Compressed Sensing Application For Sparse Array Radar

Daojing Li, Liechen Li
Science and Technology on Microwave Imaging Laboratory
Institute of Electronics, CAS
Beijing, China
lidj@mail.ie.ac.cn

Ying Xi
Key Laboratory of Microwave Remote Sensing
National Space Science Center, CAS
Beijing, China

Abstract—**Based on the sparsity of scene (moving target and few scatterers on the same resolution cell), MTD and 3D imaging are investigated by means of compressed sensing (CS) for airship sparse array radar and airborne three-aperture MMW SAR. Based on the sparsity of continuous scene sparse spectrum, side-looking 3D imaging is investigated by means of CS for airborne cross-track sparse array SAR. Some signal and data processing results are presented.**

Keywords-compressed sensing (CS); sparse array; moving targets detection (MTD);3D imaging; sparsity analysis

I. INTRODUCTION

The compressed sensing can be used for moving target detection (MTD) and radar imaging [1,2]. For MTD, the moving targets exist and the scene is sparse after clutter suppression by MTI processing, CS method can be chosen to reconstruct the locations of the moving targets.

Because the essence of 3D imaging is imaging on the contour of targets, the targets only have a few scatterers and is sparse in an azimuth-range resolution cell. Therefore, the CS theory can be introduced in 3D imaging.

The continuous scene signal is compressible. However, unlike optical image, both the raw data and image data of SAR are complex-valued. Due to the random phase of each scattering cell, the compressibility of the continuous scene can hardly be expressed. Using the multi-antenna observation structure SAR the random phase of each scattering cell can be eliminated. Therefore, the compressibility of continuous scene can be restored and bandwidth of complex-valued SAR image can be diminished. The decrease of the bandwidth means that the spatial sampling rate can be lowered. This conception can apply to not only the down-sampling of the 2D imaging, but also the down-sampling of 3D imaging by sampling sparsely on cross-track direction. When the signal spectrum is sparse, CS can be used for 3D imaging based on airborne cross-track sparse array side-looking SAR.

Some signal and data processing results about CS for sparse array radar application are presented in this paper.

Supported by National Science Foundation of China (61271422).

II. MTD BASED ON AIRSHIP LINEAR SPARSE ARRAY

Because the volume of the airship is really huge, it is possible to achieve real aperture stationary targets imaging and MTD using large size linear sparse array antenna, and the array antenna is mainly placed outside of the airship [3,4].

Consider an airship radar system working at height of 22km. And the subarray beam could scan to expand the swath. By the simulated annealing optimization algorithm, 28 subarrays (possessing 132 space positions) are used to obtain 263 equivalent phase centers. The subarray azimuth size is 0.6m, so the array length in azimuth direction is 79.2m.

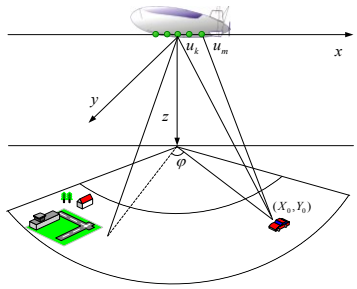


Figure 1. The signal model for airship linear sparse array radar

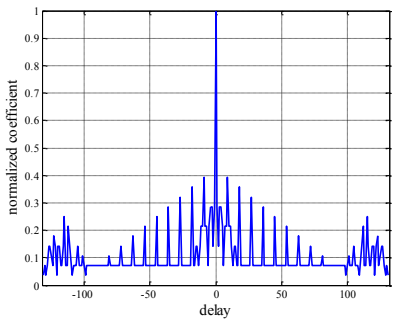


Figure 2. Correlation coefficient of linear sparse array

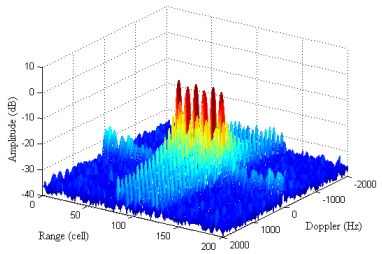


Figure 3. Range-Doppler signal before MTI

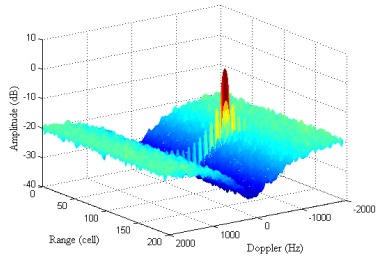


Figure 4. Range-Doppler signal after MTI

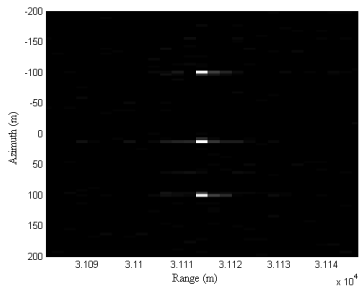


Figure 5. 3 moving targets CS reconstruction in same Range-Doppler cell

III. MTD Based on Airship Conformal Sparse Array

Based on the concept of conformal antenna, the sparse array antenna could be embedded in the body of the airship, becoming a part of the system. The stationary targets imaging can be achieved by back projection (BP) algorithm [5].

