It is problematic to make an estimate the influence of the given factors on functioning of a communication system in conditions of ground experiment at the insufficient information on characteristics of the "GLOBALSTAR" system.

The experimental data acquisition for specifying the interaction model: LEO satellite - "GLOBALSTAR system" presents the primary goal of the TNS-0 launch space experiment. Within the framework of this problem it is necessary: to estimate the relative positioning of the TNS-0 and "GLOBALSTAR" satellites in conditions of regular and unregular communication, to investigate a probability to set up a communication channel during the prescribed time interval, to define a probability to communicate during the given time, to estimate a probability of errors when the data transferring.

2. HARDWARE OF the TNS-0

For the purpose to solve these tasks there has been developed and installed at the TNS-0 platform the following hardware: system controller (SC) on the basis of a single chip microcontroller, the set of sensors ( "solar" sensor 1…”solar” sensor 4 and a “horizon” sensor), the “GLOBALSTAR” modem with antenna system, power supply consisting of 2*18 V lithium battery of 10 A-h, radio beacon of the “COSPAS” system (Fig.1). The total mass of the TNS-0 doesn’t exceed 5 kg.

The radio beacon of the “COSPAS” system serves as an independent indicator of correct turning on the TNS-0 power supply system. The standard signal transmitted from the radio beacon is to be acquired by the reception stations of the “COSPAS” system. After the power supply system is turned on, the radio beacon of the “COSPAS” system operates as far as to the full discharge of a half the battery that has been dedicated for its supply (approximately of 48 hours).

The SC is an integrated control system and provides: the TNS-0 operating modes control, the TM data acquisition and exchange with a Mission Control Center (MCC) through the “GLOBALSTAR” modem.

The SC is based on the C8051F022 microcontroller of the Silicon Laboratories Company. The SC structure includes the microcontroller, the real time clock, the linear regulator, RS-232 transceivers, controlled power supply switches for the external systems.

The microcontroller contains a built-in module for analog information acquisition in structure of a set of multiplexers and ADCs. This built-in module provides measurement of: “solar” and “horizon” sensors voltage levels (the photodetectors operating in various ranges of a spectrum), an ambient temperature, a voltage level of the power supply battery (+36V and +18V), the current consumption values of the “GLOBALSTAR” modem. Also the microcontroller contains a built-in UART, providing interaction with the “GLOBALSTAR” modem. The programmed I/O pins of the microcontroller are intended to control the power supply to the “GLOBALSTAR” modem, programming of the real time clock and the SC’s hardware change over to the power down operation.
The microcontroller has a built-in EEPROM (“flash”). It is divided into two units of identical capacity of 32 Kbytes. The first unit is intended for the program storage, the second unit is for the telemetry data storage.

The real-time clock is based on the specialized controller with an external reference quartz oscillator which provides count and storage of the current time, as well as the Reset signal output after the preassigned control time has been achieved in accordance with the flight program. The microcontroller carries out the data exchange and of the real-time clock control (current time correction and the moment of Reset signal output setting) via the I2C serial interface.

The linear regulator serves for conversion of the +18V external battery voltage into +3.0V of the SC power supply.

Initialization of microcontroller is performed after the Reset signal has been received. This signal is generated either when powered on or by the real time clock.

3. SOFTWARE OF the TNS-0

As one can see from Fig.1, the additional redundant data transmission channels in the TNS-0 hardware are not available as an alternative path besides the tested channel, and also there are no rechargeable energy sources. It imposes the special requirements on reliability of the algorithms used in the built-in software which should provide the satellite controllability during all term of active life under conditions of guarantee-free
data exchange with the MCC as well as under the limited energy storage of power supplies. The specified requirements can be solved by the following way: realization of energy-saving operating mode and adaptation to possible malfunctions or to failing the scheduled communication sessions. The software solves these problems by generating the TNS-0 functioning algorithm to be based on the successive change of three states: "sleep", "connect", "telemetry".

The software generates «the sleep» state by converting the satellite hardware operation into power down mode, the real-time clock programming of the scheduled switching duration, retention of the SC necessary parameters for the next wake up. The only real-time clock is in active mode at this state. When the programmed moment of time is brought about, the hardware RESET signal is generated resulting in the SC initialization and this state termination. The total TNS-0 energy consumption level from +18 V battery during the "sleep" state does not exceed 200 µA.

The software under the "connect" state makes an attempt to communicate with the MCC through the "GLOBALSTAR" modem by delivering the corresponding AT-commands and analyzing the replies. Such parameters of the "connect" state as the determination principles of the next communication session moment, the initiator for specifying the communication channel and duration of the communication session are set by the initial settings and can be corrected on the command data received from the MCC. The software provides two possible modes of the next communication session moment definition: on the basis of a cyclic algorithm which sets the period and duration of communication sessions by the MCC commands and on the basis of switching at the moments of time which are set by the MCC commands.

The TNS-0 always pioneers in specifying the communication session in the cyclic mode. In other mode the software can either operate for outcoming call in a set of time moments or expect an entering call. In case of successful specifying the communication channel, the delivery of the telemetry information and reception of the command information is carried out. The cyclic mode for specifying the communication session is intended for a casual search of the moment of time at which there will be conditions for successful specifying the communication channel. The preset time switching is intended for checking the predicted moments of time in which it is expected, that there will be conditions for successful specifying the communication channel. When the successful communication sessions are not available for a long time, the software is responsible for automatic reconfiguration of parameters. Under this reconfiguration, the cyclic mode of specifying the communication sessions is set with the period and duration to be loaded by default values. The total current consumption level from +18V battery at the “connect” state in condition of specifying the communication channel does not exceed 100 mA, and under the procedure of data exchange with the MCC it does not exceed 350 mA.

The "connect" state appears as the most high power input. As this takes place for estimation of an opportunity of specifying the communication channel, it is possible to take advantage of getting a value of the RSSI level for which it is not necessary to specify a communication channel. For this parameter data reception the "telemetry" state serves, the software carries out data acquisition about the RSSI value together with the contiguous parameters (such as a current time value, values of the “solar” and “horizon” sensors), when converting to this state. The software receives the RSSI value in reply for delivering the <at$qcstatus> command to the modem. The contiguous
parameters allow estimating approximately the TNS-0 orientation relatively to the current condition of the "GLOBALSTAR" satellite constellation. The acquired information is stored in a non-volatile memory and can be reproduced at "connect" state by the special MCC command. Having finished the acquiring the data, the software carries out the transition into the "sleep" state. The total current consumption level from +18V battery at the “telemetry” state does not exceed 100 mA.

On the basis of analysis of parameters to be stored in the non-volatile memory at completion of a "connect" or "telemetry" state, the software defines: to what state it is necessary to pass from the "sleep" state.

The initial code of the software is developed in C. Some of the hardware controls subroutines are developed as assemble insertions, for example, the code of the real-time clock control. The total capacity of the executed code is of about 16 Kbytes.

4. CONCLUSION

The scheduled time of the TNS-0 active life to be required for acquiring the sufficient statistical information makes about 2 or 3 months. The successful completion of the experiment is considered the situation at which on the basis of the stored statistical information and data on orbital parameters of the TNS-0 and "GLOBALSTAR" satellite constellation, it will be possible to predict the moments of successful conducting the communication sessions with a probability of not worse than 0.9.

[1] Yu.M. Urlichich, A.S. Selivanov, A.A. Stepanov, Two nano satellites for space experiments, 5th Symposium on Small Satellites for Earth Observation, April 4-8, Berlin, Germany - IAA-B5-1403