RADIO ASTRONOMY

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RESTORATION AND DEVELOPMENT OF THE GURT RADIO TELESCOPE NETWORK: OPPORTUNITIES FOR OBSERVATIONS UNDER WARTIME CONDITIONS

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ABSTRACT. The restoration of three subarrays of the Ukrainian radio telescope GURT, damaged as a result of military hostilities, marked an important milestone in the continuation of astronomical research under challenging conditions. In 2023, two of them were successfully restored and equipped with autonomous power supplies at the site of S. Braude Radio Astronomical Observatory. This enabled the resumption of systematic solar observations and the implementation of a two-element interferometer for studying cosmic radio sources.

The third subarray was relocated and restored at the site of Poltava Gravimetric Observatory, where the primary challenge for its operation was strong radio-frequency interference (RFI) caused by the uninterruptible power supply system of the observatory. This issue was effectively resolved through the development and installation of a custom external mains filter.

The restoration efforts of these instruments demonstrate that scientific work can continue even under war time adverse conditions, thanks to innovative engineering solutions and the perseverance of the research team.

Keywords: radio astronomy, radio telescope, antenna arrays, space research

АНОТАЦІЯ. Відновлення трьох секцій низькочастотного українського радіотелескопа ГУРТ, пошкоджених унаслідок воєнних дій, стало важливим етапом у продовженні астрономічних досліджень в умовах значних викликів. У 2023 році дві з них були успішно відновлені та оснащені автономними системами енергоживлення на території Радіоастрономічної обсерваторії ім. С. Я. Брауде РІ НАНУ. Це дало змогу відновити систематичні спостереження Сонця, а також реалізувати двохелементний інтерферометр для дослідження космічних радіоджерел.

Третю секцію було перенесено та відновлено на території Полтавської гравіметричної обсерваторії НАНУ. Основною перешкодою для її функціонування стала сильна радіочастотна завада (RFI), спричинена системою безперебійного живлення самої обсерваторії. Цю проблему вдалося ефективно вирішити завдяки розробці та встановленню спеціального зовнішнього мережевого фільтра.

Зусилля, спрямовані на відновлення цих наукових інструментів, демонструють, що наукова діяльність може тривати навіть у складних умовах воєнного часу завдяки інженерним інноваціям та наполегливості дослідницької команди.

Ключові слова: радіоастрономія, низькочастотний радіотелескоп, антенні решітки, космічні дослідження.

1. Introduction

The Giant Ukrainian Radio Telescope (GURT) is a next-generation radio astronomical instrument designed to operate in the 8–80 MHz frequency range (Konovalenko et al., 2016; Tokarsky et al., 2019a; 2019b). Its development began in 2001 at the S.Ya. Braude Radio Astronomical Observatory in Kharkiv’s region, Ukraine.

The GURT antenna system is modular and composed of identical 25-element subarrays, ten of which were operational as of early 2022. Each subarray includes five main components: the antenna array, phasing system, amplification system, beam control system and AC-DC power supply units. Signals from each subarray are transferred by and RF cables to a central registration system based on digital receivers ADR (Zakharenko et al., 2016), where they are digitized, processed, and stored on hard drives. These subarrays have been used to form two interferometric baselines of 56 m and 89 m. Since 2018, the implementation of an automatic and remote control system has enabled systematic daily solar monitoring observations.

In addition to solar observations, GURT has been employed to study pulsar radio emission, decametric emissions from Jupiter, Galactic background, and the supernova remnant Cassiopeia A. More than 20 scientific publications have addressed the modeling, design principles, and technical characteristics of various GURT subsystems, while over 10 papers have reported astrophysical results based on its observational data.

Figure 1: Damaged antenna elements of the GURT radio telescope.

Following the Kharkiv counteroffensive conducted by the Armed Forces of Ukraine in September–October 2022, the territory of Kharkiv's region containing the S.Ya. Braude Radio Astronomical Observatory was liberated. Preparations for restoring the observatory's infrastructure and equipment began shortly thereafter. However, the initial phase of the effort was significantly delayed due to the need for thorough de-mining of the site.

After a comprehensive safety inspection, it was decided to begin the restoration process with the GURT radio telescope. Despite the relocation of the frontline to approximately 40 km from the observatory, the risk to both personnel and equipment remained substantial. Nonetheless, the strategic importance of resuming scientific operations motivated the initiation of phased restoration activities under these constrained and potentially hazardous conditions.

Unfortunately, due to military hostilities, the GURT antenna system sustained extensive damage. Over 80% of the antenna elements became non-functional. Blast waves destroyed the arms of many elements, and the majority of low-noise amplifiers were damaged. The force of the explosions caused electronic components to lose contact with printed circuit boards, and RF transformer windings were broken. Shrapnel severely damaged the supporting stands of the antenna elements, as well as equipment cabinets and their internal systems. In some areas, the density of shrapnel was so high that even 16 mm diameter metal-plastic pipes were repeatedly pierced (see Figure 1). In most cases, the electronic equipment damaged by shrapnel was beyond repair.

