

## RADIOASTRONOMY

DOI: <http://dx.doi.org/10.18524/1810-4215.2018.31.144460>

## RADIO TELESCOPE URAN-4 AND THE PROBLEM OF RADIO INTERFERENCE

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**ABSTRACT.** The URAN-4 decameter radio telescope, which is located in the village of Mayaki of the Odessa region, is an element of system of the URAN radio telescopes (Ukrainian Radiointerferometer of the Academy of Sciences). The radio telescope is used according to the following scientific programs: measurements in the composition of the Interferometer with the Super Large Base (VLBI), to study the angular structure of discrete radio sources; the study of the nonstationarity of the flux of cosmic radio sources and the study of the influence of the space environment on the characteristics of the received signals.

RT URAN-4 operates at frequencies of 10-30 MHz and consists of an antenna and an equipment complex. A telescope antenna is an electrically controlled phased array of 128 turnstile vibrators. It identifies two linear signal components and is endowed with the possibility of changing the position of the antenna pattern in space (2048 discrete positions of the beam). The geometric dimensions of the array 238 meters (West-East direction) and 28 meters (North-South direction). The size of the antenna pattern in the modulation mode of signal reception at a frequency of 25 MHz is  $2.7 \times 22$  degrees. In the VLBI interferometer mode, a resolution of about 2 seconds of arc is realized. The instrumental complex of the RT URAN-4 is represented by two types of modulation radiometers, which make it possible to measure the flux densities of radio sources and apparatus intended for VLBB measurements.

The working frequency range in which RT URAN-4 operates has a high level of radio interference. The work gives definitions of interference acting in the decameter range. Considered methods of dealing with them. One of the methods to combat interference is the work of the radio telescope on the frequencies permitted and legally protected from interference, the list of which is given in the article. The paper deals with issues related to the organization of the security zone around the radio telescope. On its territory, the maximum allowable power for existing nearby transmitting radio facilities and interfering industrial facilities should be legitimized, in the designated working lanes. At the same time, a monitoring service for the radio spectrum should be organized. The paper deals with the developed and manufactured portable direction finder. Its characteristics are given, recommendations on its use are given.

**Keywords:** radio telescope, interference, frequency band, radiometer, direction finder.

**АБСТРАКТ.** Декаметровий радіотелескоп УРАН-4, що розташований в селі Маяки Одеської області, є елементом системи радіотелескопів УРАН (Український радіоінтерферометр Академії наук). Радіотелескоп використовується по наступних наукових програмах: проведення вимірів у складі Інтерферометра з Понад Великою Базою (РПВБ), для вивчення кутової структури радіоджерел; дослідження нестационарності потоків космічних радіоджерел і вивчення впливу середовища на характеристики прийнятих сигналів.

РТ УРАН-4 працює на частотах 10-30 МГц і складається з антени й апаратурного комплексу. Антена телескопа – це електрично керована фазована решітка з 128 турнікетних вібраторів. Вона виділяє дві лінійні складові сигналів й наділена можливістю зміни положення діаграми спрямованості в просторі (2048 дискретних положень променя). Геометричні розміри її – 238 метрів (напрямок Захід-Схід) і 28 метрів (напрямок Південь-Північ). Розміри діаграми спрямованості в модуляційному режимі прийому сигналу на частоті 25 МГц становить  $2.7 \times 22$  градуса. У режимі РПВБ інтерферометра реалізується просторова роздільна здатність близько 2 секунд дуги. Апаратурний комплекс РТ представлений двома видами модуляційних радіометрів, які дозволяють вимірювати щільності потоків радіоджерел, і апаратурою, яка призначена для РСДБ вимірів.

Робочий діапазон частот, у якому працює РТ УРАН-4, має високий рівень радіозавад. У роботі даються визначення завад, діючим у декаметровому діапазоні. Розглядаються методи боротьби з ними. Одним з методів боротьби з завадами є робота радіотелескопу на дозволених і юридично захищених від завад частотах, перелік яких наведено в статті. У роботі розглядаються питання, пов'язані з організацією навколо радіотелескопа охоронної зони. На її території повинна бути узаконена у відведених робочих смугах максимально припустима потужність для існуючих поруч передавальних радіозасобів і промислових об'єктів, що заважають. Одночасно із цим, повинна бути організована служба контролю за радіо спектром. У роботі розглядається розроблений і виготовлений переносний пеленгатор. Наводяться його характеристики, даються рекомендації з його використанням.

