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The Cyclicity of Radio Interference Manifestation in the Data of Cosmic Radio Sources Monitoring in the Decameter Wavelength Range

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Abstracts

A special feature of radio astronomical observations in the decameter wave range is the high level of radio interference, the main sources of which are broadcast radio stations, various radio engineering systems, industrial and natural sources of radio emission. Due to ionospheric propagation, radio interference signals entering the receiving path of the radio telescope through the central and side lobes of the antenna pattern can come from radio sources located at a distance of hundreds and thousands of kilometers from the radio telescope. The interference level is determined by the power and operating mode of radio interference sources, radio range congestion, ionospheric propagation conditions, which change depending on the time of day, season of the year, and phase of the solar activity cycle. Different types of interference manifest themselves in observational data in different ways. This depends on the observation technology, equipment used, and data processing methods. In this paper, we consider the interference environment by analyzing the manifestation of radio interference in radiometer signal records obtained during long-term monitoring of a group of compact space radio sources on the URAN-4 radio telescope (Odessa region, Ukraine). The results obtained can be used to improve the efficiency of planning radio astronomical observations, and also allow us to track trends in the change in the intensity of radio interference affecting radio astronomical observations.

Key words: cosmic radio sources; decameter wavelength range: radio interferences.

1. Introduction

The quality of observation data of cosmic radio sources in low-frequency radio astronomy largely depends on the type and intensity of radio interference. The influence of radio interference is especially significant during measurements in the decameter range of radio waves. The level of interference is determined by the power and operating mode of radio interference sources, the load of the radio range with such sources, the conditions of ionospheric propagation, which change depending on the time of day, season of the year, and phase of the solar activity cycle. Information on how radio interference manifests itself at different time intervals from a day to several years can be used to improve the efficiency of planning radio astronomical observations, and will also allow us to track trends in the change in the intensity of radio interference affecting radio astronomical observations. The study of patterns in the occurrence of radio interference affecting the efficiency of radio astronomical observations in the decameter wavelength range, on the one hand, is of practical importance for radio telescopes of this range, in particular, such as the URAN and GURT radio telescope networks [Konovalenko et al., 2016], [Yerin et al., 2018]. On the other hand, given that the intensity of radio interference is largely determined by the state of the ionosphere, a change in the efficiency of radio astronomical observations in the decameter wavelength range can be an indirect factor characterizing changes in the state of the ionosphere and can be used in space weather studies, such as those carried out on the URAN radio telescope network [Shepeliev and Lytvynenko, 2021], [Kalinichenko et al., 2021].

The aim of the work is to study the cyclic manifestations of the appearance of radio interference based on observations of cosmic radio sources in the decameter range of radio waves.

2. Observation data and processing method

The cyclic variations of the radio interference manifestation were studied using materials of the monitoring observations of the power cosmic radio sources (3C 144, 3C 274, 3C 405, 3C 461) which carried out on the radio telescope URAN-4 (Figure 1) on frequencies 20 and 25 MHz and on two polarization A and B since 1987. The radio telescope is located in the Odessa region and is part of the URAN radio interferometer system, which is located at several points on the territory of Ukraine [Megn et al., 1997]. Since 1998, digital data recording has been used at the radio telescope [Derevyagin et al., 2019]. As a result, the paper considers time intervals under consideration when observations were carried out regularly: 1998-2007 and 2011-2024.

Figure 1. *Radio telescope URAN-4.*

Observations with the URAN-4 radio telescope are carried out in the form of recordings of several passes of each radio source through the direction pattern of the radio telescope during the day. Each record was processed separately and its characteristics were placed in a text file in the computer's memory [Lytvynenko et al., 2023]. During processing, a visual evaluation of each record was performed. The scores were also placed in the computer's memory along with other characteristics [Lytvynenko and Panishko, 2020]. Figure 2 shows records of radio sources with different levels of interference. Depending on how much the interference distorted the type of recording, the following estimates were applied:

0 – the recording was not processed due to high interference;
1 – good recording quality;
2 – interference in the form of short-period emissions is observed;
3 – interference is significant.

