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Exploring Side Information for DVB-t-based Passive Radars

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***Abstract*— Passive radars based on DVB-t transmissions can benefit from the outstanding advantages that compressed sensing offers in terms of less acquired data, hence potentially reducing hardware requirements, and achieving reconstructed scene simplification. Adequate signal modeling enables sparse scene reconstructions which can be complemented with side information from previously known scene conditions and, thus, further reducing the amount of required data to achieve similar performances or even improve them.**

I. Introduction

NON-controlled, third-party transmitters can be used as opportunistic illuminators to perform moving target detection within the airspace with limited hardware and deployment costs. These passive radars receive and process the echoes from the targets without requiring a transmitter, limiting their exposure to enemy interception. The versatility of passive radars has been proven in multiple occasions for civilian applications: by using FM, GSM or terrestrial digital video broadcast (DVB-t) transmissions [1,2], moving targets can be spotted providing different performances and resolutions depending on the parameters of the selected transmission (e.g., channel bandwidth, carrier frequency). The amplitude range-Doppler (ARD) algorithm is based on the cross ambiguity function (matched filtering) and is commonly used to generate diagrams of the moving targets [3]. The authors of this work have demonstrated in a previous contribution [4] that random subsampling of the received signal combined with the perfect knowledge of the DVB-t pilot carrier structure transmitted by the illuminator can be exploited thanks to compressed sensing (CS) algorithms [5], achieving perfect target detection with $P_d = 1$ while minimizing the amount of required data to 0.1% of the original data volume (full Shannon-Nyquist rate [6]) even under low signal-to-noise ratio conditions.

II. Compressive Sensing and Side Information

Passive radar performances may suffer due to mild or severe clutter generated by the typically complex setups in urban areas. Clutter due to nearby or distant buildings, large manmade structures acting as unintentional reflectors, etc., may reduce the sparsity level of the scene which could have a negative impact in CS scene reconstructions. Scene clutter can be learned and incorporated in the CS minimization problem as side information. By having this a priori information, the solver can concentrate on finding a sparse solution rather than reconstructing the clutter —of no interest for this application.

Side information can also be exploited to provide the minimization solver with additional details about the contents

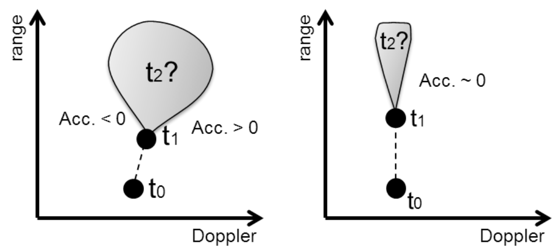

Figure 1: Example of range-Doppler diagram schemes. Left, an accelerating target is surveilled during timeframes t_0 and t_1. The area of interest for the CS solver will be restricted by the t_2 zone in grey which assumes that the target may increase, decrease or keep a constant acceleration. Right, a target with very low speed fluctuation (cruise speed) moves away from the receiver.

of the scene. The range to the surveilled target and its speed as seen from the passive receiver at a given instant —in the form of a range-Doppler pair— can be fed to the solver as additional information in the successive scene reconstructions (see Fig. 1). Knowing that a target is moving at a certain speed and distance, and assuming that this behavior will not change abruptly in the following reconstructions, the vast majority of the solutions for a newer detection can be discarded and only those within the foreseeable distance-speed evolutions can be reconstructed. This process is repeated for every timeframe with updated information. Moreover, certain reconstructions within the foreseeable options are more likely to happen, which introduces the idea of weighted side information [7]. Thanks to side information, the amount of data and computational power needed to reconstruct the surveilled scene (range-Doppler diagram) are reduced.

References

[1] Griffiths, H.D. & Baker, C.J.. (2005). Passive coherent location radar systems. Part 1: Performance prediction. Radar, *Sonar and Navigation*, IEE Proceedings

[2] H. D. Griffiths and C. J. Baker, "Measurement and analysis of ambiguity functions of passive radar transmissions," *IEEE International Radar Conference, 2005.*, 2005, pp. 321-325.

[3] D. Petri, C. Moscardini, M. Martorella, M. Conti, A. Capria and F. Berizzi, "Performance analysis of the batches algorithm for range-Doppler map formation in Passive Bistatic Radar," *IET International Conference on Radar Systems (Radar 2012)*, Glasgow, UK, 2012, pp. 1-4.

[4] E. Cristofani, O. Mahfoudia, M. Becquaert, X. Neyt, F. Horlin, N. Deligiannis, J. Stiens, and M. Vandewal. Compressive Sensing and DVB-T-Based Passive Coherent Location. In *26th URSI Benelux Forum*, Brussels, Belgium, 2017.

[5] D. Donoho, “Compressed sensing,” IEEE Trans. Inform. Theory, vol. 52, no. 4, pp. 1289-1306, Apr. 2006

[6] C. E. Shannon, “A Mathematical Theory of Communication,” The Bell System Technical Journal, Vol. 27, No. 3, 1948, pp. 379-423.

[7] H. Mansour and R. Saab, “Weighted one-norm minimization with inaccurate support estimates: Sharp analysis via the null-space property,” in IEEE Int. *Conf. on Acoustics, Speech and Signal Processing*, Brisbane, Australia, Apr. 2015