**Ключові слова:** радіотелескоп, радіозавади, смуга частот, пеленгатор.

## 1. Introduction

Radiotelescopes are highly sensitive instruments and therefore the requirements for the cleanliness of the spectrum, in the range in which they operate, are extremely important. The URAN-4 decameter radio telescope, which is located in the village of Mayaki of the Odessa region, is an element of system of the URAN radio telescopes (Ukrainian Radiointerferometer of the Academy of Sciences). Its main purpose is to work in the mode of the very large base interferometer (VLBI). The RT URAN-4 is used for the following scientific programs: VLBI measurements with the UTR-2 radio telescope to study the angular structure of galactic and extragalactic radio sources; studying the nonstationarity of cosmic radio sources; study of the influence of the space environment on the characteristics of received signals; improvement of methods for receiving and processing signals.

The place for the RT URAN-4 was chosen after lot of research based on the following considerations. The place was located on the edge of the village, with developed engineering networks, and the lack of industrial facilities and, as a result, the absence of industrial interference. Studies of the radio band showed that there are no transmitters of considerable power in the radius of propagation of a direct wave and the range is relatively free from various kinds of interference of artificial origin. The radio telescope began its work in 1985.

Unfortunately, since then, the interference environment has changed dramatically, and the fight against interference has become more urgent.

## 2. Radio telescope URAN-4

The URAN-4 radio telescope (Galanin, 1989) consists of an antenna and a measuring complex and operates at frequencies of 10-30 MHz. The antenna is an electrically controlled phased array of 128 turnstile vibrators. It is endowed with the ability to separate the two linear components of the signal and change the position of the antenna pattern (AP) in space. In the North-South direction, 16 beam positions were implemented, and in the West-East direction, 128 (a total of 2048 individual beam positions) were implemented. The geometrical dimensions of the array are 238 meters (West-East direction) and 28 meters (North-South direction). The dimensions of the AP in the modulation mode of receiving a signal with a frequency of 25 MHz are  $2.7 \times 22$  degrees. In the VLBI interferometer mode, a resolution of about 2 seconds of arc is implemented. The maximum value of the directivity of the antenna at a frequency of 25 MHz is 618. The efficiency at the same frequency is 0.1.

The measuring complex includes Dicke radiometers, which allow measuring the flux densities of radio sources and apparatus intended for VLBI measurements. During the operation of the RT URAN-4, the measuring complex has undergone several modifications. Initially, narrow-band receivers with a bandwidth of up to 20 kHz were used. Currently, the band has increased from 250 kHz to a single MHz. The expansion of the bandwidth of the receiving equipment, has led to an increase in the sensitivity of the radio telescope. At the same time, digital

registration and digital signal processing allowed the use of various methods of filtering interference. In spite of this, a significant deterioration of the interference environment in recent years in some cases reduces the effectiveness of conducting observations

## 3. The Decameter Interference

World Administrative Radiocommunication Conference, (WAKR-79) held in 1979, gave the definition of harmful interference. Harmful is considered to be interference, which increases the noise temperature of the radio telescope by more than 10%.

The Interference of decameter range can be divided into two groups: remote and local.

The remote sources of interference include broadcasting radio stations, communication systems and radar, ionospheric stations. In this case, ionospheric propagation of the interference occurs.

Ways to deal with them: conducting observations at night, when the possible maximum applicable frequencies are below the operating frequency of the radio telescope; use of narrow antenna pattern with narrow side lobes; frequency, temporal and spatial filtering of interference; the dynamic range of signal amplification systems increase; the allocation and use for radioastronomic studies of legally protected frequency bands defined by the International Telecommunication Union.