2. Restoration of GURT Radio Telescope Subarrays at S. Braude Observatory

The restoration of two subarrays of the GURT radio telescope at the S.Ya. Braude Radio Astronomical Observatory in Kharkiv's region marked the first and one of the most crucial steps in resuming the instrument's operation. LiFePO4The recovery process began with key prerequisites: de-mining of the observatory site and establishing an autonomous power supply system, as the centralized electrical grid had been completely destroyed due to hostilities.

To power the equipment of the observatory, a self-sustained power system was designed and implemented, consisting of ten solar panels supplemented by a backup gasoline generator. This hybrid energy solution provided a stable and reliable power supply, essential for operating the restored GURT subarrays and supporting other observatory infrastructure. The solar power plant thus became a vital component in ensuring the continuity of scientific observations under wartime conditions.

Key Parameters of the Autonomous Power System:

Inverter: Altek Atlas 6 kW – 48 V.

Solar Panels: 10 mono-crystalline panels (model UL-550M-144HV), each rated at 500 W, providing a total peak power output of 5 kW.

Battery System: Atlas 48 V B3 LiFePO4Lithium-Fe-Polymer battery with a nominal capacity of 200 A·h and a nominal voltage of 48 V.

Power Consumption: Each GURT subarray of 2 linear polarizations consumes up to 1 kW of power. Linear regulated DC power suppliers provide power for phase shifters, RF high-linear amplifiers, beam control unit in the subarray cabinet. Additional power is consumed by ADR receiver and preamplifier in the receiving equipment room.

This configuration was specifically designed to power two GURT subarrays simultaneously while enabling extended nighttime observations. During daylight hours, the high-efficiency solar panels not only meet the system's real-time energy requirements but also charge the high-capacity battery. Consequently, the system ensures uninterrupted radio astronomy operations for up to seven hours after sunset. The invertor gasoline generator supplies energy in case the sky is cloudy and does not allow fully charge the batteries with solar power during the light day, which is most usual in winter.

2.1. Diagnostics and maintenance

Following the restoration of the power supply, diagnostic and repair work on the damaged systems commenced. One of the first subsystems to be restored was the frequency standard module (ADC clock generator), which is essential for ensuring the precision of astrophysical measurements. A lot of equipment was lost and some systems were replaced with spare ones or older models used when the GURT systems were developed. Considerable effort was dedicated to resolving instabilities in the control system. Investigation revealed that data exchange issues between the control unit and the new PC were caused by conflicts with the OS firewall and microcontroller software incompatibilities. These issues were resolved by updating the firmware and optimizing network protection settings, thereby restoring stable operation of the control infrastructure.

Direct field work on the subarray restoration began only in September 2023. The first subarray was repaired in a relatively short time: dipoles of one linear polarization were restored till September 21, followed by the complete antenna system on September 28. Over 50% of the antenna elements were replaced to the new ones. On October 12, the first solar observations were successfully conducted using the restored subarray. Leveraging the experience gained, the team was able to quickly restore the second subarray, which was brought into operation on November 20, 2023.

2.2. Scientific Results

The restoration of the initial subarrays of the GURT radio telescope enabled the resumption of systematic scientific observations, which began in 2024 under the framework of the “Favorit-Astro” projectfunded by NAS of Ukraine. Preliminary test observations of solar radio emission revealed heightened solar activity, characterized by a variety of radio burst types. The GURT data correlated well with optical observations from the SDO and SOHO satellites, confirming the association of the detected radio bursts with solar flares and coronal mass ejections.

Observations were conducted monthly in week-long campaigns, during which up to 34 GB of data were collected per day, which provided unique valuable data for solar astronomers of IRA NASU. This allowed the detection and analysis of bursts originating from specific active regions on the solar disk.

In addition to solar observations, the two restored subarrays were successfully configured as a two-element short-base correlation interferometer. This configuration facilitated the initiation of monthly monitoring of the secular decrease in the flux density of Cassiopeia A, using the radio galaxy Cygnus A as a calibration source (see Figure 2). Owing to the narrow beam pattern of the interferometer, measurements were significantly less affected by background radio emission.

The data acquired during these sessions enriched and continued long-term set of measurements on this instrument, demonstrated high stability and enabled precise tracking of the flux ratio between these two prominent astronomical sources, confirming the interferometric system’s sensitivity and robustness.

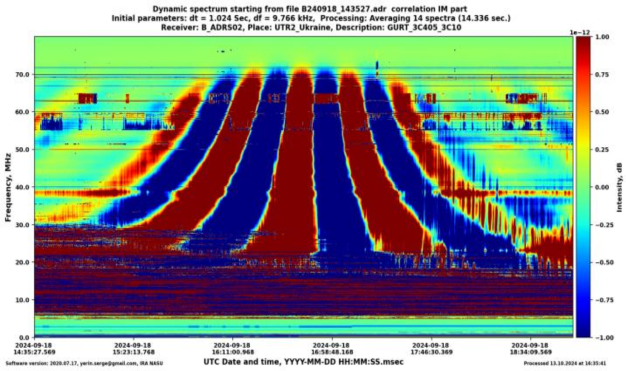

Figure 2: Dynamic spectrum of the real part of the cross-power spectral density between the two GURT subarrays during the transit of the radio source *Cygnus A* through the interferometer's beam pattern as observed 18 September 2024.

