Estimating critical ionosphere parameters from received, wideband HF signals

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The goals of this effort are to study the effects of ionospheric variability with temporal scales ranging from seconds to hours on symbol error rates in wideband HF skywave communications, and to develop a method of using realized HF communication signals to ascertain critical ionosphere characteristics in near real-time, for use in updating propagation predictions.

Advancements in HF communications systems, including the utilization of wider bandwidths for higher data throughput, raise questions about the impact of ionospheric dynamics on wideband channel performance, as well as drive an increasing need for current, local characterizations of ionospheric conditions.

One of the most commonly utilized tools for measuring ionosphere profiles is vertical sounders, which analyze pulse echoes throughout the HF band to sample the vertical refractive profile up to the altitude of the peak density of free electrons. However, many HF communication systems (e.g., shipboard) are generally sufficiently distant from a vertical sounders that the regularly generated profiles provide little useful information for predicting propagation locally. Moreover, in extreme cases where sounder data may not be available at all, prediction ability is limited to the use of climatological models such as the Voice Over America Communications Prediction (VOACAP). Software defined radios (SDRs), because they allow access to signal data at nearly any point in the processing stream, afford an opportunity to utilize communication signals as ad hoc ionosphere measurement systems.

The approach of this study is to simulate HF skywave channel responses at numerous HF frequencies using a ray-based HF propagation model, paired with an environmental background model consisting of the International Reference Ionosphere (D. Bilitza et al., J. Geodesy, 2010, doi 10.1007/s00190-010-0427-x) and modules to simulate diffuse scattering, Doppler drift and fading effects. Simulated received digital data are then generated using various wideband (3-24 kHz) modulations and the resulting channel simulations. The constellation diagrams resulting from these simulated channels will be analyzed to identify distortions caused by the various sources of variability in propagation. The focus of analysis of these symbol errors is to develop an empirical mapping between received, digital signals and critical ionosphere parameters. In addition to PC-based communication simulation, the waveforms and channel responses are analyzed using an Arbitrary Waveform Generator (AWG), and a SDR is used to capture and analyze the realized, simulated communications data. The SDR-captured IQ data will be used to compute the critical ionosphere parameters using the aforementioned mappings, and those estimates will be compared to values computed directly from the background environment model. Success of this project will lead to further field testing, and will inform on-going design of wideband communications systems.