LINEAR AND NONLINEAR REPRESENTATIONS OF WAVE FIELDS AND THEIR APPLICATION TO PROCESSING OF RADIO OCCULTATIONS

M. E. Gorbunov *(1), K. B. Lauritsen (2), S. S. Leroy (3), and A. V. Shmakov (1)

(1) Obukhov Institute for Atmospheric Physics, Moscow, Russia (2) Danish Meteorological Institute, Copenhagen, Denmark (3) Harvard University, Cambrigde MA, USA

Linear representations of wave fields arose early in quantum mechanics. Each wave function can be represented as a sum of basic functions corresponding to eigenvalues of the operator of an observable quantity. Change of the basis in the space of wave functions corresponds to a linear operator. Such operators are termed canonical transforms in the quantum mechanics and they are linked to canonical transforms in classical mechanics. Wave functions are oscillating functions representing specific projections of ray manifold. In areas of single-valued projections the frequency of the oscillations is proportional to the momentum. In areas of multi-valued projections the wave function can be thought of as a sum of multiple components with different momenta. Each linear operator in space of continuous oscillating functions induces a canonical transform in the phase space of coordinate and momentum. Known a single-valued projection of the ray manifold, it is possible to construct such a linear operator that transforms the wave function into a single ray representation, where the structure of the ray manifold can be globally reconstructed from the wave function. This idea has been widely used for processing radio occultation (RO) data, where multipath propagation is a common phenomenon in observations of the lower troposphere. For a spherically symmetrical atmosphere it proved to be straightforward to find the universal coordinate that always implements a single-valued projection of the ray manifold. This coordinate is the ray impact parameter, which is invariant along each ray and different for different rays. This property, generally speaking, does not hold for a real atmosphere with horizontal gradients. This explains the necessity of a technique of data analysis that can reconstruct the general structure of the ray manifold in the 2D phase space independently from any assumptions of the atmosphere. Formerly, the role of this analysis tool was played by the radio holographic (RH) analysis of the spectra of the wave field divided by the reference signal in small sliding apertures. Such a technique generally suffers from insufficient resolution in areas of complicated signal structure induced by multipath contaminated with high noise. We suggest using the Wigner Distribution Function (WDF) which has a significantly higher resolution. WDF describes the energy quasi-density distribution in the phase space. This function can be represented as a sum of real density, which tends to the micro-canonical delta-like distribution in the vicinity of the ray manifold, and quantum oscillations. To suppress the quantum oscillation we use the Weighted WDF (WWDF). Processing real and simulated RO data corroborates an extremely high potential of WDF as a means of RO data analysis, alternative to the RH technique and providing a higher resolution. We demonstrate examples of observation where WDF allowed for identifying multi-valued projections of the ray manifold. These situations may be responsible for some component of the negative bias of the retrieved bending angles and refractivity.