Detection of Ionospheric Structures with L-Band Synthetic Aperture Radars

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Ionospheric irregularities are produced by a wide range of fluid and kinetic instability processes. Understanding these processes can benefit from images of the phase and polarization changes introduced onto transiting radio waves. L-Band synthetic aperture radar (SAR) signals, such as produced by the Japanese ALOS PALSAR at 1.27 GHz , can be used to study the ionosphere with either phase delays or, in the case of severe radio scintillations, amplitude and polarization effects. Ionospheric physicists can use the distorted SAR signals to measure natural and artificial ionospheric irregularities. Near the geomagnetic equator, at sunset, the ionosphere often becomes distorted by ionospheric bubbles rising nearly vertically to 600 km or higher. The availability of an orbiting SAR makes the study of such bubbles possible by detecting the distortions of the SAR images for waves passing through the disturbed ionosphere. At high latitudes, auroral electric fields transport the ionospheric plasma to high speeds causing fluid instabilities to split the layers in patches. Such structures may be imaged using space-based SAR.

Artificial ionospheric irregularities in the ionosphere may be generated by the transmission of high power radio waves. High power radio waves with effective powers greater than 100 MW affect the F-layer ionosphere by thermal-self focusing instabilities and by electrostatic coupling into upper hybrid waves. The high power HF facility in Alaska called HAARP has been shown to greatly amplify the amplitude of field aligned irregularities in the auroral ionosphere. These irregularities corrugate the phase fronts of L-Band SAR signals enough to possibly produce distortions in the SAR image or the SAR polarization. The use of artificial ionospheric modification with high power radio waves is most easily seen with the SAR waves are propagating along the magnetic field lines. The feasibility of using distorted SAR images for detection of artificial field-aligned-irregularities (FAI) is under current research.

To detect the usefulness for space borne SAR for measurements of ionospheric structures, a full wave propagation code was coupled with a first-principles model of ionospheric irregularities. The simulations show that polarization fluctuations are relatively easy to introduce into the SAR signal for ionospheric diagnostics purposes. Amplitude scintillations at L-Band are usually less and 1 dB so they are less useful for ionospheric irregularity detection (Figure 1). Near the equator, the strongest distortions of SAR signals are predicted to come from propagation along the gradients of the ionospheric bubbles.

The computed radio disturbances are used to plan experiments with ALOS/PALSAR near the equator and at high latitudes. The ALOS PALSAR provides imagery for many repeating orbits. Observations of the natural ionosphere near Kwajalein in the Marshall

Islands and Fairbanks Alaska are planned using incoherent scatter radars and satellite radio beacons to provide ionospheric data complementary to the SAR measurements. Similarly, the Alaska HAARP facility and the high power radio facility near Arecibo Puerto Rico that is due to be constructed in a few years will be used to produce artificial structures for detection with space-based SAR.. The incoherent scatter radars near these facilities will provide scans of the effects of the HF waves along a single radar beam. The space-based SAR images are complementary to the radars because they scan the full regions of ionospheric modification.

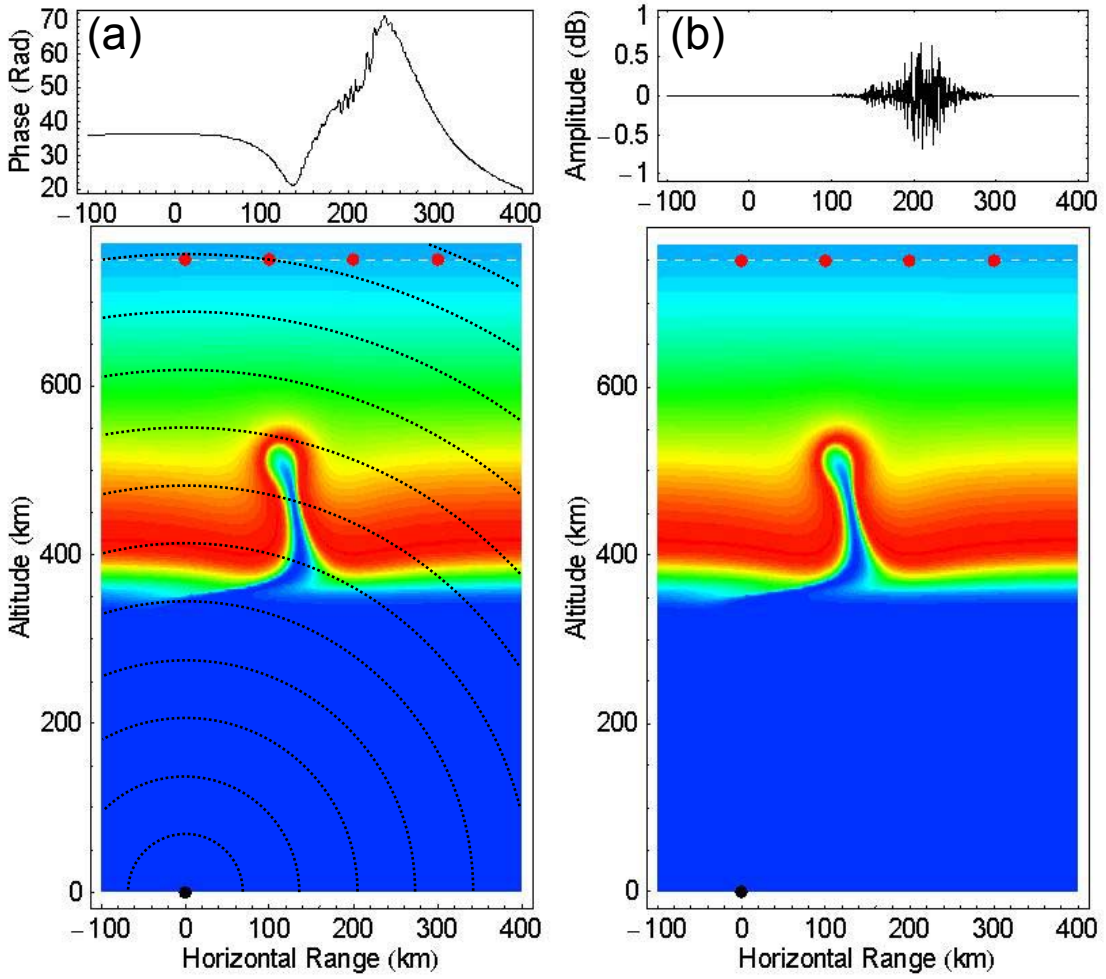

Figure 1. Simulated effects of the equatorial ionosphere on a 1.27 GHz electromagnetic wave scattered from a point on the earth (black dot) and received on a satellite at 750 km altitude (red dots). The simulation represents distortion of SAR backscatter by a single bubble irregularity in the equatorial ionosphere.