RESEARCH ON INTERFEROMETRIC DEFORMATION DETECTION FOR GEOSYNCHRONOUS SAR

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ABSTRACT

Repeat pass interferometry synthetic aperture radar (SAR) for surface deformation detection is a main profile of satellite SAR application. From the deformation interferograms, movements on earth surface at centimeter or even more minute levels can be monitored [1]. Therefore, many earth physical phenomena can be discovered and analyzed, such as earthquake, volcano, ice sheet movement and subsidence [2]. However, repeat pass interferometry with spaceborne SAR is still under development [1,2]. Due to the revisit time of satellites, the time decorrelation is one of the main bottlenecks that need to be resolved. Additionally, the deformation interferograms generally contain the surface deformation information only in the radar's line of sight because of the side-looking work mode of SAR. Both the problems are hard to resolve in the present spaceborne SAR system.

A geosynchronous SAR (GEOSAR) concept has previously been presented by Tomiyasu [3]. The synthetic aperture is obtained with an apparent motion of the geosynchronous satellite induced by non-zero inclination and eccentricity of the orbit [3-5]. Geosynchronous synthetic aperture shapes can be near-circular, elliptical and "Figure 8", which depend on the orbit inclination angle, orbit eccentricity and argument of perigee [5,6]. The curved paths can provide true 3D image with improved ground resolution [7].

Repeat pass inrerferometry for geosynchronous SAR could be carried out, comparing images taken with a near zero baseline at 24 hours interval. The temporal decorrelation will be decreased in the geosynchronous SAR system. Besides, a geosynchronous SAR can irradiate a single target area for extended periods of time, and it will benefit the disaster management [8]. Furthermore, most areas within the coverage region can be mapped from different view directions and a geosynchronous SAR can provide three-dimensional displacement data on a daily basis. The subject of this study concentrates on analyzing the characteristics of the interferometric deformation detection for geosynchronous SAR.

Firstly, the connection between the interferometric phase and the deformation of repeat pass geosynchronous SAR is derived. Assuming the synthetic aperture of GEOSAR is within (θ_s, θ_e), the image reconstruction with curved path is accomplished with confocal imaging algorithm based on the geosynchronous SAR geometry of elliptical aperture. By approximation processing to the range difference and resolving the integral of the slow-time, the interferometric phase of the signal before and after deformation is extracted.

Then, from the phase information, we analyze the characteristics of the interferometric deformation phase, discuss the sensitivity of interferometric phase to surface deformation in different direction and interpret its capability of mapping 3D surface deformation. Different from the conventional interferometry SAR signal, the surface deformation information included in the interferogram is no longer in the radar's line

of sight. When the GEOSAR imaging is made with full aperture measurements, i.e., θ_e-θ_s=2π, the interferometric phase is a linear function of the corresponding deformation value and the phase is independent of the synthetic aperture. Also from phase expression we can get the sensitivity of phase relative to the corresponding surface deformation, and conclude that the interferometric phase is most sensitive to the height movement. When the GEOSAR reconstruction is made with partial aperture measurements, i.e., θ_e-θ_s<2π, the interferometric phase becomes a non-linear function of corresponding deformation and the phase value varies with the start aperture and end aperture. Hence a geosynchronous SAR can provide a 3D deformation measurement when imaging measurement is made with at least three subapertures.

Finally, in order to validate the above analysis of deformation detection for interferometric geosynchronous SAR system, several simulations have been implemented. Fig.1 is an ellipse subsatellite track with an inclination angle of 6^0, an orbit eccentricity of 0.052, and an argument of perigee of 90^0.

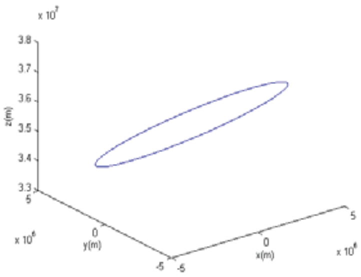


Fig.1 Subsatellite track

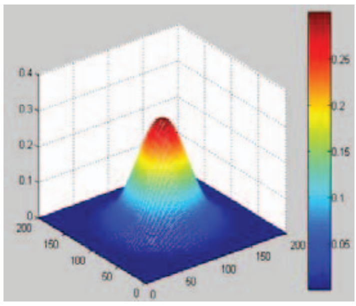
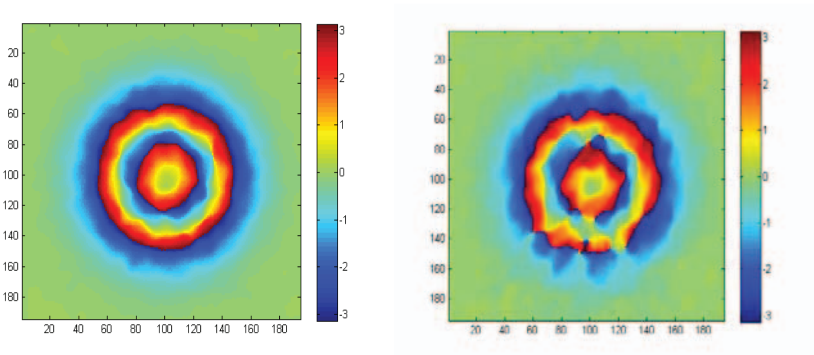
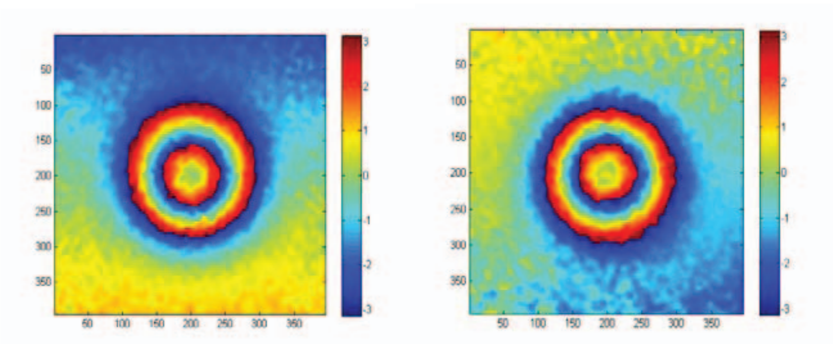


Fig.2 simulated height deformation



(a) with 2π aperture measurement (b) π/2 aperture measurement

Fig.3 Filtered height deformation interferogram



(a) aperture is within (-π/3, π/3) (b) aperture is within (-π, -π/3)

Fig.4 three-dimensional deformation interferograms with partial aperture measurements

In the simulations, the deformation is firstly set only in the height direction for conveniently observing the effect of different aperture length to the interferometric phase. The height deformation is illustrated in Fig.2. Fig.3 (a) is the interferogram with full aperture measurement and Fig.3 (b) is interferogram with aperture measurement of $\pi/2$ radian. Nonlinear phase exists in the interferometric phase result with partial aperture measurement, which behaves discontinuity of the interferograms. Adding horizontal deformation into the above height deformation simulations, we can get the interferograms presented in Fig.4. The interferograms are obtained with partial subapertures, where Fig.4 (a) is within $(-\pi/3, \pi/3)$ and Fig.4 (b) is within $(-\pi, -\pi/3)$. Although of the same surface deformation, the interferograms vary with the different subapertures. This implies that an interferometric estimation of three-dimensional (3D) surface deformation can be obtained using three or more geosynchronous subapertures.

***Index Terms*—**Repeat pass interferometry, Geosynchronous synthetic aperture radar, Subapertures, Three-dimensional (3D) surface deformation detection

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