MODERNIZATION OF COMMUTATION DEVICES AND AN IMPROVEMENT OF MAIN PARAMETERS OF THE UTR-2 RADIO TELESCOPE

V. V. Zakharenko, N. K. Sharykin, E. R. Rudavin

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna Str., Kharkiv, Ukraine

The paper describes the results of modernization of the calibration system commutation devices and a check of pattern parameters of the UTR-2 radio telescope. As a result of the modernization an effective area of the telescope has been increased by 23 percent. In a frequency range from 20 to 32 MHz an improvement in sensitivity more than 1.2...1.5 dB has been obtained. On the lower end of the UTR-2 operating frequency range (from 8 to 12 MHz) the interference immunity has been increased by 10 dB.

INTRODUCTION

The decameter wavelengths UTR-2 radio telescope is intended for the absolute measurements of the radio sources flux density. Up to now the UTR-2 is still the largest instrument in the decameter wave range. The main design philosophy and parameters of the radio telescope are presented in [2, 3].

During UTR-2 exploitation the separate systems of the radio telescope were subjected to considerable improvement. This concerned the modification of recording equipment, control units of beam steering devices, *etc.* The most considerable recent improvement was connected with installation of a broadband ($7.7 \div 37$ MHz) antenna preamplification system (PAS) with a high dynamic range (D) [1]. The new PAS, from one side, has opened more broad capabilities in posing and solving of the radio astronomy problems, and from other side it has imposed high requirements on other telescope systems. It appeared that the UTR-2 parameters were limited by commutators on diodes that were successfully exploited before PAS improvement. This paper describes next logical step in modernization of the radio telescope which aim was the increasing of sensitivity and interference immunity of UTR-2.

BLOCK-DIAGRAM OF THE UTR-2 TAKING INTO ACCOUNT THE CONTROL AND CALIBRATION UNITS

UTR-2 [2] contains more than two thousands of dipoles. Its linear dimensions are 1800 m for the antenna “North–South” and 900 m for the antenna “East–West”. In the framework of radio telescope elaboration the problem of reliability and functional testing of such large and complex instrument was considered as one of the first rank questions.

To control the main parameters of the radio telescope (namely the directional pattern (DP), directive antenna gain (DAG) and efficiency) a special high-frequency broadband test system was incorporated in the telescope antenna system. The first test, in dipole rows, is intended for monitoring of phasing equipment along shorter sides of the arrays. This system includes the check units for the series of six dipoles “check of dipole row” (CDR). The second (differential) test meant for checking of the narrow-beam phasing equipment along the longer sides of the antenna. It is carried out by comparison of the amplitude and phase distributions of signals in individual channels with the standard distribution “check of signal transit” (CST) generated in a reference channel. One of the main parts of check system is a set of the sectional commutators (SC) that execute of various switching in work, calibration and check modes of the telescope. Commutator of the main cables (CMC) also needed for these functions. The number of vibrators, high frequency commutators of CDR, CST, SC for each section of the “North–South” and “East–West” antennas and also for the whole UTR-2 radio telescope are given in Table 1. The losses of CDR and CST commutators are directly transformed into efficiency of the circuits that are not locked by the calibration system, and also determine a sensitivity of the telescope at upper end of the working frequency range.

Table 1. The list of parameters

	Antenna "N–S" 8 sections (1 section)	Antenna "E–W" 4 sections (1 section)
dipoles	1440 (180)	600 (150)
CST	180 (30)	100 (25)
CDR	48 (6)	20 (5)
SC	8 (1)	4 (1)

PROPERTIES OF DIODE COMMUTATORS AND PURPOSES OF MODERNIZATION

The D312 diodes were used as switching devices for commutators in the operating and monitoring modes of the radio telescope, whereas in a system of beam control the hermetic relays with contacts from a special alloy were used. To guarantee a long-term minimum transfer resistance of relay contacts and to ensure thereby a design value of efficiency for any beam position the direct heating current 60–80 mA was passed through the relays.

For the maximum linearity of the diode commutators forward current ("switch on") and the reverse voltage ("switch off") should have as high as possible values for given type of diodes. However, combination of a relay beam orientation system (as it was mentioned earlier this one requires a noticeable "heating" current) with diodes results in occurring of overload pulse currents which flowing in a system during beam reorientation. It can lead either to a failure of the radio telescope (rather rare occurrence) or to the spontaneous avalanche breakdowns of separate diodes during a measurement session. These discharges lead to appearance in recordings of short broadband interferences of the different intensity. Thus, the reliability of the monitoring system appeared to be lower than reliability of the beam orientation system.

Noticeable signal losses in a frequency range from 25 to 32 MHz appeared to be another severe disadvantage of commutators. At last, the weakest point of commutators was a low dynamic range. The advantage of the dynamic range of the new PAS at low frequencies reaches 12 dB in comparison with an old one (that correspond to the suppression of the third order distortions on 36 dB). Also, the D3 of SC commutators (94–95 dB/μV) was higher by 16 dB than D3 of a former PAS. It should be mentioned that a low-frequency end of the operating range is most "loaded" by interferences. Since the commutators do not have a subband structure (like new PAS) the harmonics and intermodulation distortions of commutators affect all operating frequencies. Therefore, increasing of a dynamic range of commutators was a main task of modernization.

