I. THE STRUCTURE OF GAMMA-400 GAMMA-RAY TELESCOPE

Scientific project GAMMA-400 [1, 2] relates to the new generation of space observatories intended to perform indirect searches for signatures of dark matter in the cosmic rays fluxes, precision investigation of characteristics of diffuse gamma-ray emission and gamma-rays from the Sun during periods of solar activity, gamma-ray bursts, extended and point gamma-ray sources in the wide energy range from several MeV up to TeV region, and measurement of the cosmic-ray nucleon fluxes with \( E > 10^{-3} \) GeV by means of the GAMMA-400 gamma-ray telescope. The GAMMA-400 gamma-ray telescope represents the core of the scientific complex. For gamma-rays with the energy \( > 100 \) GeV expected angular and energy resolution are \( \sim 0.01^\circ \) and \( \sim 1-2\% \) respectively and electron/protons rejection factor is \( \sim 10^5 \).

The GAMMA-400 space observatory is planned for the launch at the end of this decade on the Navigator service platform [3] designed by Lavochkin Association on the elliptical orbit with following initial parameters: an apogee \( \sim 300000 \), a perigee \( \sim 500 \) km, a rotation period \( \sim 7 \) days, and inclination of \( 51.4^\circ \). The GAMMA-400 observatory is expected to operate more than 5 years, reaching an unprecedented sensitivity in the detection of gamma-ray sources. The planned scientific complex main technical parameters are: weight \( \sim 2500 \) kg, power consumption \( \sim 2000 \) W, total scientific and service downlink transmission up to 100 Gbps.

II. THE READOUT ELECTRONICS FOR FAST TRIGGER AND TOF

The under consideration variant of GAMMA-400 gamma-ray telescope includes following detecting modules (figure 1):

- A converter-tracker C consists of 13 layers of double (x, y) tracking coordinate detectors. The first 11 layers are interleaved with tungsten conversion foils meanwhile the last two layers have no tungsten. The total converter-tracker thickness is about 1 radiation length. The data from converter-tracker is used for high precision determination of the gamma-quanta conversion point coordinates and reconstruction of primary and secondary charged particles trajectory;

- An anticoincidence system AC: AC1 is top layer and AC2 is four lateral layers AC1-AC4 surrounding converter-tracker for discrimination between incoming charged particles and gamma-quanta with an efficiency of \( \geq 99.999\% \). All anticoincidence counters are made of two layers of 1 cm thickness, 10 cm width BC-408 polyvinyltoluene scintillator strips with different length;

- A hodoscope of four oriented perpendicularly layers of 1 cm thickness, 10 cm width, 10 cm height for S1 and 80 cm for S2 length BC-408 plastic scintillation counters (time-of-flight system TOF) combined in two detector planes S1 and S2 located at the distance of 50 cm between converter-tracker C and calorimeter CC. TOF system provides the fast trigger to gamma-ray-telescope readout electronics through the system of triggers formation signals ST and measures the particle charge, crossing time and position, and separates upward from downward going particles within at most 10^{-2} level;

- An 80 cm x 80 cm, ~18 radiation length thick coordinate-sensitive calorimeter CC to measure the incoming particles energy with resolution of 1-2\% for gamma-rays with \( E_{\gamma} \geq 100 \) GeV and separate e± and photons from hadrons at the ~5\% level. The CC includes preshower CC1 (consists of CsI(Tl) planes with total thickness of \( \sim 2\times \) radiation length) and fast plastic scintillation detector S3, the total absorption calorimeter CC2, based on the set of CsI(Tl) crystals, and anticoincidence and LED leakage S4 plastic detectors.

Three fast plastic detectors of the gamma-ray telescope AC, TOF and S3 are included in fast trigger logic in the main telescope aperture. The construction and electronics of these detectors are similar with the exception of absence of time analysis units in S3 and difference in counters number, length and orientation. Each side of every plastic scintillation counter in gamma-telescope sub-detectors is viewed by photo sensor block on the basis of matrix of 16×16 integrated 8-channel SPACEWARE switch, and sent to scientific data acquisition system SDAS for temporary receiving and transmission of the certain telemetry parameters to the satellite onboard telemetry system.

The GAMMA-400 telescope acceptance, when at least one counter side in each TOF plane produces a signal above a threshold according to the threshold characteristics passed. Indeed in the case of more than 5\% of events both a low ~40\% MP threshold is implemented for signals from each counter side. Then the signal originated from one plane side is matched in OR and AND with one coming from the other side (depending on a programmable setting). The coincidence of TOF planes with a trigger mask enables TOFL signals. The TOFL signal is send to TOF, AC and S3 detectors as LVLI trigger:

- The level 1 trigger LVLI formation begins with the TOF particle hit counters pattern analysis and crossing time one for acceptance checking and upward/downward particles selection. Then the AC hit counters pattern is considered, taking into account backscatter events suppression by time analysis method [5]. The LVLI trigger response is also included in trigger for hadron and electromagnetic showers separation, and the S3 signal is enabled if the conditions on a defined combination of the S3 hit counters pattern with enough energy deposition are fulfilled. The leakage detector S4 signal indicates that some part of incident particle energy is not absorbed in CC2 total absorption calorimeter and this event has a bad energy measurement precision. In this case the subsequent analysis of the shower spatial profile in calorimeter is needed for the energy reconstruction. The LVLI trigger initiates the process of data extraction from gamma-telescope subdetectors and storing it into intermediate buffer memory. The set of counters in trigger modules count how many various discriminators, subtriggers and triggers signals are presented in a predefined time interval.

Then the collected event information is compressed, structured, combined with the service data by means of master trigger formation module, based on 100 MHz 1907/V6506 32-bit hard RISC-microprocessor with integrated 6-channel SPACEWARE switch, and sent to scientific data acquisition system SDAS for temporary storing in non-volatile mass memory or for direct transferring into high-speed scientific radio line. Control module represents interface with one-time commands and power supply system OCPSS of gamma-telescope, providing secondary power supply for trigger signals formation system, one-time pulse radio commands receiving and transmission of the certain telemetry parameters to the satellite onboard telemetry system.

III. CONCLUSION

The readout electronics for fast trigger and time of flight system of the GAMMA-400 gamma-ray telescope constitutes the multiprocessor structure which collects data from the gamma-ray telescope detector subsystems and produces summary information used in forming the trigger decision for each event. The use of the flexible distributed system provides possibility for adaptive and operational management of the parameters of gamma-telescope registration modes, allows for the optimization of a search for a specific physics channel according to the survey strategy. In order to increase the reliability, the system is double redundant and selected electronics components are space qualified and rad-hard or rad-tolerant.

REFERENCES


Fig. 1. The functional diagram of GAMMA-400 gamma-ray telescope

Fig. 2. The functional diagram of GAMMA-400 gamma-ray telescope

Fig. 3. Functional diagram of interconnections within trigger formation cluster. FTM and MTM are “fast” and “master” trigger modules. The _n_ and _p_ prefixes designate the opposite ends of connection strips

Fig. 4. Functional diagram of functions formation unit