https://doi.org/10.18524/1810-4215.2025.38.340381

VISUALIZATION AND ANALYSIS OF VECTOR NETWORK ANALYZER DATA FOR THE EXPERIMENTAL MODEL OF THE ACTIVE ANTENNA SECTION OF THE GURT RADIO TELESCOPE

V. I. Myrhorod, I. M. Bubnov, V. Yu. Selin

Institute of Radio Astronomy, National Academy of Sciences of Ukraine,
Kharkiv, Ukraine

ABSTRACT. **Subject and purpose of the work.** During the development and testing of radio engineering devices, in particular the active antenna sections of the GURT radio telescope, there is a need for prompt and efficient processing of experimental data. Large volumes of measurements obtained from vector network analyzers require tools for fast interpretation and statistical analysis. The purpose of this work is to create software that ensures high-quality processing and visualization of such data, contributing to improved accuracy in the evaluation of antenna system parameters.

Methods and methodology. To achieve this goal, the Graphics v.1.9 software was developed, functioning in the Windows environment on the .NET Framework 4.8 platform. The program employs the ScottPlot library for building interactive plots and ClosedXML for handling Excel data. The architecture of the solution is designed according to a modular principle, which facilitates the integration of new functionality. The main methods include parsing data from the Obzor-103 analyzer, generating plots, performing statistical averaging of results, and exporting data into formats suitable for publications and presentations.

Results of the work. The Graphics v.1.9 program enables advanced visualization of measurements, the creation of high-quality graphical reports, as well as the averaging of data of the same type to detect statistical deviations and assess the repeatability of results. This makes it possible to obtain generalized characteristics of the studied devices, quickly detect instabilities in individual elements, and perform comparative analysis within a series of identical components. Practical application of the program in the testing of GURT antenna sections has confirmed its efficiency and feasibility for scientific research.

Conclusions. The developed software significantly increases the efficiency of experimental data analysis in radio astronomy and radio engineering. Graphics v.1.9 not only reduces the time required for data processing but also provides deeper insight into system characteristics and contributes to its optimization. Prospects for further development of the program include support for new input data formats, expansion of processing tools, and the implementation of advanced visualization features, making it a universal tool for a wide range of scientific and applied tasks.

Keywords: GURT radio telescope, active antenna, data processing, visualization, statistical analysis, averaging.

АНОТАЦІЯ. **Предмет і мета роботи.** Під час розробки та випробування радіотехнічних пристроїв, зокрема активних антенних секцій радіотелескопа ГУРТ, виникає потреба в оперативній та ефективній обробці експериментальних даних. Значні обсяги вимірювань, отриманих з векторних аналізаторів мереж, потребують інструментів для швидкої інтерпретації та статистичного аналізу. Метою роботи є створення програмного забезпечення, яке забезпечує якісну обробку та візуалізацію таких даних, сприяючи підвищенню точності оцінки параметрів антенних систем.

Методи та методологія. Для реалізації поставленої мети було розроблено програму Graphics v.1.9, яка функціонує у середовищі Windows на базі платформи .NET Framework 4.8. У програмі використано бібліотеку ScottPlot для побудови інтерактивних графіків та ClosedXML для роботи з Excel-даними. Архітектура рішення побудована за модульним принципом, що забезпечує зручність додавання нового функціоналу. Основні методи включають парсинг даних з аналізатора Obzor-103, побудову графіків, статистичне усереднення результатів і експорт даних у формати, придатні для публікацій та презентацій.

Результати роботи. Програма Graphics v.1.9 дозволяє виконувати розширену візуалізацію вимірювань, створювати графічні звіти високої якості, а також здійснювати усереднення даних одного типу для виявлення статистичних відхилень і оцінки повторюваності результатів. Це дає змогу отримати узагальнені характеристики досліджуваних пристроїв, швидко виявляти нестабільності в окремих елементах та проводити порівняльний аналіз у межах серії ідентичних компонентів. Практичне застосування програми у випробуваннях антенних секцій ГУРТ підтвердило її ефективність та доцільність використання в наукових дослідженнях.

