Joint science session of the division of general physics and astronomy of the USSR academy of sciences and the academy's council of radioastronomy

(Submitted October 25-26, 1972)
Usp. Fiz. Nauk 109, 769-778 (April 1973)

A joint science session of the Division of General Physics and Astronomy of the USSR Academy of Sciences and the Academy's Science Council on Radioastronomy was held on October 25 and 26, 1972, in the Conference Hall of the P. N. Lebedev Physics Institute. The following papers were presented at the session:

1. S. Ya. Braude and A. V. Men'. The UTR-2 Decameter-Band Radiotelescope and the Problems of Decameter Radioastronomy.

2. V. S. Troitskiĭ. Radioastronomical Observations with the Aid of Interferometers with Independent Reception (with Ultralong Base Lines) in the USSR.

3. M. M. Kobrin, A. I. Korshunov, and V. V. Pakhomov. Quasi-periodic Components in the Fluctuations of the Solar Radio-Frequency Radiation.

4. Yu. P. Shitov. Pulsar Observations at the Radioastronomical Station of the USSR Academy of Sciences Physics Institute.

5. V. V. Zheleznyakov. On the Origin of Pulsar Radiation.

6. Yu. N. Pariĭskiĭ and N. S. Kardashev. The Problems of Large-Telescope Construction.

We publish below summaries of the papers presented.

S. Ya. Braude and A. V. Men'. The UTR-2 Decameter Wave-Band Radiotelescope and the Problems of Decameter Radioastronomy. Progress in radioastronomy is substantially determined by the level of the measuring techniques, especially of radiotelescopes. Until recently, in the decameter band ($\lambda > 10$ m), in contrast to shorter-wavelength bands, there were no sufficiently efficient instruments with large effective area and resolution that operated in a wide scannable sector with an operational program switching. A characteristic of such radiotelescopes is that they must have large antennas which do not allow the application of mechanical means of orientation of the instruments. Because of the high noise level in this band, it is expedient to use broadband antennas with the object of increasing the noise-proof capacity by tuning out the noise and performing the observations at a number of frequencies simultaneously. The high temperature of the radio-frequency radiation of the cosmic background and the necessity for the elimination of the effect of the "entanglement" arising from the reception of cosmic signals by the secondary lobes of the directional diagram require the use in decameter radiotelescopes of special methods of signal modulation and those antenna systems that guarantee the optimum matching of the effective area with the resolution and in which the level of the fringe radiation can be controlled.

The complexity of the numerous systems and devices in a modern radiotelescope—in particular, of the radioelectronics used in the nonmechanical methods of beam control—leads to the necessity in principle for the optimization of its structure for its installation. With the object of working out principles of construction of receiving antennas satisfying these requirements, researchers at the Institute of Radiophysics and Electronics of the Academy of Sciences of the Ukrainian SSR (IRE AS UKrSSr) constructed and experimentally investigated during the decade 1960–1970 four decameter radiotelescopes operating in the 10–40 MHz band: an interferometer consisting of two parallel 24-element arrays, an interferometer consisting of two orthogonal 128-element arrays, a 208-element UTR-1 radiotelescope, and a 2040-element UTR-2 radiotelescope[1,2]. Investigations showed that the most optimum type of antennas for decameter radiotelescopes is the multielement wide-band antenna arrays with electrical beam control. They consist of broadband radiators with auxiliary matching devices and signal phasing and integrating systems. In order to have a broadband phasing system, the researchers rejected the widespread method of phasing with the aid of dispersion phase shifters, and used instead a temporal method of phasing with the aid of time-delay lines.

For illustration, let us consider in greater detail the last of the IRE AS UkrSSR instruments, i.e., the UTR-2 decameter radiotelescope, constructed on the basis of the indicated principles[2]. It has an optimum—from the point of view of sensitivity-resolution matching—configuration in the form of the letter T and consists of three multielement horizontal antenna arrays of dimensions 900 $\times 60$ m each. At the center of these arrays stands the technical building. Two of the antennas (the northern and southern) are oriented along the meridian, the third (western) along the parallel. The first two consist of 1440 radiators, forming from north to south six 240-element arrays. The third antenna contains 600 radiators—six 100-element arrays from west to east. All the 2040 radiators of the UTR-2 are symmetric, broad-band, horizontal, shunt-type dipoles oriented along the east-west direction. In all the three antennas the signals are electrically phased in two coordinates by the temporal method. The signal phasing and integration are first carried out along the short sides of the arrays with the aid of 240 identical phase-shifter units in the northern and southern antennas and 100 such devices in the western antenna, the former set of devices being synchronously controlled with respect to one coordinate and the latter set with respect to the second coordinate. The HF signals of six radiators of one array are phased and integrated in one phase shifter. Then the signals are phased along the long sides of the arrays in the northern and southern antennas in a 4-stage scheme involving 73 phase shifters and in the western antenna in a 3-stage scheme involving 25 phase shifters. The output section of the western antenna contains another phasing unit that guarantees the mutual phasing of the antennas.

