MAR12-2011-008014

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Advanced methods in synthetic aperture radar imaging

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For over 50 years our world has been mapped and measured with synthetic aperture radar (SAR). A SAR system operates by transmitting a series of wideband radio-frequency pulses towards the ground and recording the resulting backscattered electromagnetic waves as the system travels along some one-dimensional trajectory. By coherently processing the recorded backscatter over this extended aperture, one can form a high-resolution 2D intensity map of the ground reflectivity, which we call a SAR image. The trajectory, or synthetic aperture, is achieved by mounting the radar on an aircraft, spacecraft, or even on the roof of a car traveling down the road, and allows for a diverse set of applications and measurement techniques for remote sensing applications. It is quite remarkable that the sub-centimeter positioning precision and sub-nanosecond timing precision required to make this work properly can in fact be achieved under such real-world, often turbulent, vibrationally intensive conditions. Although the basic principles behind SAR imaging and interferometry have been known for decades, in recent years an explosion of data exploitation techniques enabled by ever-faster computational horsepower have enabled some remarkable advances. Although SAR images are often viewed as simple intensity maps of ground reflectivity, SAR is also an exquisitely sensitive coherent imaging modality with a wealth of information buried within the phase information in the image. Some of the examples featured in this presentation will include: (1) Interferometric SAR, where by comparing the difference in phase between two SAR images one can measure subtle changes in ground topography at the wavelength scale. (2) Change detection, in which carefully geolocated images formed from two different passes are compared. (3) Multi-pass 3D SAR tomography, where multiple trajectories can be used to form 3D images. (4) Moving Target Indication (MTI), in which Doppler effects allow one to detect and geolocate moving targets within SAR images. (5) Real time video SAR, where one forms a continuously updated SAR image by “staring” at an area of interest.