Of the above methods of dealing with interference, which are widely reported in the literature, let us dwell on the latter. Already during the formation of radio astronomy, much attention was paid to the allocation of frequencies for radio telescopes. So, frequencies: 2.5, 5, 10, 15, 20, 25, 37, 73, 79 MHz for low-frequency radio astronomy observations were recommended by the Radio Frequency Body of the International Telecommunication Union, Geneva, Switzerland. (Kraus, 1973). In 1979, the World Administrative Conference on Radiocommunication allocated a number of legally protected bands for low-frequency radio astronomy: 13.360-13.410 MHz, 25.550-25.570 MHz, 37.5-38.25 MHz, 73.0-74.6 MHz. Allocated bands have different legal protection statuses. The prerequisite for protection is the registration of transmitters and radio telescopes at the State Telecommunications Inspection and the International Registry (Dubinsky, 1985).

The local sources of interference include industrial and domestic interference, including corona discharges on high-voltage power lines, special process equipment, switching power supplies, and high-power fluorescent lighting devices. Most of the interference from local sources have a broadband spectrum, which significantly complicates the fight against them. Therefore, the main method of dealing with local interference is to identify and solve the problem by organizational and administrative methods.

To implement this approach, an important task is to establish a radio telescope security zone (Dolan, 1973). On its territory, the maximum permissible radiation power of transmitting radio equipment, industrial and household object should be legalized, in the designated working bands. At the same time, a radio monitoring service should be organized on the radio telescope, the task of which would be to detect interference and determine their location.

#### 4. The effect of interference on the operation of a radio telescope

Radiometers of URAN radio telescopes are formed according to the interferometer with a small base. The elements of the interferometer are the two halves of the antenna array of the radio telescope, the signals from the halves of the arrays go to the two channels of the radiometer and are subsequently multiplied. This scheme allows you to suppress galactic noise, the intensity of which exceeds the signal intensity of most discrete cosmic sources in the decameter range. This scheme allows the use of correlation and modulation radiometers. Regular for RT URAN-4 are modulation radiometers.

Radio interference penetrating the reception path of the RT URAN-4 and affecting the operation of the modulation radiometer can be divided into three groups:

1. Narrow-band continuous interference.
2. Narrowband impulse interference;
3. Broadband interference.

An example of three types of interference is shown in Fig. 1. The recording of the spectra was made at RT URAN-4 using an SDR receiver with a bandwidth of 1 MHz.

Narrowband continuous interference leads to a zero offset when recording a cosmic source. In the case of moderate intensity of interference, this effect is eliminated by digital data processing, by frequency filtering of interference. Offset of the zero level is not always possible to detect in the output signal of the radiometer. In particular, it is possible to use the tracking mode of a cosmic source, in which the source completely crosses the fixed antenna pattern. In this case, it is possible to apply the technique of inscribing the antenna pattern, which excludes measurement error associated with the offset of the zero recording level (if the interference power during this time remains constant).

Narrow-band impulse interference leads to emissions of the output signal of the radiometer (note that if the pause between pulses is less than the constant integration of the radiometer, then the interference is perceived as continuous). Frequency and temporal filtering can be used to combat such interference. Broadband interference is not amenable to frequency filtering. Continuous broadband interference leads to a zero offset of the cosmic recording. When the above conditions are met, to reduce the measurement error possible to use the technique of inscribing the antenna pattern. With the fluctuating power of broadband interference, the inscribing technique becomes ineffective. Temporal filtering can be applied to combat impulse broadband interference.

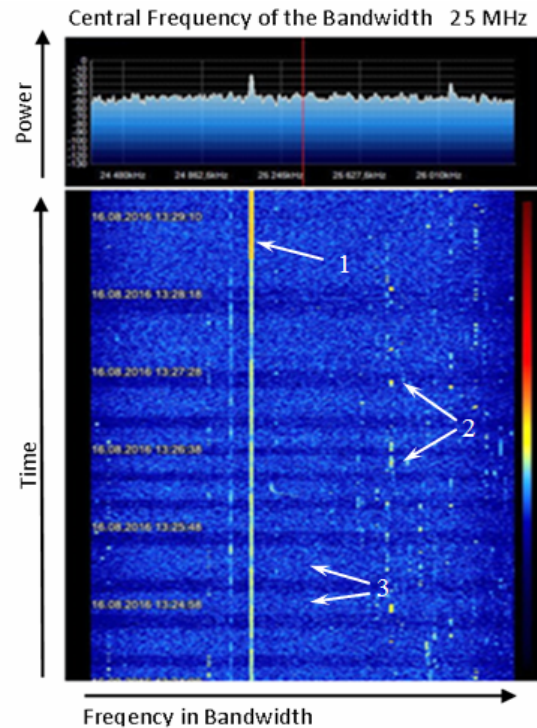


Figure 1: The signal spectrum containing three types of interference. The upper panel is the power spectrum in the time interval of 6 minutes. The bottom panel is a dynamic spectrum on the same time interval. 1 – continuous narrowband interference, 2 – pulsed narrowband interference, 3 – wideband pulsating interference.