All the phase shifters of the radiotelescope consist of time-delay, relay-switched (discharge) lines made of sections of a HF coaxial cable and collected together in accordance with a binary code. Signal integration in the phase shifters is carried out at all stages with the aid of broad-band, hybrid, ferrite integrators without communication between the channels that can be coupled Control of all the devices phasing and integrating the signals of the dipoles and groups of dipoles spaced along the meridian is performed with the aid of 11 driving signals (discharges); control along the second coordinate, with the aid of 10 discharges. Thus, in all, more than 2×10^6 beam-orientation directions can be used in the scannable sector. The phasing apparatus is remotely controlled from the control panel of the central apparatus, on account of which the orientation of the beam of the radiotelescope can be changed in a fraction of a second. To ensure a high accuracy in the reproduction of a given directivity pattern, the directional grain and efficiency of the instrument, an exact impedance matching and a precise adjustment of the electrical lengths of the time-delay lines have been carried out in all the HF circuits and communications of the phasing system in the operating frequency band; a broadband matching of the impedances of all the radiators with the wave impedance of the phasing system has been carried out with the aid of 2040 special reactive quadripoles. The matching devices were located at the centers of the dipoles to which they were connected through broadband balancing ferrite junctions.

Because of the large dimensions and the wide scannable sector of the antennas and, connected with this, the heavy losses in communications and in the phasing apparatus, a two-level distributed system of built-in antenna amplifiers is employed in the radiotelescope. In the beginning the losses are compensated with the aid of 12 amplifiers connected to the outlets of units containing 180 radiators each in the northern and southern antennas and 150 each in the western antenna. The second level, which contains nine antenna amplifiers is connected to the outlets of all the antennas before the beam-shaping unit. For a high sensitivity and noiseproof capacity of the antenna amplifiers against thermal noise and combination interferences, a specially constructed broadband amplifier circuit with a matched division of the entire frequency band to be amplified into a number of narrow-band channels and the subsequent synthesis of them after amplification is employed in the amplifiers. An effective automatic system of protection against and detection of malfunctions is provided for in the radiotelescope. In particular, an automatic-control system allows us to control, according to the exact form of the diagram, the normalcy of the antenna as a whole, to verify the amplitude and phase of the signals in all channels of the phasing system, and to determine the normalcy of the dipoles of the arrays.

The construction and putting into operation of the UTR-2 radiotelescope with its unique characteristics allow the promotion of extensive radioastronomical investigations in the decameter band. The large effective area (about 150,000 m^2), high resolution ($20'\times 20'$ at a frequency of 25 MHz), a wide scannable sector ($150°$ of declination and from 8 to 24 hours of right ascension) with the possibility of a rapid beam swinging, and the wideness of its operating frequency band substantially distinguish the radiotelescope from all the instruments operating in this band. To allow for refraction in the ionosphere and the increase in the volume of information, the UTR-2 radiotelescope operates simultaneously with five beams distributed in space over the declination. In each beam the measurements are carried out at six frequencies ranging from 10 to 25 MHz. Therefore, the radio receiving apparatus of the UTR-2 consists of 30 radiometers with analog and digital recording systems. The primary duty of the instrument is to modulate. In this regime a "pencil" beam is formed by multiplying the directional diagrams of the western and north-southern antennas by the discrete phase modulation method. Reception can be simultaneously conducted in the modulation and compensation regimes with all the UTR-2 antennas and their units connected up separately or in diverse combinations.

Let us discuss briefly the problems which will be solved on the UTR-2. The primary investigations that can be carried out on it are the scanning of discrete and extended cosmic radio-frequency radiation sources, in order to compile catalogs of their spectra, and the determination of the angular dimensions and radio-luminosity distribution in the decameter band. Measurements on the radio emissions of the "quiet" sun, solar flares, and the occultation by the sun's supercorona of discrete cosmic radio sources are also going on. The radio emissions of pulsars and the occultations of cosmic radio sources by the moon are being observed regularly. A search is going on for a nonthermal radio-frequency radiation from the planets of the solar system. Using the radio-frequency radiation of cosmic sources, we can study with the aid of the UTR-2 the refraction, damping, and fluctuations of radio waves in the ionosphere. After some changes in the operating conditions of the instrument, it is planned to use it to compile charts of the distributed cosmic radio emissions and, in particular, of the absorption regions of this radiation in ionized hydrogen clouds. Preparatory work is in progress on the construction on the basis of the UTR-2 of several radiointerferometers with long base lines for the measurement of the angular dimensions of radio sources. The execution of these and a number of incidental programs will allow in the next few years a substantial expansion of the volume of information that can be obtained in the decameter band on cosmic radiation.

