Testing the Method of Transverse Displacements for calculating paths of the HF radio wave propagation in three dimensional inhomogeneous media

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There are two approaches for radio wave ray tracing when the endpoints of the ray are fixed. The standard approach is the shooting method where a ray is sent out in some direction and its landing point is used to modify the shooting direction and obtain the desired endpoint. However, there is no systematic, universal algorithm for refining the shooting direction. Another approach is based on direct utilization of the variational principle for the optical path (Fermat's principle). The idea is to transform an arbitrary trajectory to an optimal one, while the endpoints of the trajectory are kept fixed according to the boundary conditions.

In this study, we propose a version of such a direct variational method, where only transverse displacements of the radio wave ray are used in the optimization algorithm. In our method, a chain of points which gives a discrete representation of the ray is adjusted iteratively to an optimal configuration. The advantages of transverse displacements include better computational efficiency and improved stability as compared to methods based on minimization of the optical path length. The method has been applied to various test problems. Results show good agreement with known analytical solutions. Two examples of the point-to-point ray tracing are shown in Fig. 1.

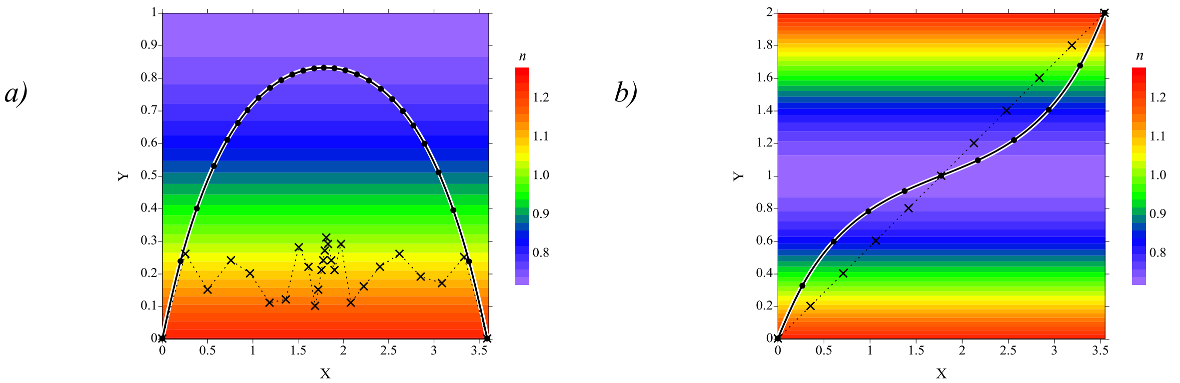

Fig. 1 Reflected (a) and transmitted (b) radio wave paths in parabolic refractive-index profile obtained by the method of transverse displacements (black solid line). The filled circles show the location of the points used in the optimization procedure. The crosses connected with dotted lines represent initial guess for the ray. Analytical solutions are shown with white solid curves. Endpoints of the rays are kept fixed at the predefined positions.

The method has also been applied to study 3D point-to-point ionospheric ray tracing where the properties of the propagation media have been derived using the Global Self-Consistent Model of the Thermosphere, Ionosphere and Protonosphere. Both quiet and disturbed geomagnetic conditions have been considered.