SAR TOMOGRAPHIC FOCUSING BY COMPRESSIVE SAMPLING: EXPERIMENTS ON REAL DATA

Alessandra Budillon[(1)], *Annarita Evangelista*[(2)], *Gilda Schirinzi*[(1)]

[(1)] Dipartimento per le Tecnologie, Università di Napoli "*Parthenope*",
Centro Direzionale di Napoli, Isola C4, 80143 Napoli, Italy
{alessandra.budillon, gilda.schirinzi}@uniparthenope.it

[(2)] DAEIMI - Università di Cassino, via Di Biasio 43, 03043 Cassino (Italy)
annarita.evangelista@unicas.it

Synthetic Aperture Radar (SAR) is an active microwave system which allows to generate high resolution 2-D images of the scene observed in the azimuth and range directions.

However, because of the geometry of the system and the possible presence of layovered steep areas in the scene observed by a single SAR sensor, it is not possible to separate the contributions of two or more scatterers positioned at different elevations, but within the same azimuth-range SAR resolution cell.

Then, different 3-D reconstruction techniques by using multi-channel SAR systems have been proposed, as the Polarimetric interferometric SAR systems which allow the estimation of the 3-D altimetric profile of the imaged scene, but are not able of providing the scatterers distribution along the height direction [1]. SAR tomographic techniques, instead, allow generating 3-D images, providing an estimation of the scatterers distribution along the elevation direction [2-6]. These techniques require a second aperture synthesis in the elevation direction, in addition to the synthetic aperture along the azimuth direction. The aperture synthesis in the elevation direction can be performed by using several multi-pass acquisitions on the same scene, taken with different view angles.

At this purpose two problems have to be taken into account: the number of acquisitions in the elevation direction is usually much lower than that required for the aperture synthesis and the acquisitions are unevenly spaced along the elevation direction.

The above mentioned problems can introduce a degree of ill conditioning in the processing step required for focusing in the elevation direction, that may generate severe ambiguities and numerical instabilities in the elevation imaging process [3,4]. This problem can be solved by exploiting different spectrum estimation strategies such as Truncated Singular Value Decomposition (TSVD) [4] and MUSIC algorithm [6], or exploiting the non-uniform sampling theorem [5]. This theorem is based on the band-limited properties of the signal acquired along the elevation direction, and imposes a constraint on the maximum sampling interval and on the minimum samples average density.

Anyway all the methods referenced above are not able of providing elevation focused images with a resolution higher than the nominal resolution obtainable with the given elevation aperture size.

We proposed a new method [7], which reduces the required number of measurements and enhances the elevation resolution achievable with a given aperture 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 and exploits Compressive Sampling [8,9,10]. 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 point-like targets. 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. The technique defined hereinafter will be named TCS (Tomographic CS focusing).

In [7] we showed the effectiveness of the proposed method on simulated data and we noted that the elevation image reconstruction obtained with TCS is much better than the one obtained using the TSVD based method, especially when the number of acquisitions decreases. Moreover we showed that the achievable elevation resolution can be noticeably increased.

In this paper we show the performance of the method on real data. We consider real data acquired by the sensors ERS1-2 over the city of Naples, (San Paolo stadium). We carry out the tomographic processing of four azimuth-height sections, indicated with four segments in the ortophoto image shown in Fig. 1. The images focused starting from 15 acquisitions and using TCS and TSVD for section B are shown in Fig. 2. The high resolution performance of TCS is quite evident.

A complete performance analysis will be presented in the final paper. This analysis is regarding the evaluation of the minimum number of acquisitions required to achieve a given elevation resolution, the maximum resolution achievable with a given acquisition configuration and the relation between the Cramer Rao Lower Bound (CRLB) for the estimated elevation and the maximum achievable resolution.

Figure 1. Ortophoto image of the Stadium San Paolo in Naples (ITALY).

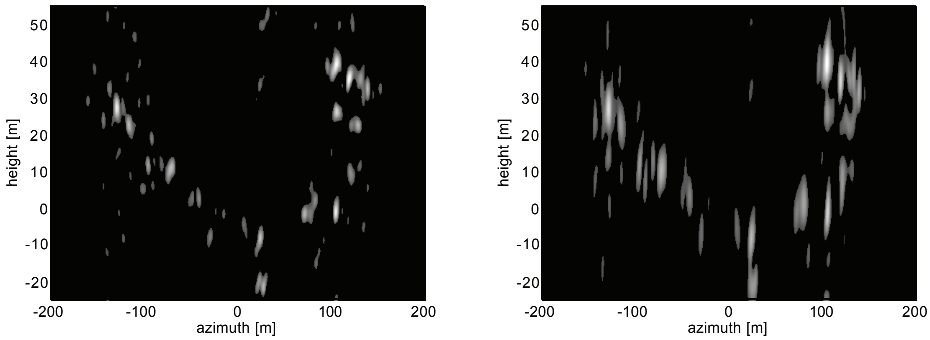

Figure 2. Azimuth height section B of Fig.1 of tomographic reconstruction over the San Paolo stadium in Naples (ITALY), obtained with (left column) TCS and (right column) TSVD.

REFERENCES

[1] S. R. Cloude, K. P. Papathanassiou, “Polarimetric SAR Interferometry”, *IEEE Trans. Geosc. Remote Sensing*, vol. 36, pp. 1551-1565, 1998.

[2] J. L. H. Webb, D. C. Munson Jr., “Radar imaging of three-dimensional surfaces using limited data”, in *Proc. ICIP*, Washington, DC, 1995, pp. 136-139, 1995.

[3] A. Reigber, A. Moreira, “First Demonstration of Airborne SAR Tomography Using Multibaseline L-Band Data”, *IEEE Trans. Geosc. Remote Sensing*, Vol. 38, pp. 2142-2152, 2000.

[4] G. Fornaro, F. Lombardini, F. Serafino, ”Three-Dimensional Multipass SAR Focusing: Experiments With Long-Term Spaceborne Data”, *IEEE Trans. Geosc. Remote Sensing*, Vol. 40, pp. 702-714, 2005.

[5] F. Meglio, G. Panariello, G. Schirinzi, “Three dimensional SAR image focusing from non-uniform samples”, *Proc. IEEE Int Geoscience and Remote Sensing Symposium, (IGARSS 2007),* pp 528 – 531, 2007.

[6] M. Nannini, R. Scheiber, A. Moreira. “Estimation of the Minimum Number of Tracks for SAR Tomography”, *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 47, pp. 531-543, Feb. 2009.

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

[8] E. Candès, M. B. Wakin, “An Introduction To Compressive Sampling” *IEEE Signal Processing Magazine,* vol. 25, pp.21–30, March 2008.

[9] 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.

[10] R. Baraniuk, P. Steeghs, “Compressive Radar Imaging”, *Proc of IEEE Radar Conference 2007*, pp. 128-133, 2007.