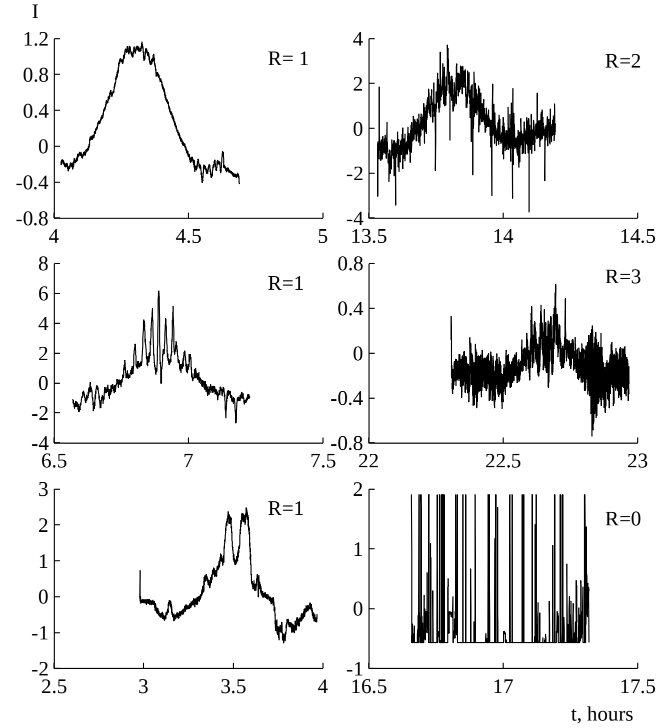

Figure 2. *Samples of the radio source records with different level of radio interferences.*

Table 1 shows the data on the number of records of radio sources obtained by the radio telescope URAN-4 during the intervals under consideration.

Table 1. *Statistics of the radio source records obtained on the radio telescope URAN-4.*

1. Time interval	2. Number 3. of observation 4. records	5. Number 6. of processed 7. records
	12. 528376	90762
14. Sum	15. 726716	24828

Table 2 shows the distribution of the number of observation records depending on the quality assessment. If we take into account that records with ratings 1 and 2 are mainly used for data analysis, then a significant part of the records (about 69%) is affected by radio interference.

Table 2. *Distribution PR of the observation record number N on dependence of the quality estimation R.*

17. R	18. N	19. PR, %
20.	21.	22.
		5.0
		28. 6.1
		31. 25.1

cycle of solar activity (May 1996 – January 2009), while the second period (2011-2024) coincides with the 24th cycle (January 2009 – December 2019) and the ascending branch of the

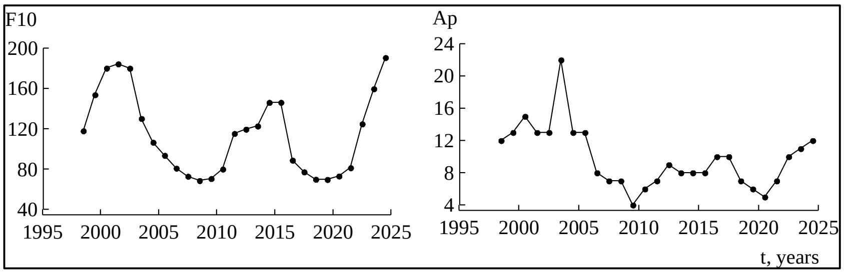

Figure 3. *Graphics of the solar flux F10 and geomagnetic index Ap for time intervals under consideration.*

3. Analysis of radio interference manifestation during time intervals from days to years

Further on the graphs the following curve colors are applied for data on different channels: 20 A – blue; 20 B – green; 25 A – red; 25 B – lilac. The left graphs show data for 1998–2007, and the right graphs show data for 2011–2024.

Figure 4 shows the hourly distribution of radio interference. From the figure it can be seen that in the case of high levels of interference (R = 0, R = 3), a similar distribution is observed with maximum values in the daytime, mainly from 08 to 20 hours local time (UT+2^h). In some graphs, you can see several peaks in the distribution, which are most likely related to the moments of sunrise and sunset. When there is no interference or its intensity is weak (R = 1, R = 2), the distributions are also similar. The minimum number of records of good quality is observed during the daytime from 08 to 20 hours local time. At night, their number is much higher. Thus, the effect of the daily distribution of the level of radio interference in the observation of cosmic radio sources can be considered significant. Measurements at night lead to a better result, and during the day, the intensity of radio interference increases, which affects the quality of the data obtained.

