NEW METHODS AND EQUIPMENT OF DECAMETRIC RADIO ASTRONOMY FOR CONTINUUM OBSERVATION AT THE UTR-2 RADIO TELESCOPE

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At present time the modernization of the giant decametric radio telescope UTR-2 is under way. New back-end facilities and methods which open up new possibilities for radio astronomical observations are developed. Some equipment was made in cooperation with Austrian and French radio astronomers. Current back-end facilities and methods used at the UTR-2 radio telescope are described and compared with former traditional methods, equipment and their characteristics. Some prospects regarding current progress in developing new generation of back-end facilities are also discussed. The main focus of the presentation is the observation methods and equipment applied at the UTR-2 radio telescope for the investigation of continuum radio sources: Galactic background, discrete sources (preparation for the catalogue of sources in the whole Northern Sky), SNR, H II regions. Some results of using the new back-end facilities (such as Digital Spectral Polarimeter) and processing methods are presented.

INTRODUCTION

At present time the modernization of giant decameter UTR-2 radio telescope, located near Kharkiv is under way. A lot of work has been done by us and also together with French colleagues (Paris–Meudon Observatory) and Austrian colleagues (Space Research Institute, Graz). The main subject of our joint efforts is the development and implementation of modern back-end facilities and data processing methods for the UTR-2 radio telescope. In the frame of INTAS joint projects during last five years of cooperation we had conducted four joint observational campaigns [4] with use of new Digital Spectral Polarimeter [3], which allowed us to greatly improve sensitivity, time and frequency resolution of the radio telescope. Specially designed data processing methods and observational algorithms allowed us to decrease duration of observations in several times. The main focus of the presentation is the observational methods and equipment applied at the UTR-2 radio telescope for the investigation of continuum radio sources: Galactic background, discrete sources (preparation for the discrete sources catalogue in the whole Northern Sky), supernova remnants, H II regions.

MODERNIZATION OF THE UTR-2 RADIO TELESCOPE

T-shaped UTR-2 radio telescope [1] can be represented as shown in Fig. 1a: North–South antenna and East–West antenna are phased with electrical phase system based on switched delay lines. Phase system produces knife-like antenna patterns for both antennas. The phase system has six outputs: first is the output from East–West antenna, *i.e.*, knife-like beam, which is 0.5° wide in East–West direction and 15° wide in North–South direction. Outputs from second to sixth are five knife-like beams formed from North–South antenna. These beams are 15° wide in East–West direction and 0.5° wide in North–South direction and are separated by 0.5° in each declination. All these outputs are then put to back-end facilities. Before modernization of back-end facilities the receivers were set, *i.e.*, a filter bank with six frequency channels and five independent beams, thus forming 30-channel receiver. On output from the receiver we obtained five pencil-like beams, which were formed in a process of multiplication of North–South and East–West antenna signals. Later on thirty channels these signals were digitized and stored with eight-bit A/D converter.

