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Radio wave propagation in a disturbed ionosphere – a ray-tracing code and electromagnetic simulation compared

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1 Extended Abstract

Information on radio wave propagation in the ionosphere is needed e.g., in communication utilizing links extending over the horizon. Commercial ray-tracing codes are useful in estimating the average conditions for successful communication, but their performance is not optimal in disturbed ionosphere, where spatial gradients much deeper than present in statistical models can appear. Furthermore, commercial ray-tracing tools are not optimal in scientific work because access to their source code is typically restricted, and they offer only limited flexibility in their input parameters and ray-tracing methodologies.

We will study radio wave propagation at HF frequencies (3-30 MHz) from the basis of two different research-oriented approaches, the AU-Ray and the AU-EM. The AU-Ray [1, 2] uses Hamiltonian formalism where the ray is propagated either according to the Booker quartic or the Appleton-Hartree refractive index. The AU-EM [3] is a simulation where wave propagation is characterized by solving non-linearized Maxwell's equations and accelerating charged particles by the Lorentz force. Both approaches have been originally developed at the Aalto University. The AU-Ray has been further developed in the Finnish Meteorological Institute with the option for the user to feed in a model on the background ionospheric electron density with variations in latitude, longitude, and altitude. The AU-EM yields a more profound understanding of plasma waves' behavior than the AU-Ray, but as a computationally heavy code its testing has been started with simpler background conditions than those of the AU-Ray.

Our work will show some comparisons of the AU-Ray with a commercial code (Proplab-Pro). In addition, results from the first comprehensive tests of the AU-EM will be presented. These tests have been conducted at Aalto with a set of one and two-dimensional background conditions. AU-EM results on wave front behavior will be compared with the AU-Ray estimates on ray-paths in different ionospheric plasma conditions mimicking realistic structures at high latitudes (e.g., the appearance of ionospheric troughs).

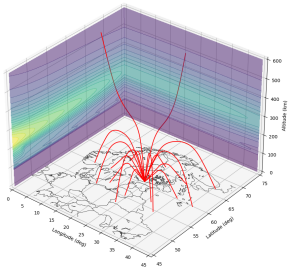

Figure 1. AU-Ray propagation path calculated using a simple 3D ionosphere.

References

[1] M. Fontell, "Numerical Ray Tracing of Medium and High Frequency Radio Waves in the Terrestrial Ionosphere," Master's Thesis, Dept. App. Phys., Aalto Univ., Espoo, Finland, 2018.

[2] E. Kallio, A. Kero, A.-M. Harri, A. Kestilä, A. Aikio, M. Fontell, et al, "Radar — CubeSat transionospheric HF propagation observations: Suomi 100 satellite and EISCAT HF facility," *Radio Science*, **57**, 10, September 2022, pp. 1, doi: 10.1029/2022RS007516.

[3] V. Pohjola and E. Kallio, "On the modeling of planetary plasma environments by a fully kinetic electromagnetic global model HYB-em," *Ann. Geophys.*, **28**, March 2010, pp. 743–751, doi: 10.5194/angeo-28-743-2010.