On the Target Detection in OFDM Passive Radar Using MUSIC and Compressive Sensing

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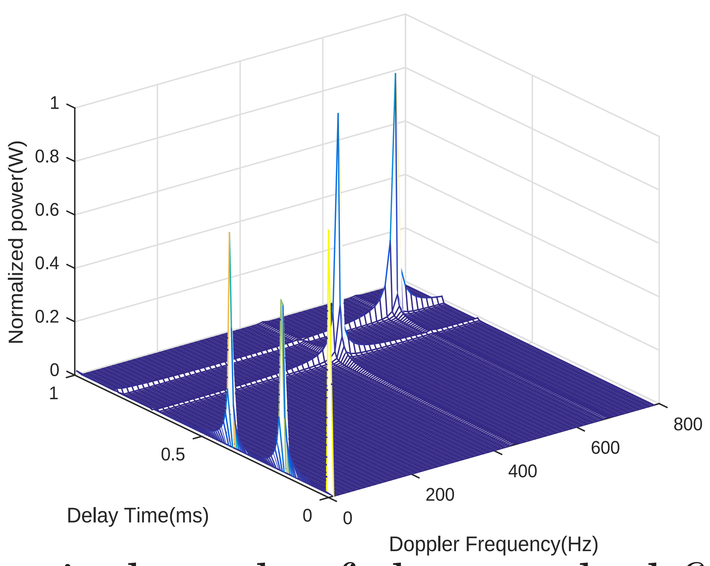
Introduction

- The passive radar, *a Green Radar*, exploits the commercial broadcasting signals as the sensing signals in bistatic configuration. It can be handled more economically than the conventional radars as there is no subsystem for signal transmission. Due to the operation of the transmitter of opportunity, the surveillance can be obscured. Their frequency diversities are able to provide the detection for low speed and low altitude targets.
- Wireless Internet and mobile communications are currently functioned with the Orthogonal Frequency Division Multiplexing (OFDM) signals, whose orthogonal characteristic between subcarriers is used to reduce the intersymbol interference and increase the bandwidth efficiency. The generation of the OFDM signals efficiently applies the Discrete Fourier Transform.
- This work proposes a single time sample as well as multiple time samples compressive sensing, l_1-SVD, for the target detection problem in the OFDM passive radar. The simulation results are also compared with 2-D MUSIC algorithm with multiple snapshots.

System and Problem Model

- The ith symbol of the transmitted OFDM signal is declared as
$$x_i(t) = \sum_{n=-\frac{N}{2}}^{\frac{N}{2}-1} s_i[n] e^{j2\pi n\Delta f t} q(t).$$
- The matched filter output can be effectively generated using a 2-D DFT of the channel estimates, which can be shown as
$$H_n^{(i)} \approx A_0 T |s[n]|^2 e^{j2\pi(ia_0 f_c T' - n\Delta f \tau_0)}.$$
- Using spatial smoothing technique, the channel estimates can be derived to
$$\mathbf{h}_{n',i'} = \sum_{p=1}^{N_p} A_p \mathbf{b}_{n',i'}(\hat{\tau}_p, \hat{a}_p),$$



Numerical result of the matched filter.

Target Detection Algorithm for OFDM Passive Radar

A. The MUSIC Algorithm The target detection problem for the passive radar is a 2-dimensional problem, which involves the Doppler frequency and time delay. The cost function of the 2-D MUSIC can be displayed as