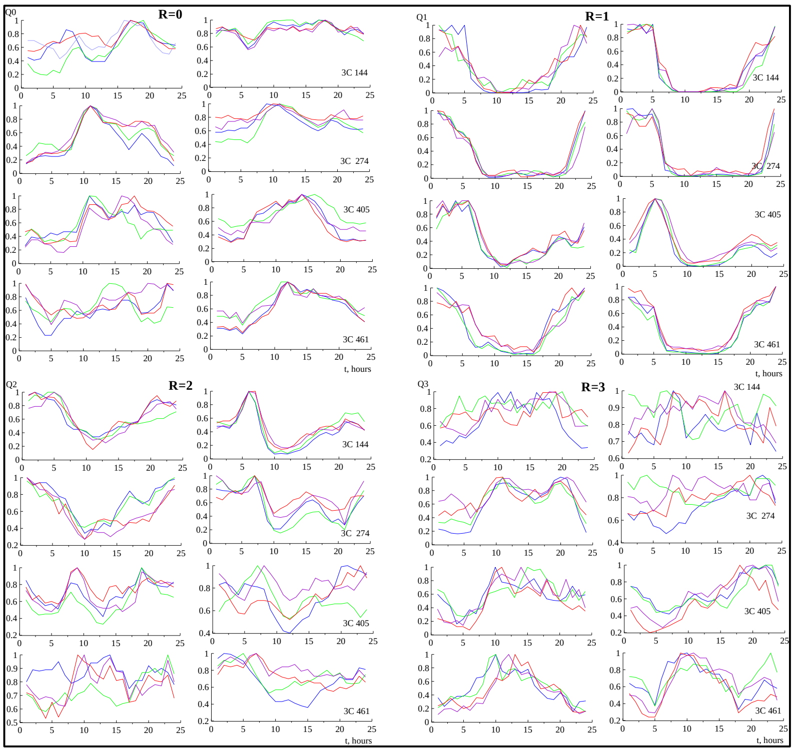

Figure 4. *Hourly distributions of record quality scores.*

Figure 5 shows the seasonal dependence of the recording quality estimates. Since radio sources 3C 144 and 3C 274 are observed at night in the winter months and during the day in the summer, and 3C 405 and 3C 461 are observed in the daytime during the winter months and at night in the summer, there is an interrelated seasonal-daily relationship. Thus, the seasonal dependence reflects the daily dependence for each radio source. This can also be seen from the Table 3 where are the times of the culmination of radio sources in the middle of the month during the year. The data for the months in which the maximum number of records of good quality was observed is underlined. Basically, these periods coincide with observations which obtained at night.

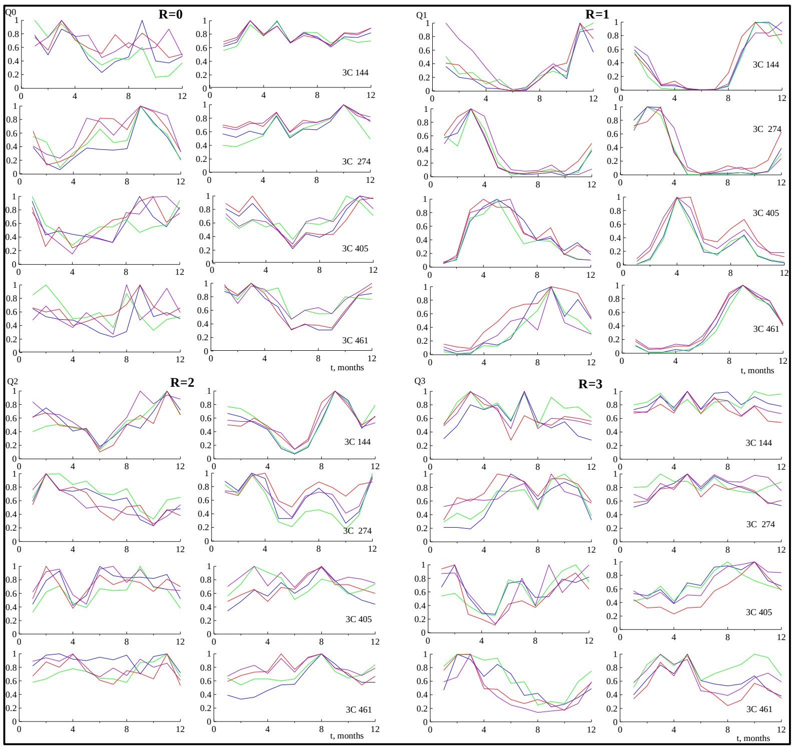

Figure 5. *Seasonal distributions of record quality scores.*

Table 3. *Culmination time of radio sources on months.*

35. M	36. 3C 144	37. 3C 274	38. 3C 405	39. 3C461
40.	41.	42.	43.	44.

Figure 6 shows the annual distributions of quality assessments of space radio source recordings. From the graphs, you can see that the data on different channels are quite correlated. It can also be noted that the distributions for the time intervals under consideration behave differently, although both cases are characterized by periodic variations with periods of about 3–4 years. For the 2011-2024 data, there is a trend of increasing radio interference since 2013, for the 1998-2007 data there are only periodic changes. Due to the presence of a periodic structure, it is quite difficult to determine how much the resulting distributions follow the cycles of solar activity and variations in geomagnetic data, although at the maxima of the F10 index there are maximums of radio interference. Thus, the data on annual distributions requires further research and interpretation.

