Resolving Small-Scale Structures in Planetary Atmospheres and Ionospheres by Radio Sounding

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Radio waves propagating through a refractive medium like a planetary atmosphere or ionosphere experience a phase change that can be used to study the refraction of the medium along the signal ray path. The refractivity derived from these phase measurements can be used to obtain height profiles of electron density in the ionosphere and neutral number density, temperature, and pressure in the lower atmosphere.

Radio occultation experiments were first conducted in 1965 during the flyby of the Mariner 4 spacecraft at Mars [1]. The high accuracy of the retrieved profiles established radio occultation experiments as a powerful tool for the study of planetary environments. Since then, these experiments have become an essential component of almost all flyby and orbital missions.

One of the significant characteristics of the radio occultation profiles is the high vertical resolution. It is usually in the range of a few hundred meters, limited by the Fresnel zone, if typical retrieval methods are used.

Difficulties occur when the refractivity of the atmosphere or ionosphere changes very rapidly over a very limited vertical range. This is a common phenomenon in the Earth troposphere, in the Venus cloud layer, or in the Jovian ionosphere. Different retrieval techniques have been developed to overcome these so-called “multipath” effects. All of these methods convert the multi-valued time series of signals into a single-valued signal. Different approaches can be used to accomplish this. Examples of such approaches include the full spectrum inversion FSI [2], the backpropagation method [3], the canonical transfer method [4], and the use of Wigner distribution functions [5]. These retrieval methods significantly improve the vertical resolution of the profiles and are able to achieve vertical information at the sub-Fresnel-zone level. They can also be used to correct diffraction effects [3]. The different retrieval techniques have different advantages and disadvantages, depending on the available a priori information and the atmospheric density.

The improvement of retrieval methods is complemented by improvements in the measurement technique. The accuracy of the occultation profiles is influenced by the stability of the radio subsystem, the choice of the radio wavelength, and the distance and geometry of the transmitter and receiver (e.g. via spacecraft-to-spacecraft occultations). The advantages and disadvantages of these retrieval techniques are discussed for a number of different applications.

References