Висновки. Розроблене програмне забезпечення значно підвищує ефективність аналізу експериментальних даних у радіоастрономії та радіотехніці. Graphics v.1.9 не лише скорочує час на обробку вимірювань, але й забезпечує глибше розуміння характеристик системи та сприяє її оптимізації. Перспективи подальшого розвитку програми полягають у підтримці нових форматів вхідних даних, розширенні інструментарію для

програми полягають у підтримці нових форматів вхідних даних, розширенні інструментарію для обробки та реалізації додаткових можливостей візуалізації, що робить її універсальним засобом для широкого спектра наукових і прикладних завдань.
Ключові слова: радіотелескоп ГУРТ, активна антена, обробка даних, візуалізація даних, статистичний аналіз, усереднення.

1. Introduction

New-generation radio telescopes play a key role in modern radio astronomy, enabling high-sensitivity observations across a wide frequency range. One such instrument is the Ukrainian radio telescope GURT, built on the principle of a phased array antenna (PAA). Its design is based on the use of active antenna elements, in which the amplifier is integrated directly into the dipole structure. This approach provides preliminary signal amplification at the reception stage, reduces losses, and increases the overall sensitivity of the system.

Each section of the GURT consists of 25 cross-oriented dipoles (Fig. 1), forming 50 independent active channels for two mutually perpendicular polarizations. For the telescope to work effectively, all channels must be highly identical. Even slight differences in parameters, such as impedance, gain coefficient, or phase characteristics, can cause distortion of the directional pattern and deterioration of observation quality.

The analysis of such multichannel systems requires obtaining a large amount of experimental data from vector network analyzers, such as Obzor-103. However, manual processing of dozens and hundreds of measurement files is difficult, time-consuming, and prone to errors. In these conditions, there is a need for specialized software capable of automating the processing, visualization, and statistical analysis of results.

For this purpose, Graphics v.1.9 software was developed to provide comprehensive processing of experimental data. Its use reduces analysis time, minimizes the risk of errors in manual processing, and improves the accuracy of active antenna system parameter estimation.

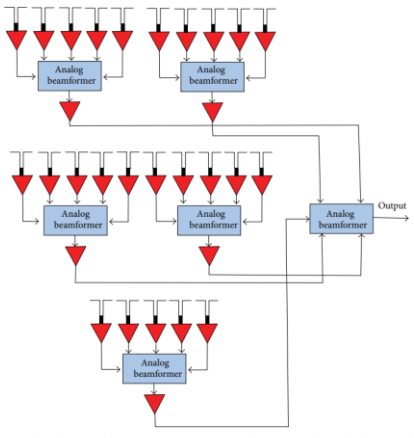

FIGURE 2: Block diagram of the active antenna array in one polarization. Red triangles denote amplifiers.

Figure 1: Diagram of a single polarization of the GURT sublattice

2. Implementation of Graphics v.1.9

Graphics v.1.9 software was created as a tool for efficient processing of experimental data obtained in the course of research on the active antenna sections of the GURT radio telescope. The main task was to ensure the possibility of quick interpretation of measurements with minimal time expenditure by the researcher. The choice of the Windows development environment in combination with the .NET Framework 4.8 platform was dictated by both technical and practical reasons. This solution made it possible to combine performance, a wide range of libraries, and ease of integration with hardware.

The key implementation language was C#, which is the standard for creating modern desktop applications in the Windows environment. The language provides both an object-oriented code structure and advanced capabilities for working with graphics, multithreading, and interfaces. The program has a modular architecture: each component performs its own set of functions, but they interact closely with each other, allowing the user to obtain a complete result without the need for complex additional settings.

Among the main elements of the architecture, it is worth highlighting the data loading and pre-processing module, the analysis module, the visualization block, and the export module. This structure allows users to flexibly manage the processing process: from opening source files from the Obzor-103 device to creating reports in the form of graphic materials or spreadsheets.

