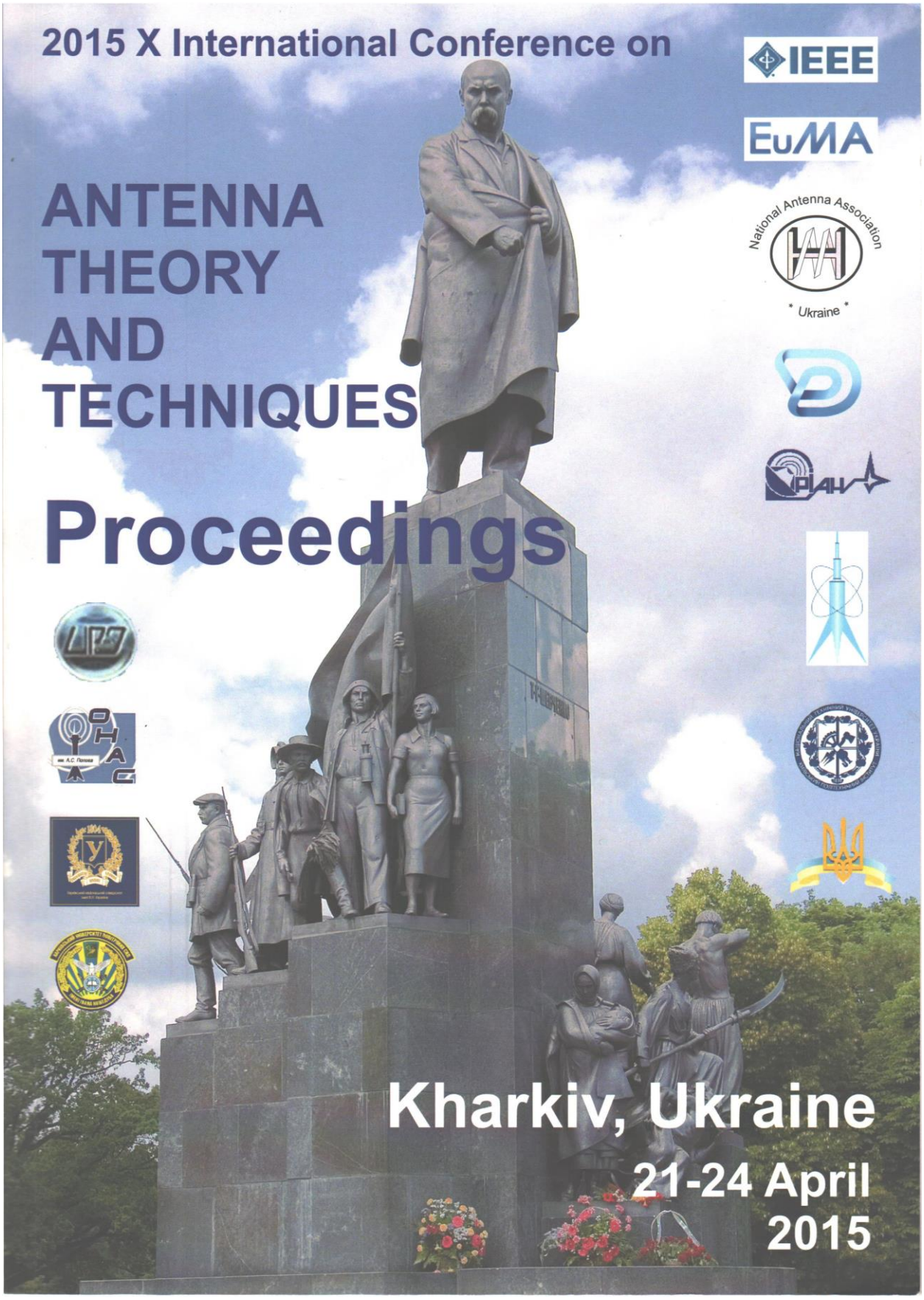
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NEW SOFTWARE AND HARDWARE CONTROLLING COMPLEX OF THE UTR-2 RADIO TELESCOPE

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Abstract

In 2013-2014, a new software and hardware controlling complex was developed and installed on the UTR-2 radio telescope. Controlling complex is designed for planning observations of discrete cosmic radio sources and areas of the celestial sphere, for programming control of UTR-2 pattern position with UTC time scale synchronization, for monitoring of control codes execution, as well as for control of other UTR-2 systems. Operating and control of the radio telescope parameters are carrying out by a host computer in a local area network or by Internet via a control and monitoring unit based on the ARM microcontroller STMicroelectronics of the STM32 set. The functionality of the new complex significantly automates the radio telescope operation. The report describes the structure of this complex, basic functionality and implemented radio telescope operating modes.