#### 5. Direction Finder

To interference combat, a portable direction finder was designed and manufactured with a working range of 10–30 MHz. The device consists of a tunable loop antenna with dimensions less than 0.1 wavelength, a whip antenna, antenna switch and receiver, covering the entire decameter range.

The development of a loop antenna was carried out in two stages. Initially, using a computer program, a future loop antenna was designed. Fig. 2 shows its calculated antenna pattern. Then several experimental samples were made, one of which was adopted as a worker. For field tests, a portable transmitter was used, with which the shape of the beam antenna pattern was checked.

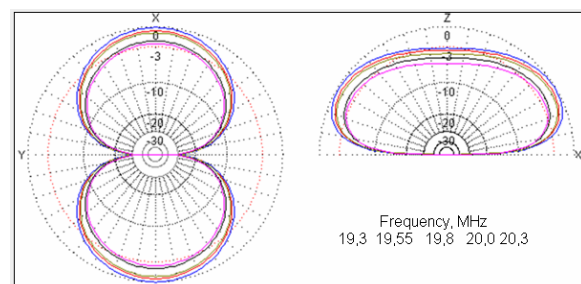


Figure 2: The calculated antenna pattern of the direction finder antenna

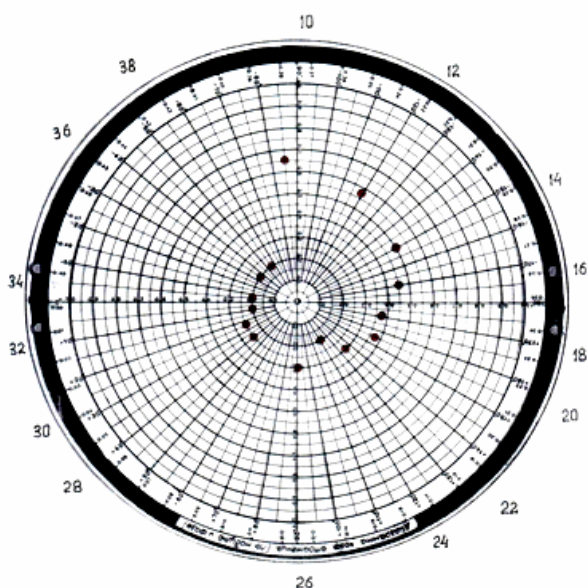


Figure 3: The reflection coefficients of the antenna direction finder, measured at frequencies of 10-38 MHz

The characteristics of the loop antenna of the made direction finder are measured. Fig. 3 shows the reflection coefficients of the loop antenna, measured at frequencies from 10 to 38 MHz. The calculated antenna efficiency at 10 and 38 MHz was 0.6 and 0.96 respectively.

Work with the direction finder includes two modes. The operator using a whip antenna scans the specified frequency band. Upon detecting interference, the operator switches the receiver to a loop antenna, adjusts it to the receiving frequency. To determine the location of the source of interference, it is necessary to take several bearings and plot them on the map of the study area.

## 6. Conclusion

The characteristics of the URAN-4 radio telescope are given. An analysis of interference affecting the radio telescope was carried out. Made their classification. The main software and hardware methods of dealing with this interference are considered. It is noted that not all interference that occurs can be eliminated in this way. This especially applies to local interference, as a rule, occupying a wide frequency band. In this case, there are two ways: the use of legally protected frequencies and the organization of the radio telescope protection zone, which determines the permissible economic activity, in terms of radio emission levels. For the protection zone to function, the service of monitoring the radio spectrum and identifying sources of interference is necessary. A portable decameter direction finder has been designed and manufactured for solving these tasks.

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