[1]L. L. Bazelyan, Yu. M. Bruk, I. N. Zhuk, A. V. Men', and N. K. Sharykin, Élektrosvyaz' 5, 14 (1964); L. L. Bazelyan, Yu. M. Bruk, I. N. Zhuk, A. V. Men', L. G. Sodin, and N. K. Sharykin, Izv. Vyzov (Radiofizika) 7, 215 (1964); Yu. M. Bruk, N. Yu. Goncharov, A. V. Men', L. G. Sodin, and N. K. Sharykin, ibid. 10, 608 (1967) [Radiophysics and Quantum Electronics 10, 331 (1967]; Yu. M. Bruk, N. Yu. Goncharov, I. N. Zhuk, G. A. Inyutin, A. V. Men', L. G. Sodin, and N. K. Sharykin, ibid. 11, 28 (1967) [Radiophysics and Quantum Electronics 11, 14 (1968)].

[2]S. Ya. Braude, Yu. M. Bruk, P. A. Mel'yanovskiĭ, A. V. Men', L. G. Sodin, and N. K. Sharykin, Preprint No. 7, IRÉ AN UkrSSR, Khar'kov, 1971.

V. S. Troitskiĭ. Radioastronomical Observations with the Aid of Interferometers with Independent Reception (with Ultralong Base Lines) in the USSR. The application of interferometers in radioastronomy allowed the measurement of the angular dimensions of sources with a high resolution computed in fractions of the width of the interference fringe and equal to $\Delta = \lambda/d$, where d is the distance between the antennas and λ is the wavelength. Attempts to increase the resolving power of the interferometer by increasing the base line encountered insurmountable difficulties in the construction of long communication lines between the two stations, lines necessary for signal integration and the transmission of heterodyne voltages. From roughly 1965 there began in the USA, Canada, and the USSR (at the Gor'kiĭ Radiophysics Research Institute (GRRI)) the development of interferometers with independent reception based on the registration of signals at each point with the subsequent reproduction and processing. In this case lasers were used at each point as heterodynes; they also guaranteed precise time makings on the signal recording (see, for example, [1]).

The first transcontinental interferometer in the USA and Canada started operating at 67-cm wavelength in 1967. In the USSR the first interferometer with independent reception based on the rubidium frequency standards and with processing on the BÉSM-4 computer was constructed in 1969. In 1969–1970 the dimensions of two quasi-stellar sources were measured at 3.5-m wavelength with the aid of the ASPI (Academy of Sciences Physics Institute) antennas and this interferometer with a 230-km base line. The fringe width was $\Delta = 3''$. These measurements at ultrashort wavelengths with a long base line were the first and, for the present, remain the only ones that have been performed[2]. In Table I the results obtained are compared with foreign data for close values of d/λ: foreign data are available only for shorter waves. The main result of the measurements is that the dimensions of the indicated quasars at a substantially longer wavelength turned out to be roughly the same as at decimeter wavelengths. From this follows the important conclusion that the halo, if there is one, is small, and that scattering by the inhomogeneities of the interstellar and interplanetary media does not lead to a substantial increase.

In 1972, at the GRII, a more accurate interferometric system was constructed jointly with the Byurakan Astronomical Observatory (BAO) of the Academy of Sciences of the Armenian SSR on whose computer, the

TABLE I

$\lambda = 3.5$ m, d = 230 km, $\Delta = 3''$

Source	Frequency MHz	d/λ	Visual range γ	Angular dimensions of source, angle x sec	Position angle θ	Literature
3C 298	86	$6.5\cdot10^4$	0.94	$\leqslant 0.4$	32	This report
	1422	$4.7\cdot10^5$	0.65	0.2	150	[3]
3C 380 (V)	86	$6.5\cdot10^4$	0,8	0.9	24	This report
	1422	$6\cdot10^5$	0,43	0.4	0–180	[3]
	2695	$8.32\cdot10^4$	0 76	0.8	—	[4]

TABLE II

f = 408 MHz, $\lambda = 73$ cm, d = 1100 km, $\Delta = 0.15''$

Source	Frequency MHz	$d/\lambda\cdot10^{-6}$	Visual range γ	Angular dimensions of source, angle x sec	Position angle θ	Literature
3C 147	408	1.3	0.27	0.11	58	This report
	408	1.12	0.22	0,13	126	[5]
	1400	2.6	0.2	0.07	128	[6]
3C 273B (V)	408	1.3	0.9	$\leqslant 0.03$	58	This report
	408	4.6	0,48	0.02	95	[5]
3C 286	408	1,3	0.63	0,07	58	This report
	448	1,33	0,5	0.08	52	[5]
	1400	1.75	0.75	0.04	170	[6]
3C 454,3 (V)	408	1.3	1,0	$\leqslant 0.03$	58	
	2690	1.1	0.96	$\leqslant 0.02$	0–180	This report
	4998	2.1	0.99	< 0.02	0–180	[3]