Unit for solar hard X-Ray polarimetry PING-P: structure, control, data acquisition

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Abstract. Architecture and operational concept description of the PING-P unit are presented. In-flight calibration and stabilization procedures are listed. Data and technology characteristics are presented. Two key functional modes, the “Patrol” and the “Burst”, are described. Spectral data: single detector spectra, double coincidence spectra, calibration spectra, automatic calibration LED amplitude spectra. A burst detection system which is aimed to detect bursts in a pseudo-stationary flux. In-flight control procedure is described. Raw data acquisition, processing and storing techniques implemented in the PING-P unit are considered. Also a prompt data processing procedure and data transmission protocols are reviewed.

1. Introduction
The PING-M experiment is a continuation and development of the experiment to search for polarization of hard x-ray radiation from solar flares “PENGUIN-M” [1,2] onboard "CORONAS-PHOTON" satellite. The PING-M device is a part of the scientific instruments complex in project “Interhelioprobe” [3]. It consists of two modules: spectrometry unit (PING-PIRS) and polarimetry unit (PING-P). The PING-M device is designed to observe the Sun from close distances either in the ecliptic plane or at some heliolatitude, as well as to provide measurements close to the Sun.

2. Structure, purpose and technical characteristics of PING-P
The PING-P unit is intended for:

- measuring degree of linear polarization of hard x-ray radiation of solar flares in 20–150 keV energy range.
- hard x-ray radiation solar flares spectrometry in energy range up to 45 keV.

PING-P unit consists of two parts: the detector and instrument compartments (see figure 1). The unit body has a cylindrical shape with a square base. In the structure detection part of the unit consists of two main elements:

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- Active hard x-rays scatterers (DS1...DS3), representing an Assembly of three paraterphenyl (PTF) crystals with a diameter of 40 mm and a height of 40 mm. Each crystal is glued from the bottom to the photomultiplier tubes (PMT). The PMT work provide: voltage divider (VD), preamplifiers (PU) and high-voltage power supply (HVS). These elements are not shown in figure 1. The PMT assemblies are identical for all scintillation detectors.

- Detectors build of the scattered photons (DP1...DP6), covering the lens and consisting of 6 crystals CsI(Tl) with a diameter of 45 mm and thickness of 5 mm in the cases with beryllium entrance windows along with relevant PMT assemblies.

The unit upper part (detector compartment) contains the Assembly of detectors and closed thin (1 mm) metal hood from alloy AMG made by the method of rolling. On assembling, for active scatterer detectors it’s possible to install entrance beryllium window, but in order to save weight with thickness of 1 mm foil.

The lower part of the unit (the instrument compartment) includes: two interchangeable the signal processing units (SPU) ("cold reserve"); 2 units of low-voltage converters LVC circuit board ("cold reserve"); 2 units of pulse regulators ("cold reserve"); LED circuit unit ("cold reserve"). At the lower part of the block is placed external connectors to interconnection with unit PING-PIRS.

![Figure 1. The PING-P polarimeter assembly (bottom - electronics compartment).](image)

The PING-P dimensions, max –320x320x300 mm. The PING-P unit mass is not more than 10 kg.

3. Technical characteristics of PING-P unit

3.1. Main technical data

External power supply is stable DC voltage (12±0.6) V from the PING-PIRS block. The unit power consumption is not more than 10.0 W. Daily volume of scientific information, transmitted to unit PING-PIRS, no more than 30 MB.
3.2. The unit PING-P modes of operation
PING-P unit works in three modes: "Patrol", "Flare" and "Programs". In “Patrol” mode the acquisition, processing and transmission amplitude spectra and polarization hard x-ray radiation matrices with a frequency of 1 every 60 seconds. In the "Flare" mode – once in 1s.

The PING-P unit switches from "Patrol" mode to "Flare" mode by PING-PIRS command. The switching is based on the signal "FLARE" generated by the PING-P unit and using also PING-PIRS data.

The measurement parameters (criteria of generation of "FLARE" signal, duration of Flare, the frequency of polling) can be changed by Ground command. Mode "Programs" for PING-P is possible only from "Patrol" mode. This operation is performed by Ground command.