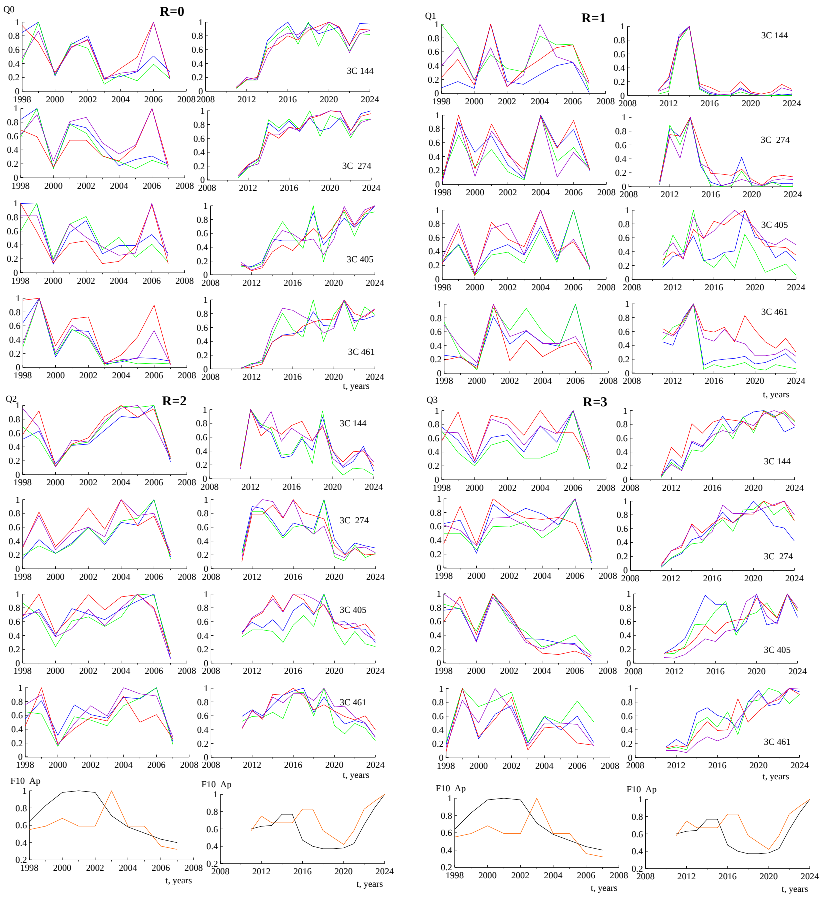

***Figure 6.** Annual distributions of record quality scores and a graph (at the bottom of the graph) of the behavior of the relative values of the F10 (black curve) and Ap (orange curve) indices during the time intervals under consideration*

4. Conclusions

Based on observations of radio source (3C 144, 3C 274, 3C 405, 3C 461) passes through direction pattern of radio telescope URAN-4 on frequencies 20 and 25 MHz and on two polarizations (A and B), the daily, seasonal and annual distributions of quality assessments of records were analyzed.

1. As expected, the daily distribution of quality assessments of radio source records shows that high-quality records are made at night. When observations were made during daylight hours, the amount of radio interferences increased significantly.
2. More likely, the seasonal distributions of values R also reflect the diurnal distribution, since radio sources 3C 144 and 3C 274 are observed at night in winter months and during daylight hours in summer. At the same time, the radio sources 3C 405 and 3C461 are observed during the daytime in the winter months, and at night in the summer. Thus, there is an interconnected seasonal-daily dependence.
3. The annual distributions of values R for the time intervals under consideration are quite complex. The first period (1998–2007) almost coincides with the 23th solar activity cycle, while the second (2011–2024) coincides with the 24th solar activity cycle and with ascending branch

of 25th cycle. In general, the amount of radio interferences increases with increasing of solar activity. There are periodic variations in the annual distributions that require further research and interpretation.

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