A PHASE SCREEN SIMULATOR FOR PREDICTING THE IMPACT OF SMALL-SCALE IONOSPHERIC STRUCTURE ON SAR IMAGE FORMATION AND INTERFEROMETRY

Charles S. Carrano[1], Ronald G. Caton[2], and Keith M. Groves[2]

[1]Institute for Scientific Research, Boston College, Boston, MA
[2]Air Force Research Laboratory, Hanscom AFB, MA

The effects of the ionosphere on synthetic aperture radar (SAR) can be categorized into two different types. The first type consists of effects caused by the ionospheric background such as refraction, polarization rotation, group delay, and phase change. These effects can be largely mitigated if a suitable model for the ionosphere is used during SAR processing. The second type consists of effects caused by small-scale ionospheric structures which are generated by plasma instability processes. These instability processes act predominantly at polar latitudes and equatorial latitudes at night, the effects being more intense during periods of high solar activity. As radio waves penetrate these small-scale structures, they are randomly scattered in different directions resulting in spatial variations in signal phase. These phase variations cause interference to occur as the radio wave continues to propagate, resulting in a diffraction pattern on the ground with spatial fluctuations in both amplitude and phase. These fluctuations are intensified as the reflected wave traverses the ionosphere a second time after reflection from the ground. Amplitude and phase fluctuations which decorrelation across the synthetic aperture of the radar reduce the resolution of a SAR image, and alter critical differential phase relationships between images collected during satellite revisits that are required by InSAR and change detection applications.

In this paper we present a phase screen simulator for predicting the impact of small-scale ionospheric structure on SAR image formation and interferometry applications. This simulator consists of a screen generator and a propagator. The screen generator creates a random realization of spatial phase fluctuations resulting from propagation through small-scale irregularities in the ionosphere. The irregularities are specified statistically in terms of a power spectral density that depends on 1) the vertically integrated strength of turbulence, 2) the spectral index, 3) the outer scale, and 4) the anisotropy ratio along and transverse to the local magnetic field direction. The screen generator accounts for the motion of the radar platform, the drift of the ionospheric irregularities, and the angle of propagation, all of which determine the scale sizes of the irregularities that are sampled by the radar beam. The statistical parameters which specify the irregularities can be input to the simulator manually, or provided by the WBMOD ionospheric scintillation model, which is a global climatological model of scintillation constructed from an extensive database of observations. The propagator solves the parabolic wave equation using the split-step, multiple phase screen technique to yield the 2D diffraction pattern of amplitude and phase after two-way propagation through the ionosphere. By the principal of superposition, this diffraction pattern can be added to the SAR signal due to terrestrial features in order to assess the ionospheric impact on SAR image formation and interferometry. Sample output from the simulator is shown in Figure 1. In the full paper, we demonstrate the technique in detail by simulating the impact of small-scale ionospheric structure on PALSAR imagery collected during satellite passes over South America.

a) b) c) d)

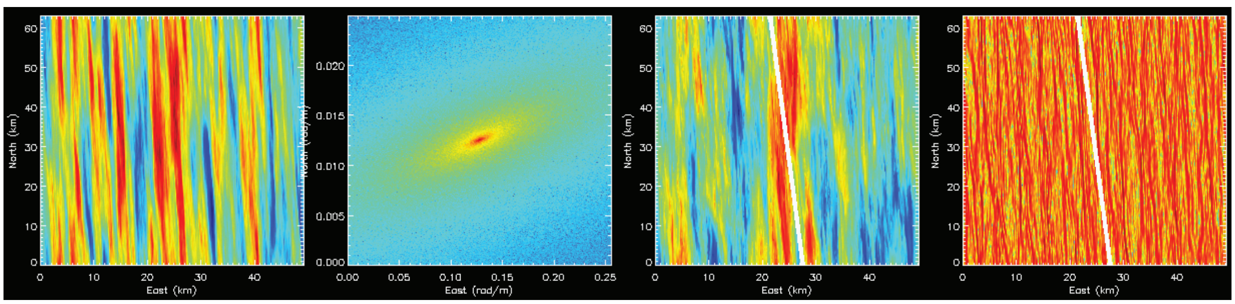

Figure 1. Phase screen simulation of two-way radar propagation through highly anisotropic electron density irregularities in the ionosphere. a) Simulated phase fluctuations after one-way passage through the ionosphere, b) power spectral density of these phase fluctuations, c) simulated signal phase on the ground, and d) simulated signal intensity on the ground. The satellite track over the region is shown in white.

References

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