METHODS OF PHASE EXTRACTION FROM 95 GHz HETERODYNE MICROWAVE INTERFEROMETER SIGNALS FOR DETERMINING THE PLASMA DENSITY IN DISCHARGE ON THE PN-3 DEVICE [[1]](#footnote-1)\*)

DOI: 10.34854/ICPAF.2023.50.2023.1.1.137

Bragin E.Y., Bunin E.A., Drozd A.S., Sergeev D.S., Sukhov A.E., Dias Mikhailova D.E., Zhil’tsov V.A., Khairutdinov E.N.

NRC "Kurchatov Institute", Moscow, Russia, [970107@bk.ru](mailto:970107@bk.ru)

The National Research Center "Kurchatov Institute" conducts plasma experiments on a prototype helicon engine [1], which is the PN-3 device [2, 3]. Plasma density measurements are carried out with a heterodyne microwave interferometer [4], plasma probing is carried out by ordinary waves in the vertical direction in the region of the diagnostic volume. The frequency of the probing radiation is 95 GHz, measurements are carried out at the intermediate frequency of 78 MHz, followed by a decrease to 200 kHz. The quartz oscillator signal of 10 MHz also serves as an output.

The value of the phase shift during plasma probing by ordinary electromagnetic waves is proportional to the density of the probing plasma [5]. The aim of this work is to compare different methods of phase extraction from the signals of the PN-3 microwave interferometer: post-processing of digitized signals using the Hilbert transform and zero-crossing, obtaining data from the AD8302 phase detector, post-processing of signals from the quadrature detector.

The signal from the quartz (10 MHz) was divided by 50 times in frequency (to 200 kHz) and was used as a reference. To reduce parasitic intersecting influence, voltage followers based on operational amplifiers were used for signal splitting. To adjust the equipment and determine the measurement accuracy of each of the methods, signals were applied from a waveform signal generator AKIP-3409/3, which imitated the signals of the heterodyne microwave interferometer.

The paper presents the characteristic values ​​of the phase error when using each method without additional filtering and after applying a frequency filter. The results of processing experimental data on the linear density of the plasma, measured using the microwave interferometer at the PN-3 device, are presented. Data were collected simultaneously from the phase and quadrature detectors, as well as the IF2 (200 kHz) and reference (200 kHz) signals. The obtained data were then processed and analyzed. As a result of the analysis, the pros and cons of each of the methods used, as well as ways to improve them, are shown.

References

1. Takahashi K. Helicon-type radiofrequency plasma thrusters and magnetic plasma nozzles // Reviews of Modern Plasma Physics. - 2019. - Vol. 3. - No. 1. - S. 1-61.
2. Zhil'tsov V.A., Kulygin V.M. Fusion and Space //Physics of Atomic Nuclei. - 2019. - T. 82. - No. 7. - S. 963-976.
3. Kutuzov D. S. PN-3 helicon plasma device as a testing facility for plasma propulsion study //Space Propulsion Conference. – 2021. – SPC2020\_0301
4. Bragin E.Y., Bunin E.A., Drozd A.S., Sergeev D.S., Sukhov A.E. The first results of plasma density measurements with a 95 GHz heterodyne microwave interferometer at the PN-3 bench Proceedings of the VIII International Conference "LaPlaz-2022 Laser, Plasma Research and Technologies": Moscow, NRNU MEPhI, March 22-25, 2022, p. 134.
5. Veron D. Submillimeter interferometry of high-density plasmas. NY: Academic Press, 1979.

1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/L/Lt/ru/FV-Drozd.docx) [↑](#footnote-ref-1)