3. Relocation of GURT subarray to Poltava region and its Restoration

Another strategically significant step was to relocate at least one GURT subarray to a safer place to provide safe uninterrupted restoration and observations. As such a place the Poltava Gravimetrical Observatory of NASU site in Stepanivka village of Poltava’s region was chosen.

The restoration process was divided into two parallel workflows: component preparation in Kharkiv at IRA NASU and field deployment in Stepanivka. In Kharkiv, the team focused on restoring and modernizing the radio telescope’s hardware, while simultaneous earthworks and installation activities were conducted at the new site. Final assembly commenced on 29 October 2024, beginning with the installation of cross-dipoles. By 1 November, the full antenna field had been installed.

The first successful test of one polarization was achieved on 6 November 2024, and solar radio bursts were detected the following day confirming the full operability of the restored subarray. Final assembly concluded on 20 December 2024, with the launch of the second polarization subarray equipment. From that point onward, the third GURT subarray entered regular operation.

3.1. The Problem of Electromagnetic Interference

Following the successful deployment of the GURT subarray in Stepanivka, the team encountered two major challenges: frequent power outages and high levels of radio frequency interference (RFI). To maintain uninterrupted observational capabilities, an uninterruptible power supply (UPS) system was developed and installed. However, this very system was identified as the primary source of conducted RFI, propagating along the 230 V power line.

To diagnose the issue, a dedicated test setup for measuring conducted RFI was assembled. Measurements revealed that at a frequency of 7 MHz, the interference level reached 37 dBμV – an intensity that rendered astronomical observations unfeasible. The root cause was traced to inadequate built-in filtering within the UPS unit. This is attributable to the fact that most inverter systems are engineered to comply with general household electromagnetic compatibility standards (e.g., CISPR, 2015), which do not account for the stringent sensitivity requirements of radio astronomical instrumentation and observatories sites.

3.2. Engineering Solution

Conventional simple mitigation techniques such as shortening cable lengths, shielding conductors, and installing ferrite rings proved insufficient to eliminate the conducted RFI. A more comprehensive engineering approach was required, involving both precise measurement and targeted suppression of interference at its source. Based on the diagnostic data obtained from the custom-built conducted RFI test stand, a specialized external mains filter was designed and installed. This filter was optimized to operate across the 100 kHz to 80 MHz frequency band and demonstrated high suppression efficiency.

Following its installation, the interference level at 7 MHz was reduced from 37 dBμV to 20 dBμV, enabling

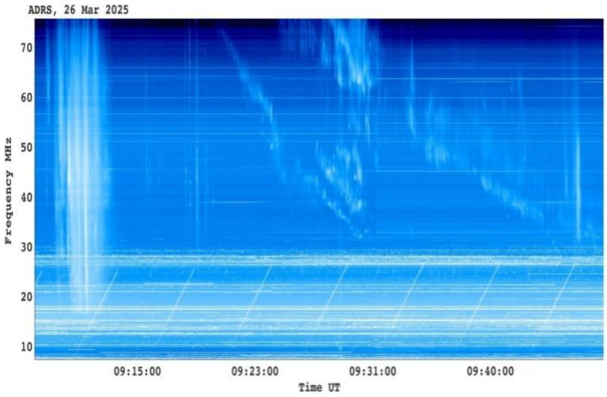

Figure 3: Example of Solar sporadic radio emission, obtained on 26.03.2025.

successful radio astronomical observations. Although some residual interference was still detectable in the test setup, the team hypothesized that it stemmed from the absence of a high-quality high-frequency grounding system at the site.

Once the power supply issue was resolved and RFI had been sufficiently minimized, continuous monitoring of solar radio emission was initiated. Figure 3 presents an example of sporadic solar radio emission received by the GURT subarray in Stepanivka. This observation represents the first scientific dataset obtained at the new location, confirming the telescope's full operational readiness.

4. Conclusion

The experience of restoring the GURT radio telescope subarrays in both Kharkiv and Poltava region marks a new chapter in the operational history of the instrument. In Kharkiv, efforts were primarily focused on rebuilding the infrastructure and establishing a reliable, autonomous power supply via a solar power plant. This enabled the resumption of systematic radioastronomical observations, including the successful operation of two restored subarrays as a two-element correlation interferometer.

In contrast, the primary challenge in Poltava region was not the physical restoration itself, but rather the mitigation of complex radio-frequency interference. Through an innovative engineering approach, the team developed a custom-designed external filter, successfully adapting commercially available equipment for use with highly sensitive scientific instrumentation.

The successful outcomes of both restoration efforts demonstrate that meaningful scientific research can continue even under adverse and unstable conditions. These achievements stand as a testament to the perseverance, ingenuity, and technical excellence of the research team, ensuring the continuity of radio astronomical observations despite significant logistical and environmental challenges.

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