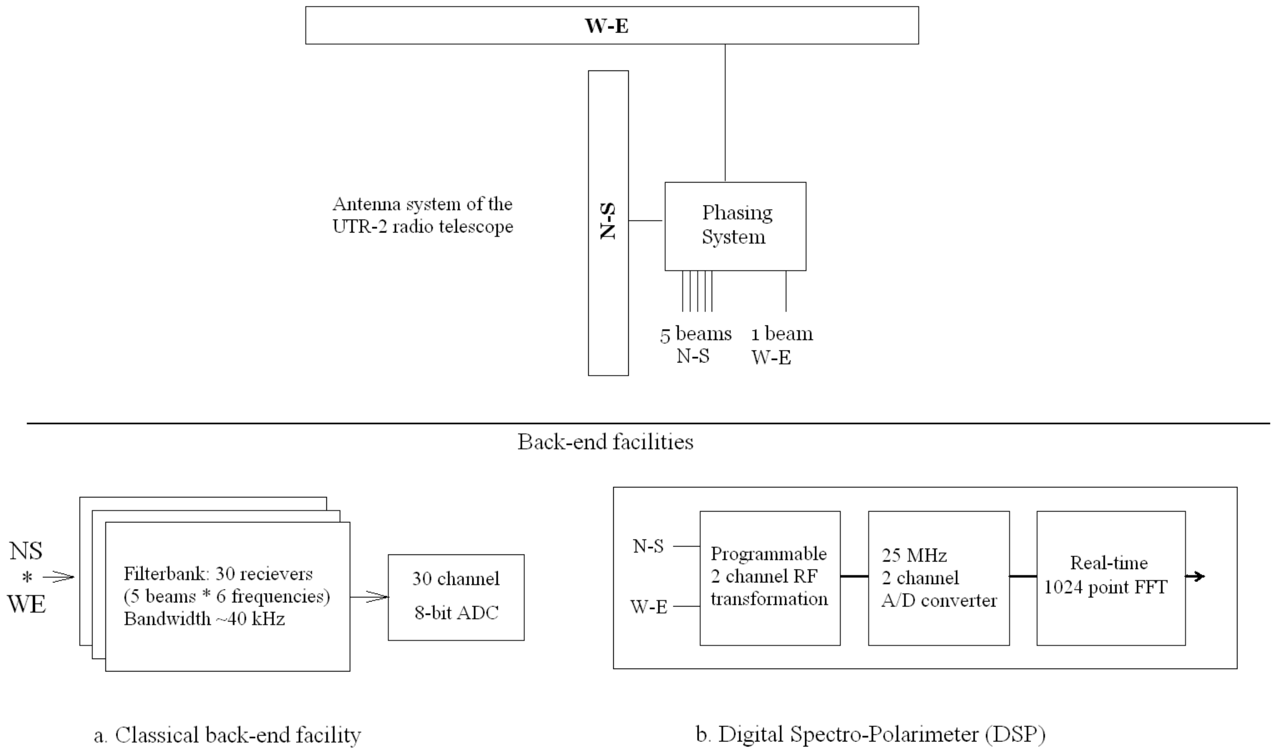

Figure 1. Scheme of UTR-2 radio telescope with classic and new back-end facilities

A new scheme was developed in the process of modernization. As can be seen in Fig. 1b, antenna and phase system remained the same, and we only changed the old 30-channel filter bank with a new digital receiver. This receiver (Digital Spectral Polarimeter) had been created in France, at the Paris–Meudon Observatory in cooperation with the Space Research Institute in Graz. The block diagram of the DSP is as follows: radio frequency block for two independent inputs, which were fed with North–South antenna central beam and East–West antenna beam. The radio frequency block performs filtration and frequency transformation to base band. The block is controlled through a serial communication port allowing to choose central frequency. The base band signal is then digitized and passed to real-time by Fast Fourier Transform module which produces power spectra of input channels and calculates cross spectrum – multiplication of both channels spectrum, thus creating pencil-like beam.

Each of 30 receivers used in the filter bank have their own tunable frequency and fixed bandwidth of 40 kHz. Receivers are grouped in sets of six units per one antenna beam. In total, there are five such groups. Typically, we use following frequencies for these sets of receivers: 10, 12.6, 14.7, 16.7, 20, and 25 MHz. Dynamic range of this system is determined by A/D converter module used, and is 48 dB. During the observation we must manually slightly tune the frequencies of filter bank receivers in order to choose frequency bands free from interferences.

The filter bank covered frequency range from 10 to 25 MHz, but we could only use six different frequencies with 40 kHz bandwidth. In such conditions we could not avoid interferences, which are very common and strong at decameter wavelength band. We had implemented several methods of detecting interferences, but they were not always successful. Still, a lot of data were damaged and could not be processed.

Main characteristics of the old and new systems are listed in Table 1. The modernization lifted us to a new

Table 1. Characteristics of old and new back-end facilities

	Frequency resolution, kHz	Number of channels	Dynamic range, dB
Filter bank	40	5×6	48
DSP	12	2×1024	70

level. With the DSP we cover 12 MHz continuous frequency band, divided into 1024 channels. Each channel is 12 kHz wide, so typical interference signal fits completely in one or two channels. We developed and implemented a method, which allowed us to automatically clean spectrum from interferences.