Keywords: directional pattern, control complex, radio astronomy, radio telescope

1. INTRODUCTION

The Ukrainian T-shaped radio telescope UTR-2 is the largest in the world radio astronomy instrument at decameter wavelengths.

The effective area of the radio telescope is 150 000 square meters.

For more than 40-year operation history the majority of improvements and upgrades to the UTR-2 was aimed to improvement of the receiving and recording devices, the phasing and amplification systems. As a result, the UTR-2 information capability was brought to the potential value of more than 15 TB of the radio astronomical data per day.

At the same time the control hardware of the radio telescope substantially lagged behind in its development of other systems and not fully supported the informational and observational capabilities of the telescope.

The UTR-2 hardware and software operating complex was upgraded in 2013-2014 to enable the full automation of the radio telescope controlling.

2. OPERATION PRINCIPLES AND MAIN FEATURES OF THE CONTROLLING COMPLEX

Radio telescope UTR-2 operates in two basic modes during the observations:

- Observations cosmic radio emission;;
- Calibration of the parameters and characteristics of radio telescope tracts.

When carrying out the observations at UTR-2 the antenna pattern beam is formed in the direction of studied radio source or the area of the celestial sphere and the beam movement in space is based on a given scanning law. The antenna pattern beam forming is realized by the telescope phase system according to commands from the UTR-2 controlling complex.

The UTR-2 phase system is controlled by two integer binary codes in the coordinate system U and V. Code U specifies the East-West antenna beam direction and code V is for North – South direction. Code U can have values between 0 and 1023, code V - from 0 to 2047 (see Figure 1).

To calculate the codes beam steering in right ascension and declination the following formulas are used [1]:

$$U = \begin{cases} 1.2 \cdot 512 \cdot u - 0.5, & for\ u \geq 0 \\ 512 - 1.2 \cdot 512 \cdot u - 0.5, & for\ u < 0 \end{cases} \quad (1)$$

$$V = \begin{cases} 1024 \cdot v - 0.5, & for\ v \geq 0 \\ 1024 - 1024 \cdot v - 0.5, & for\ v < 0 \end{cases} \quad (2)$$

$$\begin{aligned} u &= \sin(\alpha)\cos(\delta) \\ v &= \sin(L)\cos(\alpha)\cos(\delta) - \cos(L)\sin(\delta) \end{aligned} \quad (3)$$

where u, v are the direction cosines of the beam inclination angles on U and V, respectively, α - right ascension, δ - declination, L - radio telescope latitude.

Observations on the UTR-2 can be carried out with 1 or 5 beam formed by the beam splitting box at the command of the controlling complex.

When observing, eight software-defined laws on beam position controlling can be ensured. The con-

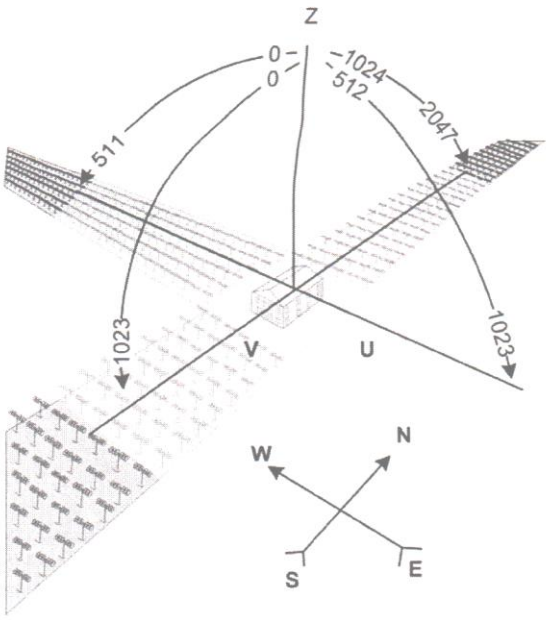

Fig. 1. Dependence of the position of the beam pattern of the UTR-2 of the control codes.

trolling law depends on the type of a radio source or a shape of a scanning area on the celestial sphere.

In moments of the control codes switching, the controlling complex may further form the block command (so-called "Gate") to protect the receivers input against arising transient processes.

The calibration mode is used to evaluate the current UTR-2 antenna and receivers parameters and characteristics. In this mode, on controlling command a diode noise generator and a programmable electronic attenuator, which provides 32 calibrated attenuation levels at the receiver input, is connected instead antenna in the telescope receiving channel

Also the UTR-2 control panel (see Figure 2) is used for technological work and troubleshooting in parallel with the hardware-software controlling complex.

