Progress in Modeling and Simulation of HF Radar Propagation

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1. Extended Abstract

HF radars that propagate through the ionosphere, like Over-the-Horizon radar (OTHR) or SuperDARN, must deal with several propagation effects in addition to refraction. These include Doppler-spread clutter from phase modulations imparted by small-scale ionization structure, backscatter clutter from geomagnetic-field-aligned ionization structure, backscatter from meteor trails, and ionization-structure-induced signal decorrelation spatially (causing angle-of-arrival spreading), temporally (causing Doppler spreading), and in frequency (causing spreading in delay).

A high-fidelity HF channel simulation has been developed that is suitable for HF radar and communication system design studies and test planning [1]. The simulation capability is called HiCIRF, for High-frequency Channel Impulse Response Function. HiCIRF provides simulated HF signals corresponding to transmissions from individual transmitter array elements to individual receiver array elements for propagation through the naturally disturbed or undisturbed ionospheric channel. Both one-way link geometries and two-way radar geometries can be simulated. HiCIRF incorporates numerical ray tracing and stochastic signal structure computations to realistically simulate signal scatter by small-scale ionization structure. Stochastic signal generation is employed to generate signal realizations that can be used for OTHR array design and advanced signal processing studies.

In this presentation we will review some of the theory incorporated in HiCIRF, including the use of the phase-screen/diffraction method of *Nickisch* [2] for the computation of signal decorrelation effects caused by small-scale ionization structure. Several examples of HiCIRF simulation results for various HF radar situations will be shown.

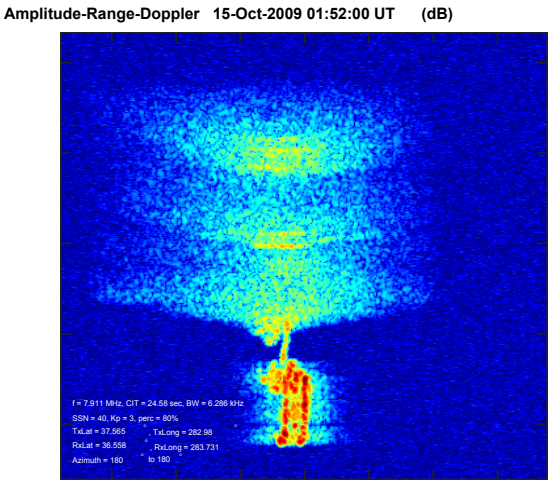

Figure 1. HiCIRF simulation of a mid-latitude OTHR directed due south, showing ocean Bragg clutter at nearer ranges and Doppler-spread clutter beyond 4000 km caused by post-sunset equatorial small-scale ionization structure.

2. References

1. L. J. Nickisch, G. St. John, S. V. Fridman, M. A. Hausman, and C. J. Coleman (2012), "HiCIRF: A high-fidelity HF channel simulation," *Radio Sci.*, **47**, RS0L11, doi: 10.1029/2011RS004928.

2. L. J. Nickisch (1992), "Non-Uniform Motion and Extended Media Effects on the Mutual Coherence Function: An Analytic Solution for Spaced Frequency, Position, and Time," *Radio Sci.* **27**, Number 1, pp. 9-22