Now we can perform radio astronomical observations in very difficult interference conditions. For 80% of observational time on average 15% of spectrum is affected by interferences. With the cleaning algorithm we can use 85% of frequency band. Thus, frequency coverage of the full DSP band is 12×0.85 MHz, instead of 40×6 kHz maximum for the filter bank. The spectrum of observed objects is a power-law, *i.e.*, it does not contain any fine structures, thus allows us to increase sensitivity by 42 times in comparison with old back-end system.

DISCRETE SOURCES SURVEY

Owing to the modernization and the progress of computers and numerical techniques the data processing methods for various radio astronomical tasks have been considerably improved. We had developed a new automatic algorithm of discrete sources detection [2]. It has allowed us to make the data processing procedure nearly completely automatic and increase reliability of the whole process. Nowadays, we had observed and processed seventy percents of the Northern Sky. The latest part of the discrete sources survey was processed using improved methods. In the latest observational campaign we covered approximately one steradian of the sky. As a result, 483 sources were detected. The coverage map is shown in Fig. 2.

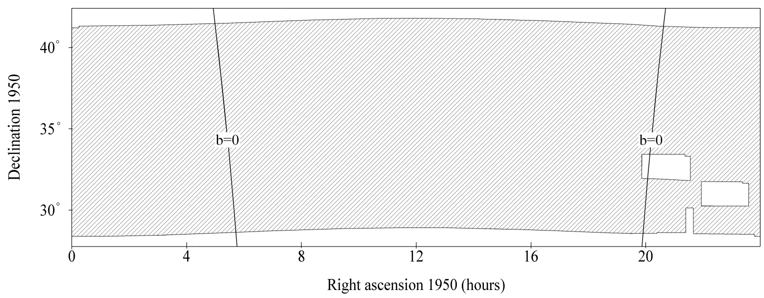

Figure 2. Coverage of the celestial sphere by the present part of the survey

GALACTIC BACKGROUND RADIATION OBSERVATIONS

Using the new back-end facilities we had developed improved algorithm for Galactic background radiation observations. To speed up the process of observation we implemented fast scanning technique. Each 10 seconds the diagram pattern of the radio telescope switches to target slightly different sky region. We change the beam position in declination. Right ascension scanning is performed due to rotation of the Earth. During ten-day experiment we covered thirty percents of the Northern Sky. In Fig. 3 you can see contour brightness map of sky region, namely from 12 to 60 degrees in declination. Frequency range for the map is 17–25 MHz. To obtain a map we used our interference-cleaning algorithm. Some areas still contain interference. The map is only obtained from North–South antenna. Its beam has knife-like form. You can see traces from Cassiopeia A, Cygnus A, and Crab Nebula. In former conditions and with old equipment and methods it would have taken us several years to build such a big map.

Using new equipment and methods of map building and interference cleaning we observed a lot of other continuum sources: supernova remnants, H II regions, and Galactic clusters.

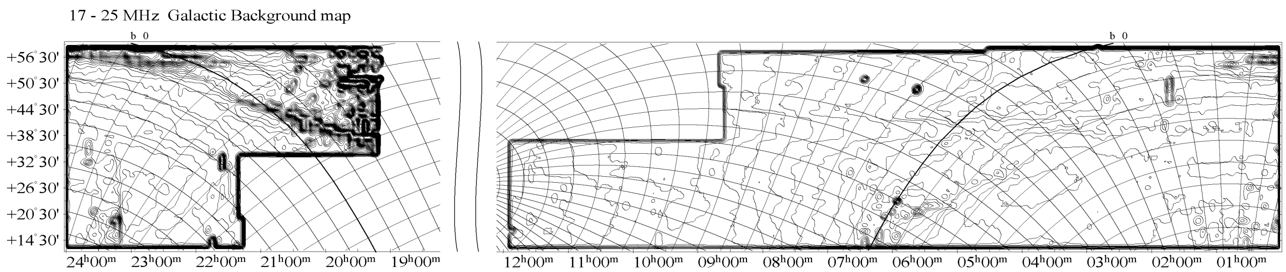

Figure 3. Experimental Galactic background map

PROSPECTS

The modernization of UTR-2 radio telescope is continuing now. We are developing new digital receiver together with French and Austrian colleagues. It will have the possibilities similar to the Digital Spectral Polarimeter with some new features.