3. THE HARDWARE IMPLEMENTATION OF CONTROLLING COMPLEX FOR UTR-2 RADIO TELESCOPE

UTR-2 controlling complex consists of the following equipment:

- Control and monitoring unit;
- GPS receiver;
- Host Computer.

UTR-2 control and monitoring unit (CMU) is designed as a stand-alone microcontroller device. A computing core of CMU is a 32-bit microcontroller STM32F107VCT6.

Connection of the complex to all UTR-2 systems is provided with the CMU interfaces. A scheme of the CMU connection to UTR-2 hardware is shown in Figure 2.

CMU provides:

- *Communication with the host computer by the* LAN Ethernet network on UDP protocol;
- Storage in RAM up to 3000 control commands;
- Reading the UTC time scale and 1PPS second mark from the GPS receiver, formation an internal timeline, as well as the instruction issue to external devices with an time accuracy of 1 ms;
- Delivery of the control codes of the beam position into the UTR-2 phasing system, as well as the receiving and analysis of the control codes execution;
- Delivery of the switching modes commands to the UTR-2 control panel;
- Activation and control of the electronic attenuator at the "Calibration" mode;
- Delivery the "Gate" signal and the 1- or 5-beam mode directional pattern switching commands;
- Indication of CMU operability through LEDs.

The GPS receiver provides the UTR-2 control complex with a high-precision UTC time scale and 1PPS time marker.

The host computer with special software installed calculates the observation schedules with the required parameters and their transmission to CMU.

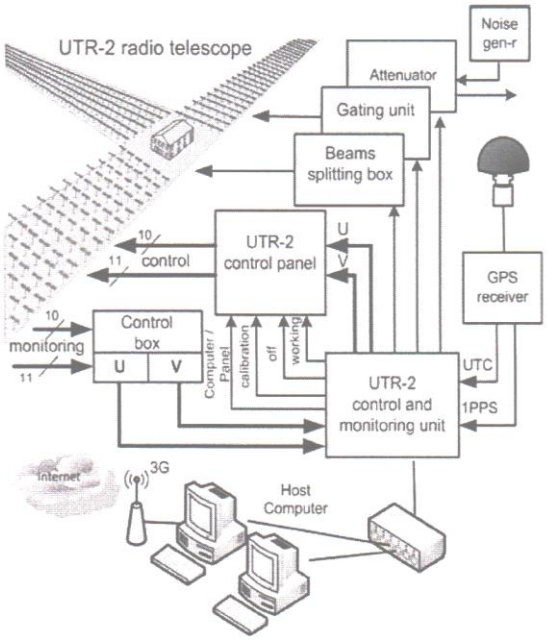

Fig. 2. The control and monitoring unit connection to UTR-2 hardware.

4. SOFTWARE CAPABILITIES OF UTR-2 RADIO TELESCOPE CONTROLLING COMPLEX

Controlling algorithm of UTR-2 operation involves a preliminary calculation of schedules of the observations and calibrations and their execution at a fixed time.

Software of a host computer allows calculating the schedules for the following kinds of observations:

- Source tracking;
- Single source transit;
- Planets tracking;
- Sun tracking;
- Moon tracking;
- Fast scanning;
- V-RA scanning;
- Multiple scans.

The following initial data of control software are used:

- The coordinates of UTR-2 radio telescope phase centre;
- The coordinates of radio sources in the 2nd equatorial coordinate system specified for the epoch of 1950s or 2000s;
- The coordinates of radio sources in a galactic coordinate system;
- Apparent declination and right ascension of Sun, Moon and primary planets;
- The coordinates of a point (area points) of the celestial sphere under observation;
- Estimated time for targeting the telescope beam at a reference point specified at Universal (UT), UT+3 or local time;
- Time interval of beam switching in space.

All the data needed for calculating the observations time-scheduling are kept in supporting files of the software.

Service functions of the software provide preliminary simulation of prospective observations with dynamic displaying the beam positions on radio source maps presented in different coordinates systems.

The software allows creating several successively running schedules which can be accompanied by calibrations. The schedules may be carried out with single- or five- beam modes and the switching points can be followed by the gate (strobe). The schedules are downloaded into in-memory of CMU and executed in accordance with the time specified. The service information of the schedule execution results are subscribed into a log-file of the host computer.

Further the possibility of a digit check of the system forming control codes and setting UTR-2 beam at specified direction are provided in order to solve technological tasks. The control function of the host computer can be delegated to the UTR-2 control panel for conducting repair works.

Software execution can be carried out in a training mode. In such a case a software simulator can be used instead of CMU.

The possibility of UTR-2 remote control was realized in 2014. Taking into account the currently existing communication channels (3G) the technical implementation is realized through a VPN-tunneling technology. As a result the observer can provide distant control of the host computer or use his/her personal computer as a host one

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