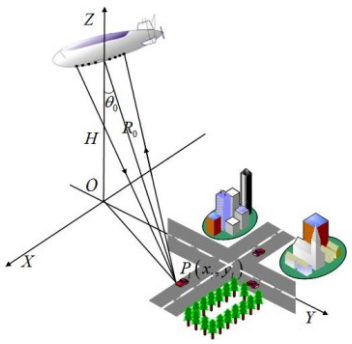


Figure 6. The signal model for airship conformal sparse array radar

Assume there are 9 stationary targets and 3 moving targets in the observation scene. Their relative locations are illustrated in Fig. 7.

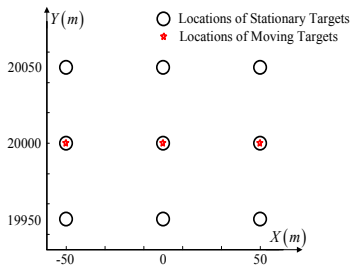
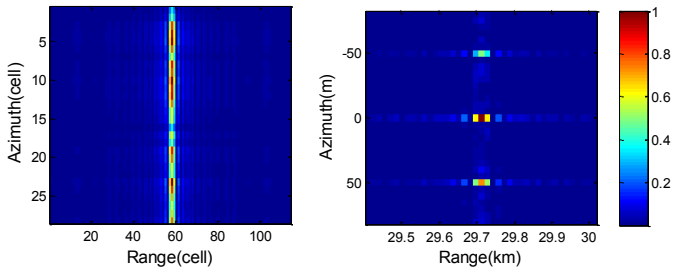


Figure 7. Relative locations of stationary targets and moving targets



(a) signal after MTI (b) CS reconstruction result

Figure 8. Moving targets detection results

For the range cell data, in which the moving targets exist, reconstruct the azimuth locations of the moving targets by the compressed sensing method. Fig. 6(b) shows the reconstruction result. The three moving targets can be exactly located.

IV. Side-looking 3D Imaging Based on Airborne Three-Aperture MMW SAR

Because the essence of 3D imaging is imaging on the contour of targets, the targets only have few scatterers and is sparse in an azimuth-range resolution cell. Therefore, the CS theory can be introduced in 3D imaging. The side-looking 3D imaging result are presented based on real data of an airborne cross-track three-aperture MMW SAR [6], developed by the Institute of Electronics, Chinese Academy of Sciences (IECAS).

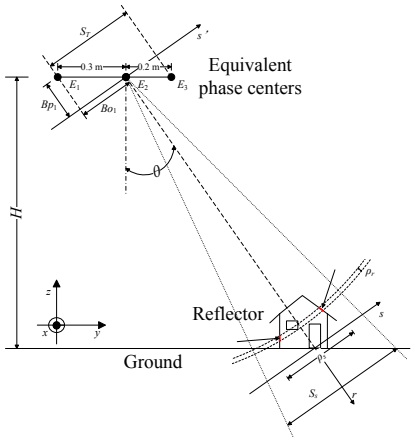
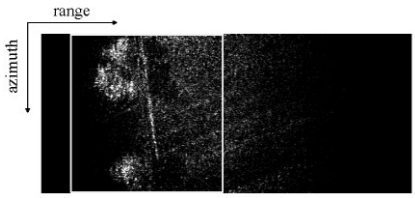
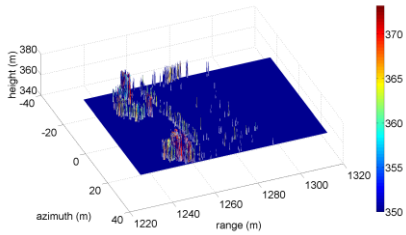


Figure 9. Side-looking 3D imaging geometry for airborne three-aperture MMW SAR



(a) signal after MTI



(b) CS reconstruction result

Figure 10. 2D image 3D results based on CS for real data

V. Side-looking 3D Imaging Based on Scene Sparse Spectrum for Airborne Cross-Track Sparse Array SAR

Due to the random phase of each scattering cell, the sparsity of SAR images is hard to express. Using the interferometry techniques to reconstruct the signal, the spectrum of SAR images becomes sparse which means that the spatial sampling rate can be lowered. Extend the reconstruction method to the 3D case, using multi-antenna observation structure in the cross-track direction, 3D SAR images can be achieved by only a few cross-track samplings. The result of a simulation is presented in Fig. 12.

