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Fridman, Sergey[1]; Nickisch, L. J.[1]; Hausman, Mark[1]; Kraut, Shawn[1]; Zunich, George[2]
1. NorthWest Research Associates
2. Zunicalc, Inc.

Assimilative Model for Ionospheric Dynamics Employing Delay, Doppler, and Direction of Arrival Measurements from Multiple HF Channels

Abstract:
We describe development of new HF data assimilation capabilities for our ionospheric inversion algorithm called GPSII (GPS Ionospheric Inversion). Previously existing capabilities of this algorithm included assimilation of GPS TEC data as well as assimilation of backscatter ionograms [Fridman et al., 2012]. In the present effort we concentrated on developing assimilation tools for data related to HF propagation channels. Measurements of propagation delay, angle-of-arrival (AoA), and the ionosphere-induced Doppler from any number of known propagation links can now be utilized by GPSII.

The resulting ionospheric model is consistent with all assimilated measurements. It means that ray-tracing simulation of the assimilated propagation links is guaranteed to be in agreement with measured data. The key theoretical element for assimilating HF data is the ray path response operator (RPRO) which describes response of ray path parameters to infinitesimal variations of electron density in the ionosphere.

We construct RPRO out of the fundamental solution of linearized ray-tracing equations for dynamic magnetoactive plasma. We demonstrate performance and internal consistency of the algorithm using propagation delay data from multiple oblique ionograms (courtesy of DSTO, Australia) as well as with time series of near vertical incidence skywave data (courtesy of the IARPA HFGeo Program Government team).

In all cases GPSII produces electron density distribution which is smooth in space and in time. We simulate the assimilated propagation links by performing ray tracing through GPSII-produced ionosphere and observe that simulated data are indeed in agreement with assimilated measurements.

References
Fridman, Sergey V., L. J. Nickisch, and Mark Hausman, Fridman, S. V., L. J. Nickisch, and M. Hausman (2012), “Inversion of backscatter ionograms and TEC data for over-the-horizon radar”, Radio Sci., 47, RS0L10, doi:10.1029/2011RS004932.