SELECTION OF SWITCHING UNITS

As alternative to operating diodes D312 the p-i-n-diodes and relay circuits were suggested. In spite of the fact that p-i-n-diodes required minimum reconstruction of the system, a preference was given to commutators on a relay basis. The first advantage of relay variant is absence of nonlinear distortions in relays (even if take into account the imperfection of relay contacts and limitation of measurement of D value at a level of 112...115 dB/μV, an experiment indicates that D of relays exceeds corresponding parameter of p-i-n-diodes by 6...10 dB in third order (D3) and by 15...18 dB in second order (D2)). The second advantage is a value of transfer resistance that by order of magnitude smaller in comparison with p-i-n-diode variant.

As the commutation units in the new monitoring system the hermetically sealed reed relays (RES55A) based on gold plated contacts were applied, which do not require "heating" current for maintenance of a constant minimum resistance. The losses (in dB) for CST, CDR and SC commutators in an operation mode for diode and relay variants are 0.9 and 0.2 for CST, 0.4 and 0.2 for CDR, and 1.8 and 1.1 for SC, respectively.

In the course of elaboration of new circuit the replacement of all diodes was recognized as unreasonable. They are completely eliminated from the main path of a radio signal in an operation mode. High decoupling of the monitoring and work circuits guarantees the minimal influence of the remained diode switchers. We succeed in elimination completely diodes from CST, CDR, and CMC commutators. Therefore, these devices now do not affect the interference immunity of the telescope. In SC units diode circuits are fractionally remained because their substitution required an additional control cable. Diodes are situated in monitoring circuits, only insignificant part of a signal to which is derived in an operation mode. New SCs exceed former commutators by about 8...10 dB for D3 parameter, that is better than D3 of PAS almost for all low-frequency end of the operating range (8...11 MHz). This provides increasing of D3 for UTR-2 in whole practically for the same quantity. The dynamic ranges of the former and the new variants of SC and CMC commutators are (in dB/μV) 94.5 and 103 for SC and 98.5 and 112 for CMC.

MODERNIZATION AND TESTING OF UTR-2 TELESCOPE

At first, the operation reliability of the radio telescope was increased. The two-year experience of operation of the new system shows that commutator failure frequency was decreased more than by an order of magnitude. The short wideband interference are observed more rarely. At second, the effective instrument area has increased due to efficiency enhancing of a part of sections from dipoles up to the first stage of PAS. The losses in the antenna, which partly depend on CST and CDR commutators, in operation mode (from an input of dipoles up to the commutator SC, where a signal from a radio source is compared with a signal of a calibration noise generator) were reduced by 0.9 dB. This lead to increasing of the effective area of the antenna by 23 percent. The signal-to-noise ratio for UTR-2 was improved a little bit more. It can be explained by a fact that at second stage input of the PAS a signal is amplified insignificantly in comparison with an input of the first stage PAS1 (about 4 dB at 25 MHz). Therefore, the total signal-to-noise ratio is still influenced by noise characteristics of the second amplification stage and SC commutator. So, if at 20 MHz a sensitivity has increased by 1.2 dB, in the range from 30 to 32 MHz the benefit reaches already the value of 1.5 dB.

The most considerable results have been obtained in increasing of the dynamic range of the radio telescope UTR-2. Now dynamic range at the frequencies from 7.5 to 9 MHz is determined only by linearity of PAS. Here the influence of commutators is vanishingly small. It means that second and third harmonics at the frequencies from 15 to 18 and from 22.5 to 27 MHz are also eliminated. We mention earlier that the new PAS does not also generate these harmonics due to its multiband structure. Besides this, increasing of dynamic range by 10 dB in the third order is equivalent to reducing of combination products by 30 dB. At the frequencies from 9 to 11 MHz a high dynamic range D is determined by new SC commutators and PAS jointly, but at the new level that is higher by 5...10 dB than earlier.

As is obvious from the foregoing, the putting into operation of the new commutators has given substantial improvement of interference immunity of the telescope as a whole. Now the observations in the extremely unfavourable conditions (day and summer time with a high level of interferences and exterior noises) are possible. A stable operation of the radio telescope during broadband observation of the Sun in time of very high activity (June – July 2002) is an illustration of aforesaid. The observation was carried out with the help of 60 high selective receivers (partial band from 4 to 10 kHz) in the range from 9 to 30 MHz. In the figure a record fragment with extremely high level of solar radiation (by 30...50 dB higher than usually) is presented. The interference level during recording was typical for this time and was about 75...85 dB/μV [1]. Additional increasing of solar background radiation leads to the extremely high total level at the telescope input. Usually, in such situation one should expect appearance of the pseudo occasional wideband spectrum of the combination products that will be detected by 60-channel spectrograph with a very high probability. However, the combination products in the records are absent. This indicates rather high interference immunity of the telescope in the range from 9 to 30 MHz.

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