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Method for Remotely Sensing Turbulence of Planetary Atmospheres

It is well known that turbulence in Earth's atmosphere affects radio communications. Practically everyone listening to a radio has sensed this phenomenon in the form of interrupted or noisy reception due to different weather disturbances and events in the upper atmosphere. Although uncontrollable, turbulence is a major indicator of atmospheric properties. It can be studied through its effects on radio communication, which yet has much information to reveal on Earth's atmosphere as well as the atmospheres of other planets. Past interplanetary missions and experiments here on Earth have already made significant contributions to this study.

Future interplanetary missions will involve atmospheric entry probes to Venus and Jupiter, whose atmospheres are dense and are believed to be turbulent. For these missions, a phase-coherent communication system may be inadequate because of its inability to track the turbulence-induced fluctuations in the radio signals. Atmospheric turbulence and its effect on radio propagation, therefore, play a key role in the design of a successful radio link with entry probes to Venus and Jupiter.

It is clear that our knowledge of the turbulence characteristics of the atmospheres of Venus and Jupiter is very limited. As a consequence, meaningful prediction of the effects of this turbulence on communications is practically impossible. Useful information on the turbulence characteristics, however, can be inferred from the radio occultation data received from the Mariner 5 mission to Venus and the Pioneer 10 mission to Jupiter. The analysis of these data provides a technique for inferring the turbulence characteristics of a planetary atmosphere from the received radio signals. Since these data require no additional spacecraft equipment, they are essentially free and provide valuable information that otherwise would not be available.

Planetary turbulence is assumed to be localized and smoothly varying, with the structure constant varying exponentially with altitude. Rytov's method is used to derive the variance of the log-amplitude and phase fluctuations of a wave propagating through the atmosphere. It is shown that when the distance between the spacecraft and the planetary atmosphere exceeds L_0^2/λ, where L_0 is the outer scale of turbulence (turbulence diameter), λ being the wavelength of the propagating wave, the effects of inhomogeneity and the finite size of the turbulent medium become important.

Based on the variances of the log-amplitude and phase fluctuations of the radio occultation data received from orbital and fly-by missions, the structure constant for the Venusian planetary atmosphere has been estimated with a high-confidence factor. The analysis indicates that the effects of inhomogeneity, finite size, and superrefractivity of atmospheric turbulence cannot be ignored.

Notes:

1. This method may be of interest to communications engineers, meteorologists, and astrophysicists.
2. Requests for further information may be directed to:
   Technology Utilization Officer
   NASA Pasadena Office
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: TSP74-10168

Patent status:

NASA has decided not to apply for a patent.

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