Radiointerferometer of Millimeter-Range Wavelengths as a Tool for Study of Hydrodynamic Flows

S.V. Katin*, G.G. Bakhirev*, N.I. Dmitriev*, Yu.I. Orekhov*, A.L. Mikhaylov†, V.N. Khvorostin†

* NIIIS, Nizhniy Novgorod, Russia
† RFNC–VNIIEF, Sarov, Russia

Summary: The authors present the basic scientific and technical solutions, which built a foundation for the developed radiointerferometer of the millimeter-range wavelengths, as well as prospects for development of radiointerferometers in millimeter and submillimeter ranges to investigate hydrodynamic processes.

Introduction

Microwave radiointerferometers (RI) are promising for study of material extreme state, ballistics of shell motion inside a gun barrel, etc., because of such advantages as undisturbance of diagnosed processes, online continuous measurement, and radio transparency of explosives [1 – 4].

Radiointerferometers are especially promising when using millimeter and submillimeter waves.

The report includes results of RI development for hydrodynamic investigations of Russian Federal Nuclear Centers. The authors present the basic scientific and technical solutions providing accuracy of measurements close to the ultimate accuracy, and possibility to develop RI possessing extensive functionalities.

Results and Discussion

A series of radiointerferometers with waves of the mm–range was developed in NIIIS. Radiointerferometers were metrologically certified. As a part of RFNC–VNIIEF gasdynamic systems, it provides measurement of movements of shock and detonation wave fronts with relative error $\delta = 10^{-4}$. Some results of the gasdynamic investigations with involvement of the developed RI are summarized in [3] and presented in detail in the paper for this Conference [5].

The obtained accuracy characteristics are provided due to application of the suggested technical solutions in each of three subsystems of RI, which are the hardware subsystem (transceiver); hard-and-software processing subsystem; wave subsystem.

RI transceiver is based on a super-heterodyne circuit with double-channel quadrature recording of the output interferential signals. The transmitter and heterodyne are based on synthesizers with phase automatic frequency control.

The synthesizer operation is based on conversion from cm-range frequencies to the required mm-range frequencies by avalanche-transit diodes (IMPATT) having a conversion order up to 30 when synchronization from the generator is 100 MHz. It provides the required level of output power when phase noises are as minimum as possible.

The problem of minimizing discrepancy at RI transmitting-receiving channel output was solved.

A special attention is paid to the RI wave subsystem. The wave subsystem includes a long flexible channel to connect RI transceiver with a diagnosed object and an irradiator generating required radiation and providing interaction with the diagnosed object.

A dielectric waveguide (DW) was used as the channel providing linear losses of 1…2 dB/m without significant phase distortions and additional losses, when the flexing is at least 20 λ. It allows to use the channels of several tens of meters. DW advantage is its low cost when electric characteristics are excellent. It is important in case of the channel destruction during gasdynamic experiments.

Taking into account diffraction nature of probe radiation generation and its interaction with the diagnosed object, which is typical for the gasdynamic experiments, the need for generating the probe radiation as gaussian wave beams was justified [6].

Dielectric irradiators, generating wave beams having the desired width, beam convergence/divergence, were developed.

The suggested scientific approaches and technical solutions enable to develop radiointerferometers adapted for various gasdynamic and hydrodynamic purposes, namely, to create combine systems (radiointerferometer–radiometer), microwave–range multichannel RIs.

References

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