119 -- 2017-03-09 11:48:58

Session 3A Paper 3

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A Joint Estimation Approach for the Geolocation of Ground HF Transmitters in the Presence of Ionosphere Perturbations

In this paper we describe a geolocation approach, which jointly estimates ionospheric state and transmitter location, being developed for the IARPA HFGeo program. The goal of the HFGeo program is to geolocate HF transmitters using a compact antenna array and associated signal processing capable of measuring the Angles of Arrival (AoA) of received sky waves, along with some (or none) measurements of the ionosphere (i.e., sounder or check targets). Given the availability of signal features (frequency, modulation, etc.), the association between a measurement and an emitter is generally straightforward. Therefore, in this paper we concentrate only on the estimation problem.

What makes the estimation problem challenging is that in addition to the unknown location of the transmitter, the ionospheric state is also partially unknown. Accurate measurement of the ionospheric state is not generally available for arbitrary time and location. Even in the most benign scenarios where a Digisonde or other ionosphere measuring devices are available, it is very unlikely that they will be located near the apogee(s) of the sky ray of interest. Unmeasured local ionospheric perturbations near the ray apogee(s) will highly impact the geolocation accuracy.

The most common approach for geolocation has been to use a magneto-ionic ray tracer to solve the reverse ray path mapping the measured AoA into a geolocation. The ionospheric state is specified by either a climatological model or a more elaborate assimilation model, like the Boston College Regionally Optimum Assimilative Model (ROAM – see companion paper by Carrano et al.). This direct approach suffers from many drawbacks, including ignoring the noise in the measured AoA, the incapability to fuse azimuth-only AoA as provided by some remote sensors used in conjunction with the HFGeo system, and the inability to exploit nearby known transmitters as check targets to improve the geolocation of the unknown transmitter.

In our geolocation approach, we follow the standard formulation of the estimation problem where the predicted emitter geolocation is mapped into an AoA via a ‘measurement’ function – instead of mapping the AoA into a geolocation. This measurement function – i.e., the mapping from emitter location to AoA – is non-linear and partially unknown. More specifically, the measurement function involves solving a ray homing problem where a 3-D magneto-ionic ray tracer provides the mapping between a measured AoA into a geolocation together with a non-linear solver to provide the mapping from a geolocation to an AoA. The ray homing solution depends on the ionosphere state, as already mentioned, only partially known due to local perturbations (Traveling Ionospheric Disturbances, or TIDS, plus local variations of both critical frequency and altitude of the different layers).

The joint estimation described here augments the transmitter geolocation state with an ionospheric perturbation state – based on either a 3-layer Chapman model or an IRI model plus a local tilt. An Unscented Kalman Filter (UKF) is used to capture the non-linear nature of the measurement function. The approach has been implemented as the Joint Ionospheric Geolocation State Estimation (JIGSE) subsystem for HFGeo and has been evaluated with data collected under HFGeo. We present geolocation and ionospheric state estimation results using simulated and measured data, demonstrating considerable improvement in geolocation accuracy with respect to the standard reverse ray tracing approach.

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