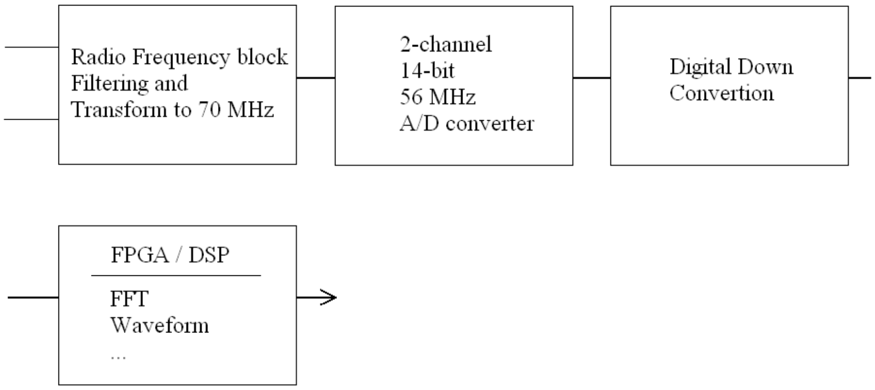

Figure 4. Diagram of perspective digital receiver for UTR-2

Radio frequency block, as the DSP, has tunable central frequency. But it does not perform frequency conversion to base band. The signal on output from the block is placed at 70 MHz starting frequency with 14 MHz bandwidth. The next block is an A/D converter, which operates at 56 MHz sampling frequency, performing undersampling frequency of input signals. Then undersampled data is processed in Digital Down Conversion (DDC) block, which produces output base band signal. Due to flexibility of modern digital circuits we can choose sub-bands of full bandwidth from 14 MHz down to 800 kHz. The next block is a programmable digital processing unit. Typical task for it is FFT transformation. But it is also possible to get raw waveform data or reprogram the block any time to perform some different tasks. The characteristics of this receiver are listed in Table 2.

Table 2. Characteristics of perspective back-end facility for UTR-2

Frequency range	Frequency resolution	Time resolution	Continuous frequency band
10–70 MHz	400 Hz – 14 kHz	1 ms / waveform	14 MHz – 800 kHz

CONCLUSION

We had significantly improved performance of the world's largest decameter UTR-2 radio telescope and developed new methods and equipment, which allowed us to obtain new astrophysical results. Also, we got a lot of experience with operating giant decameter radio telescope and processing its data. In a scope of LOFAR concept our experience can be very useful. The modernization of the UTR-2 is not stopped. We are continuing to develop modern back-end facilities and data processing methods to use with UTR-2.

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[1] *Braude S. Ya., Megn A. V., Ryabov B. P., et al.* // Astrophys. and Space Sci.–1978.–**54**, N 3.

[2] *Braude S. Ya., Rashkovsky S. L., Sidorchuk K. M., et al.* Decametric survey of discrete sources in the northern sky // Astrophys. and Space Sci.–2002.–**280**, N 3.–P. 235–300.

[3] *Lecacheux A., Rosolen C., Clerc V., et al.* Digital techniques for ground based, low frequency radio astronomy // Proc. SPIE.–1998.–**3357**.–P. 533–542.

[4] *Rucker H. O., Lecacheux A., Konovalenko A. A., et al.* New frontiers in decameter radio astronomy // Planetary radio emissions: Proc. of the 5th Intern. Workshop, Graz, Austria, April 2–4, 2001 / Eds H. O. Rucker, M. L. Kaiser, Y. Lelanc.–P. 51–61.