NEW TRENDS IN SAR TOMOGRAPHY

F. Baselice, A. Budillon,
G. Ferraioli, V. Pascazio, G. Schirinzi

Università di Napoli Parthenope
Dipartimento per le Tecnologie
Centro Direzionale, Is. C4, 80143 Napoli, Italy

A. Evangelista

Università di Cassino
DAEIMI
Via Di Biasio, 43, 03043 Cassino, Italy

1. INTRODUCTION

Three dimensional Synthetic Aperture Radar (SAR) imaging of earth surface has received a growing interest in recent years, thanks to the launch of new high-resolution radar sensors (TerraSAR-X and COSMO-SkyMed) which provide a large amount of images acquired with advanced SAR sensors. 3-D SAR image formation provides the scattering scene estimation along azimuth, range and elevation co-ordinates. It is based on multi-pass SAR data obtained, usually, by non-uniformly spaced acquisition orbits (see Fig 1). One of the main problems that have to be taken into account for the 3D SAR reconstruction concerns geometrical distortion. If we consider a ground height profile with three point scatterers (A, B and C) lying in the same range-azimuth resolution cell (see Fig 2), the acquired complex SAR signals related to the three scatterers collapse in the same resolution cell, producing the layover phoenomenon. The signal corresponding to the layover region depends both on amplitude (related to the material, roughness, viewing angle) and phase (related to the distance between sensor and object and speckle effects) of each single contribution involved.

In this paper we analyze two different techniques to retrieve the height of the different contributions that collapse in a layover cell in order to achieve 3-D SAR imaging: Compressive Sensing and SAR Statistical Tomography. We compare the obtainable results in terms of multiple scatterers resolutions capabilities, number of baselines and signal to noise power ratio on simulated data in order to provide a set of instruments for the 3D SAR imaging able to tackle different scattering mechanisms in layover areas.

2. SAR STATISTICAL TOMOGRAPHY

The first approach is based on SAR Statistical Tomography [1], which consists of trying to separate and distinctly estimate each complex contribute which collapse in layover pixels. In particular, it allows the joint estimation of both height and reflectivity of scatterers, providing the reconstruction of the height profile and of the scene reflectivity map. SAR Statistical Tomography is based on the assumption of a Gaussian distribution for the measured data, with a covariance matrix function of the unknown parameters (reflectivity and height of scatterers). The model has been analyzed in literature, and Cramer Rao Lower Bounds have been computed in a wide range of scattering and acquiring system configurations [1]. The estimation is performed via a simple Maximum Likelihood (ML) approach. The method has proven its effectiveness for the 3D reconstruction of all the pixels of the imaged scene, especially in the case of absence of dominant, stable and highly coherent scatterers. The drawback is the high number of baselines and looks needed for a correct estimation.

3. COMPRESSIVE SENSING

The second approach considered is a new method, which reduces the required number of measurements and enhances the elevation resolution achievable with a given orthogonal baseline extent. It is based on the assumption that a low number of scatterers with different elevations is present in the same range-azimuth resolution cell [2] and exploits Compressive Sampling (CS) [3-5], which provides a new sampling theory for data acquisition and allows super-resolution using only few signal samples. This approach was introduced, together with some preliminary results in [1]. The CS makes the assumption of dominant, stable and coherent scatterers, treating incoherent returns as noise. Practically speaking, the CS method has its natural applicability environment in a urban scenario.

CS is a model-based framework for data acquisition and signal recovery based on the premise that a signal having a sparse representation in one basis can be reconstructed from a small number of measurements collected in a second basis, that is incoherent with the first. In our case sparseness requires a small number of stable targets in the same range-azimuth resolution cell. Incoherence expresses the idea that objects having a sparse representation in a given basis must be spread out in the domain in which they are acquired. Instead of measuring conventional returns and sampling it at the Nyquist rate, linear projections of the returned signal with random vectors are taken as measurements. Then, by ℓ_1-norm minimization it is possible to reconstruct the full-length signal from the small amount of collected data.

4. RESULTS

The two approaches have been compared in terms of accuracy in scatterers height estimation in a simulated scenario. Different sets of multiple scatterers have been considered and the estimation has been performed for different baseline configurations and SNRs.

Obtained results allow us to identify the optimal environment for each approach, underlining the limits and the performances of both techniques.

Further work will be focused on the comparison of the considered techniques in a wide range of real, high resolution SAR images.

5. REFERENCES

[1] F. Baselice, A. Budillon, G. Ferraioli, V. Pascazio, "Layover Solution in SAR Imaging: A Statistical Approach", *IEEE Geoscience and Remote Sensing Letters,* Vol 6, no. 3, pp. 577-581, July 2009.

[2] A. Budillon, A. Evangelista, G. Schirinzi, "SAR Tomography from Sparse Samples" Proc*. IEEE Int Geoscience and Remote Sensing Symposium, (IGARSS 2009),* 2009.

[3] E. Candès, M. B. Wakin, "An Introduction To Compressive Sampling" *IEEE Signal Processing Magazine,* Vol. 25, pp. 21–30, March 2008.

[4] E. Candès, J. Romberg, T. Tao, "Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information,", *IEEE Trans. Inform. Theory*, Vol. 52, no. 2, pp. 489–509, Feb. 2006.

[5] E. Candes and J.Romberg, "Sparsity and incoherence in compressive sampling," *Inverse Problem*, Vol.23, No.3, pp.969-985, 2007.

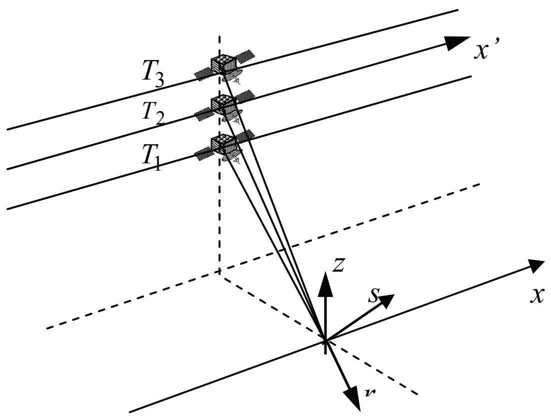

Figure 1: Multi-pass SAR geometry in the case M=3.

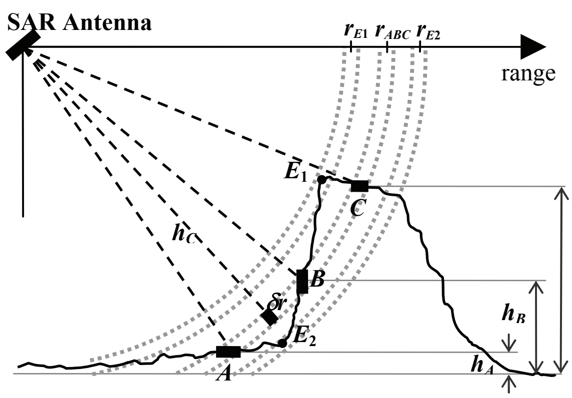

Figure 2: Layover Geometry. The echoes from points A,B and C, respectively at heights h_A, h_B and h_C collapse in the range cell positioned at a distance r_{ABC} from the sensor.