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Analyzing preliminary results of FMI's ionosonde with a ray-tracing software

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1 Introduction

An ionosonde is a radar that performs ionospheric sounding and provides measurements of the current state of the ionosphere. The critical parameters (foF2, foF1, foE) define the maximum frequencies for the ionosphere's electron density layers. These measurements are crucial for a variety of technologies and services that depend on HF radio signal propagation. In addition, the measurements are used to research ionospheric anomalies, improving our understanding of effects by space weather events and can be used to provide local forecasts.

The new FMI's ionosonde, manufactured by RF-shamaanit Oy, started its measurements recently (February 2025) in Southern Finland. The ionosonde is based on a software-defined radio (SDR) implementation, which enables its small antenna size ($\approx 1m^3$), rapid and flexible operation and low radiated power level ($< 0.5W$). In addition, the ionosonde antennas, shown in Figure 1, are easy to install and relocate when needed. The Ionosonde currently produces vertical ionograms using a 10 second sweep five times per minute. The measurements are filtered, and the critical parameters are detected in real-time. A more detailed real-height analysis is currently operated manually and an automated process is under development.

This presentation will present the first ionosonde measurements and analyze their properties using a numerical ray-tracing software, AU-Ray [1]. The code calculates the propagation path step-by-step by dividing the radio wave into singular rays and each path is evaluated by constant Hamiltonian. Depending of the ratio between the wave frequency and the plasma frequency, Au-Ray uses either Appleton-Hartree (AH) or Booker Quartic (BQ) refractive index. AU-Ray is a C++ standalone program that allows customized electron density profiles, such as idealized structures caused by space weather events. In this presentation, we use AU-Ray to analyze the variation in the electron density profiles, while comparing the simulation results to the ionosonde measurements.

Figure 1. The transmitter (left) and receiver (right) antennas of the FMI's ionosonde in Southern Finland.

References

[1] E. A. O. Hirvonen, K. Kauristie and E. Kallio. "AU-Ray Program for Modelling Radio Wave Propagation in the Ionosphere". *Radio Science*. Manuscript submitted Dec. 2024.