Special attention was paid to working with input data. As is well known, files generated by measuring equipment may contain not only arrays of useful values, but also service information, uneven measurement intervals, or formatting errors. Graphics v.1.9 takes these factors into account and automatically converts the data into a unified format suitable for further analysis. This eliminates the need for manual editing and significantly reduces the risk of errors.

3. Features and functional characteristics

One of the key advantages of the program is the function of averaging measurement results. When studying antenna channels, where each element must have the same characteristics, averaging allows you to obtain generalized indicators and evaluate repeatability. This is especially relevant when the results of different measurements differ slightly due to external factors such as electromagnetic interference, temperature changes, or equipment errors. Using the averaging function makes it possible to identify systematic deviations and form a more reliable model of the device's operation.

The program provides extensive data visualization capabilities. Graphing is implemented in such a way that the user can not only see static curves, but also interact with them. Zooming, scrolling, highlighting individual sections of the spectrum, and overlaying multiple graphs on a single screen create a flexible working environment that far exceeds the standard capabilities of measuring instruments. For example, when analyzing antenna channel parameters, you can simultaneously display amplitude and phase graphs, allowing you to quickly assess compliance with

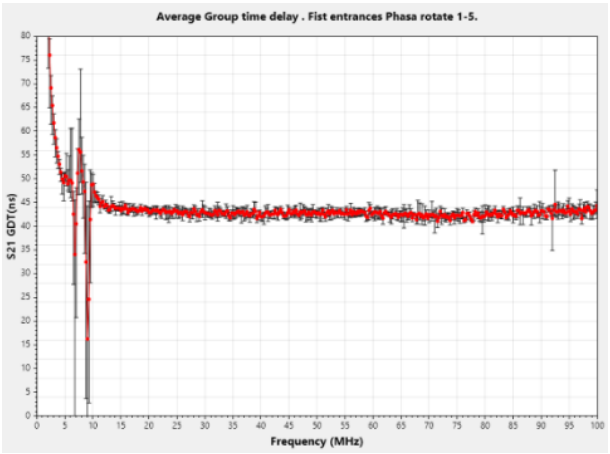

Figure 2: Example of data visualization on a plot

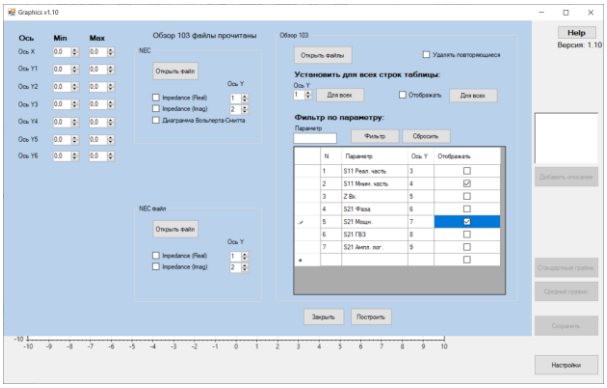

Figure 3: Graphical user interface

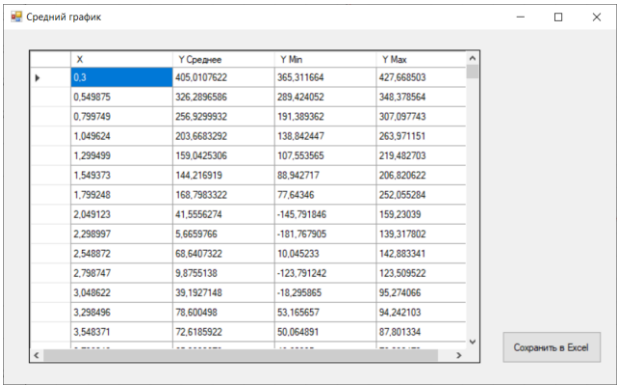

Figure 4: Average data and error bars

requirements. There are a significant number of settings for graph axes, axis value limits, etc. Figure 2 shows an example of data visualization on a plot.