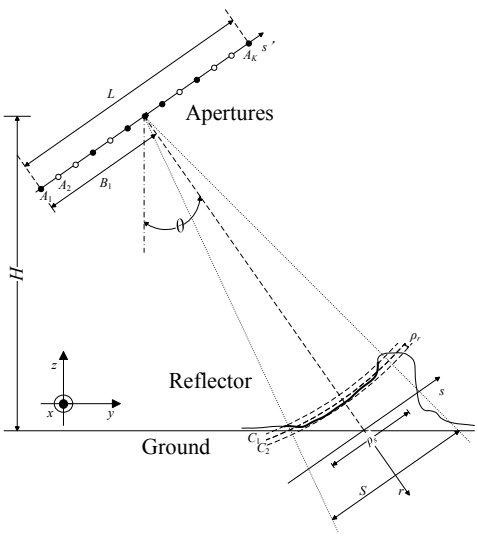
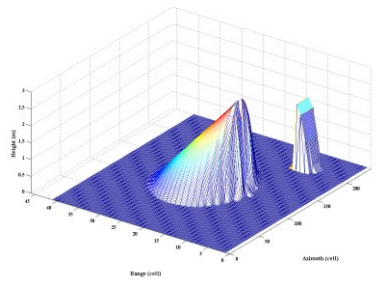
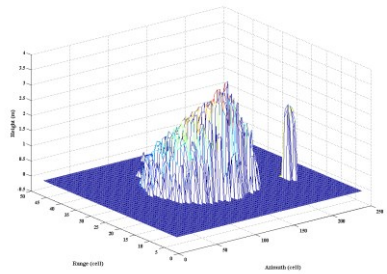


Figure 11. Side-looking 3D imaging geometry for airborne cross-track sparse array SAR

Fig. 12(a) is the simulated scene, the height of cone is 3m and the cylinder 2 m. Fig. 12(b) is the result based on CS. CS method reconstructs the scene exactly only using half of the sampling.



(a) simulated scene



(b) CS result with half sampling

Figure 12. 3D results based on signal reconstruction and CS

References

[1] D. Donoho, "Compressed sensing," IEEE Trans. Inf. Theory, vol. 52, pp. 5406-5425, 2006.

[2] M. Tello, P. López-Dekker and J. J. Mallorquí, "A novel strategy for radar imaging based on compressive sensing," IEEE Trans. Geosci. Remote Sensing, vol. 48, pp. 4285-4295, 2010.

[3] Y. N. Hou, D. J. Li and W. Hong, "Airship radar imaging for stationary and moving targets based on thinned array and code division signal," The 2nd Asia-Pacific Conference on Synthetic Aperture Radar (APSAR 2009). China, 2009.

[4] Y. N. Hou, D. J. Li and W. Hong, "Airship radar moving target imaging based on sparse array and compressed sensing theory," Progress in Natural Science, vol. 19(10), pp. 1110-1116, 2009.

[5] X. Teng and D. Li, "Stationary targets imaging and moving targets detection based on airship conformal sparse array," The 3rd Asia-Pacific Conference on Synthetic Aperture Radar (APSAR 2011), Seoul, Korea, pp. 396-399, 2011.

[6] L. Li, D. Li and Q. Zhang, "Three-aperture millimeter-wave SAR side-looking three-dimensional imaging based on compressed sensing," Jounal of Electronics and Information Technology, vol. 35, no. 3, pp. 552-558, March 2013.

[7] L. Li, D. Li, B. Liu, Q. Zhang and L. Wei, "Three-aperture inverse synthetic aperture radar moving targets imaging processing based on compressive sensing," in Instrumentation and Control Technology (ISICT), 2012 8th IEEE International Symposium on, , pp. 210 -214 , July 2012.

[8] Q. Zhang, D. Li and Liechen Li, "Research on continuous scene side-looking 3D imaging based on sparse array," Journal of Electronics and Information Technology, vol. 35, no. 5, pp. 1121 -1126, May 2013.