SPACE RADIO-HOLOGRAPHY: BISTATIC RADAR COMBINED WITH RADIO OCCULTATION AS APPLIED TO STUDY ATMOSPHERE AND IONOSPHERE OF VENUS.

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Introduction: The presence of powerful atmosphere of Venus leads to a significant refraction of radio signals during propagation at low elevation angles [1-3]. Periodically repeated radar experiments and radio occultation investigations using orbital spacecraft do not give details on the magnitude of refraction in the lower layers of the Venus atmosphere. High stability of radio signals emitted by ground-based transmitters and appropriate onboard data handling can enable high precision radioholographic investigation of the atmosphere and ionosphere of Venus by use of bistatic and radio occultation methods to obtain vertical profiles of the physical characteristics of the atmosphere and ionosphere [4-8]. Refined experimental data on the magnitude of refraction in the atmosphere of Venus obtained by use of analysis of the "Venera-10 and 15" bistatic radar experiments are presented and future direction of investigations are described.

Space radio-holography: Highly stable radio signals emitted by Earth-based transmitter after propagation through the ionosphere and atmosphere along the direct (1) and reflected path arrived to receiver aboard an artifical satellite on the near planetary orbit (Figure 1). The direct signal is used to analyse: (1) the plasma structures and vertical distribution of the electron density in the ionosphere; (2) the layers, waves activtity, absorption, bending angle, refractivity, pressure, temperature in the atmosphere above the critical level near the height 34 km. The reflected signal is analysed to reveal: (1) the relief features, subsurface structures, reflectivity, soil parameters; (2) the refractive attenuation, absorption, bending angle, and, possibly, layered or wave structures in the lower atmosphere.

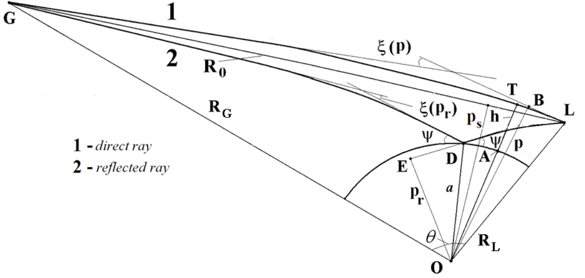

Figure 1. Scheme of radio-holographic investigation of the Venus atmosphere, ionosphere and surface.

Bending angles in the lower atmosphere from data of "Venera-9, 10 and 15, 16" orbital missions: The first bistatic experiments has been provided by "Venera 9 and 10" mission (1975) [14]. Bistatic experiments have been repeated in 1983 during existence of the orbital spacecraft "Venera 15 and 16" [5,6]. The monochromatic modee for radio signals emitted from Venus satellite at wavelength 32 cm has been used for investigation. The reflected signals have been received and analysed by a system on the Earth based station. In Figure 2 (left) the curves 1-3 described the time frequency story of the reflected signal during three RO events provided in November 1983. The frequency of the direct signal is constant because closed loop mode of receiver. Curve (1) correspond to immersion in radio shadow, and curves (2), (3) to emersion of the satellite "Venera-15". Because variations in the orbital speed of satellite the inclination of curves 1-3 and observation time of reflections are different.

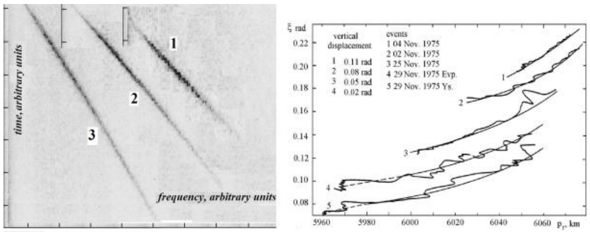

Figure 2. Left. Time-frequency map of the reflected signal observed during radio occultation experiments provided during 1983 November 09, 12, and 11, curves (1)-(3), respectively. Positions of the direct signal is shown by vertical lines (in the left, top corner of figure). Right. Results of restoration of the bending angle from bistatic radar data. The impact parameter and bending angle are indicated along the horizontal and vertical axis, respectively.