3.3. The PING-P unit data transmission
The information exchange between the PING-P and PING-PIRS units is done digitally, using differential synchronous sequential intersection, symmetric in both sides. Galvanic isolation is not provided. Data transmission electrical standard – LVDS with SPI protocol, synchronous serial, arrays with CRC16 checksum. The format of data block in modes "Patrol" and "Flare" is the same. The PING-P unit passes to the PING-PIRS unit scientific, technical, service and control information and status information from stabilization and calibration systems. The composition and volumes of the transmitted information are presented in table 1.

| Data                                      | Volume, bytes | Frequency of transmitting, times per min |
|-------------------------------------------|---------------|----------------------------------------|
|                                           |               | "Patrol" | "Flare" |
| Main Physical data (polarization matrix, spectra from detectors, data about fluxes) | 6036          | 1       | 60      |
| Technical data (temperature, “dead” time, status data from any parts etc.) | 82            | 1       | 60      |
| Service data (calibration spectra, additional spectra from etc) | 4514          | 1       | 60      |
| Total                                     | 10632         |         |         |

4. The PING-P unit structure
The PING-P unit electronics can be divided into 2 main functional groups: The analog electronics for PMT operation and digital electronics. Unit PING-P provides the following tasks:

- data acquisition from 10 scintillation detectors block;
- the 2-loop system the stabilization of the energy scale of the instrument on the reference signals of the LEDs and isotope sources (the parameters correction on commands possibility);
- allocation and the analysis of double coincidence of signals from DP (detector of scattered photons) and DS (active scatterer) detectors;
- sorting and primary processing of data;
- storage of 1 frame of data;
- data transfer to block PING-PIRS on PING-PIRS demand;
- receive control commands from PING-PIRS on serial SPI bus according to a communications Protocol;
- the reception of 4 teams switch sets of electronics on a radio channel;
output signal "FLARE" generation for the specified criteria (with the possibility of changing the criteria for the teams) and its transmission to PING-PIRS unit.

4.1. The PING-P unit analog electronics
Analog electronics of each of the 10 PMT (detectors DS, DP and DK - calibration source detector) include: voltage dividers circuit board (VD) PMT, high voltage supply (HVS) circuit board, preamplifiers (PU) block. All PU, HVS and LEDs are doubled in a circuit array. Switching on a reserve complete set can be made by a command. Each complete set is switched independently.

4.2. The PING-P unit digital electronics
The SPU circuit board concentrates the greater part of electronics of PING-P unit.

The processor performs following main functions: responsible for the initial data acquisition for different periods of reading, generates data for transmitting to the telemetry, parses the incoming command and control signals and produces the necessary control action, logs and stores the necessary parameters in non-volatile ROM, analyzes current information from the detectors to detect outbreaks, and generates a signal FLARE. It consists of two parts with different functions (PLIS1 and PLIS2).

PLIS1 realizes next functions: generates frequency 40 MHz for the ADC, performs the detection of pulses in the data stream of the ADC with a frequency of 40 MHz and measuring their amplitudes, performs self-tuning scintillation detectors on signals LEDs, producing pulse width modulated signals to control the high voltage power source (TRS) and closing thereby the internal LED circuit for each detector, PLIS1 generates clock signals TRS and the excitation signal for the pulse generator of the LED, analyzes the cases of coincidence of pulses from different detectors and generates the necessary signals for reception of amplitude spectra. Data about the amplitude of the pulses, required to be registered, is transferred in PLUS bus connection (from "familiar" naming the PLIS matrix).

PLIS2 realizes next functions: data exchange with the Central processor and the external RAM provides a RAM in the accumulation of the amplitude spectra and the processor access, produces for frequency 40 MHz for processor and 1 Hz, provides delivery of telemetry data in block PING-PIRS by implementing the negotiated exchange of information and receives control signals from block PING-PIRS.

5. Conclusion
It was developed architecture and operational concept PING-P polarimetry unit of PING-M device to international space project “Interhelioprobe”.

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