The input file does not always contain all the necessary parameters. The functionality for calculating additional values was developed specifically to solve this problem. Thanks to this, even with only a few parameters from the input file, the program allows the user to access a much larger set of physical quantities. All calculations are performed automatically while reading the files, after which these new parameters can be used for statistical research and visualization.

The user interface (Fig. 3) was designed with the needs of engineers and researchers in mind, who do not always have extensive programming experience. Therefore, the main functions are displayed on the control panel in the form of buttons and drop-down menus, allowing key operations to be performed quickly. At the same time, more complex parameters remain accessible through the settings system, allowing the program to be adapted to specific tasks. Selecting data for visualization is simplified by convenient filters, sorting, and search functions. All names, captions, and titles on the graphs are dynamic, so the user can customize them to their needs at any time.

The export module is equally important. Saving data in Excel spreadsheets simplifies further processing using statistical methods and report generation. In addition, the ability to save graphs in PNG, JPEG, SVG, and other formats allows you to prepare materials for scientific publications and presentations without additional effort. In this way, Graphics v.1.9 effectively integrates all stages of processing: from obtaining raw measurements to the final result, ready for presentation.

4. Practical application

The Graphics v.1.9 program found its main application during testing of the active antenna sections of the GURT radio telescope. When working with a large number of channels, each with its own characteristics, researchers needed to quickly assess the quality of the identity. Using traditional manual processing methods, this process took many hours, and sometimes days, especially when analyzing tens of thousands of measurement points. The use of Graphics v.1.9 reduced this time several times over and also reduced the likelihood of human error.

The actual use of the program has proven its effectiveness in tasks such as determining the average characteristics of group delay time, as well as identifying errors in the measurements of this parameter on individual components. For this purpose, the average values and error bars were calculated (Fig. 4). These data make it possible to find phase shifters whose settings need to be adjusted.

Although Graphics v.1.9 was primarily developed for the needs of the GURT radio telescope, its functionality is universal. The program can be used to study and test other radio engineering devices: amplifiers, antennas of various configurations, filters, and resonant systems. Thanks to its ability to process large amounts of data and support various formats, it is a universal tool for engineers and scientists working in related fields.

5. Conclusions

The developed Graphics v.1.9 software has proven its effectiveness in analyzing experimental data obtained during research on the active antenna sections of the GURT radio telescope. It reduces the time required to process results, minimizes the risk of errors that arise during manual analysis, and provides a deeper understanding of the system's characteristics.

The program will be useful for a wide range of users:

• scientific laboratories engaged in research in the field of radio astronomy and radio engineering;

• educational institutions, where it can be used as a teaching tool for training future engineers and researchers;

• engineering companies engaged in the development and testing of antenna systems and radio engineering devices.

Future development plans for Graphics v.1.9 include expanding the range of supported input formats, integrating new processing algorithms, improving the interface, and adding advanced visualization capabilities. This will make the program a universal platform for analyzing large amounts of experimental data not only in radio astronomy, but also in related scientific and engineering disciplines.

References

Esposito D., and Saltarello F.: 2018, Microsoft.NET: Architecture and Application Programming. (Moscow: Dialektika), 624 p.

Falkovich I.S., Konovalenko A.A., Gridin A.A. et al.: 2011, *ExA,* **32**, 2, 127. DOI: 10.1007/s10686-011-9256-z

Konovalenko A., Sodin L., Zakharenko V. et al.: 2016, *ExA*, **42**, 11, 11. DOI: 10.1007/s10686-016-9498-x

Paliichuk O.V.: 2020, Development of Application Programs Using the .NET Framework Platform. (Lviv: LNU Publishing), 312 p.

Richter J.: 2012, CLR via C#, 4th ed. (Microsoft Press), 826 p.

Tokarsky P.L., Konovalenko A.A., Yerin S.N., Bubnov I.N.: 2016, *RPRA*, **21**, 1, 48. DOI: 10.15407/rpra21.01.048

Tokarsky P.L., Konovalenko A.A., Yerin S.N., Bubnov I.N.: 2019, *ITAP*, **67**, 12. DOI: 10.1109/TAP.2019.2927841