The curves 1-5 (Figure 2, right) described results of the bending angle measurements during 1975 November RO events 04, 02, and 25 (curves 1-3) and 29 (curves 4 and 5 correspond to observations of in the Evpatoria and Yssuriisk). The curves 1-4 are displaced for comparison. The displacement values are shown in the upper left corner in Figure 2 (right). The thin smooth lines in Figure 2 (right) indicate approximation of the experimental data. The bending angle varies in the interval 0.06-0.13 radian when the impact parameter changes in the range 5060…6075 km. The irregular systematic variations of the bending angle are of order 0.01 rad and have very small correlation in data of measuments from different receiving stations (curves 4,5 in Figure 2). The noise fluctuations are about 0.002

rad and illustrate an instrumental accuracy of the receivers. The difference between data of events is about 0.015 rad that can correspond to changes of physical conditions in the investigated regions.

In Figure 3 (left) the smooth line shows functional dependence of the bending and sliding angles. The points correspond to experimental data measured in five equatorial regions of Veus [3]. The data have significant scatter caused by features of bistatic radar measurements: influence of small and large scales of relief, possible effects of horizontal atmospheric inhomogeneity, irregularities, and/or layered structures. The angle of refraction exceeds about 10 - 20 times the same value at the appropriate geometry in the Earth's atmosphere. Refractive attenuation of radio waves (Figure 3, right) is correspondingly about 5 - 10 times higher than under the same conditions in the Earth atmosphere and varies from 1-2 dB at grazing angle 14°-15° radio waves to 9-10 dB at 8°-9°. It should be noted that the sliding angle of the reflected radio waves bounded below by a value of about 8° because of capture by constantly existing waveguide in the atmosphere of planet. The first measurements made by satellite "Venus - 10" showed the possibility of determining the refractivity profile in the lower Venus atmosphere at wavelength 32 cm, and to date remains unique.

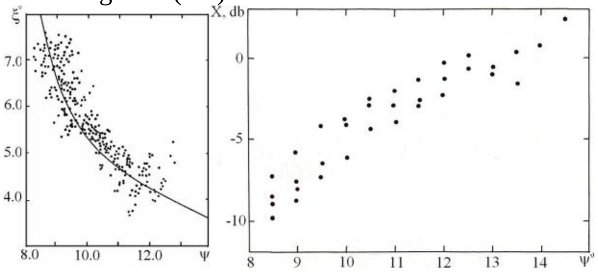

Figure 3. Bending angle (left) and refractive attenuation (right) in the atmosphere of Venus at wavelength 32 cm (data of “Venera - 9 and 10” [5]).

Directions of future investigations: Highly stable signals synchronized by atomic frequency standards and radiated by GPS satellites at wavelength 19 and 24 cm create at the altitudes from 0 to 20 000 km above the Earth surface radio fields that can be used for the development of the bistatic radiolocation and RO method as a new tool for global monitoring of the planetary ionosphere, neutral atmosphere, and surfaces [7,8]. During extended experimental and theoretical studies new radio-holographic approaches and principles have been derived that can be directly applied for bistatic radar and RO investigation during future interplanetary missions. There are four important directions: (i) innovative estimating the altitude dependence of the **total absorption** of radio waves using the RO amplitude and phase variations **at a single frequency**; (ii) evaluation of the slope, altitude, and horizontal displacement of the atmospheric and ionospheric layers from the RO signal intensity and phase data using the eikonal acceleration/intensity technique; (iii) **separation of layers and irregularities contributions** in the RO signal, determination of vertical profiles of the turbulent and small-scale structures by joint analysis of the RO signal eikonal and intensity variations **at a single frequency**; and (iv) introduction of the new combined phase-intensity index for the RO study of multilayered structures and wave processes. This regularity is valid for every RO ray trajectory in geometrical optics approximation including reflections from the surface [7,8].

Conclusions:. During the GPS RO analysis it is shown that the eikonal acceleration has the same importance for bistatic radar and the RO method as the phase path and Doppler shift for radio location [9]. Therefore, satellite radio-holography approach derived during multiple satellite missions working in the near Earth space can be directly applied for planetary investigations

References:

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