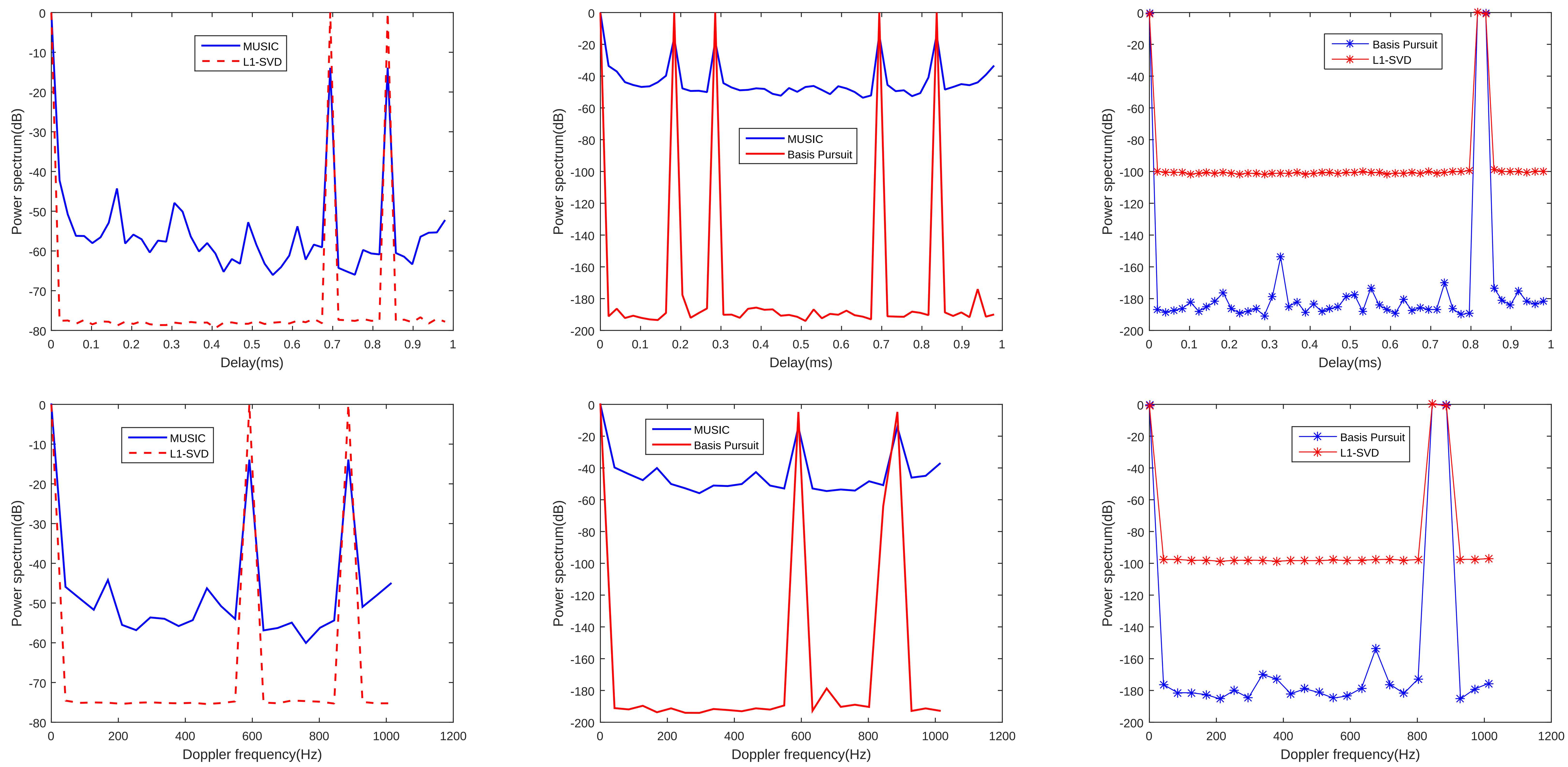
$$\begin{aligned} f_{MUSIC}(\hat{\tau}, \hat{a}) &= \left(|\mathbf{b}^H(\hat{\tau}, \hat{a}) \mathbf{E}_N|^2 \right)^{-1} \\ &= \left(N'L' - |\mathbf{b}^H(\hat{\tau}, \hat{a}) \mathbf{E}_S|^2 \right)^{-1}, \end{aligned}$$

B. Compressive Sensing The basic narrowband observation model can be expressed as
$$\mathbf{h}(t) = \mathbf{B}(\hat{\tau}, \hat{a})\mathbf{a}(t) + \mathbf{w}(t), \quad t \in \{t_1, \dots, t_M\}.$$

where M is the number of snapshots.

- (For a single time sample, $M = 1$) With the sparse representation of $\mathbf{a}$, this problem can be realized as l_1-norm reqularization in Basis Pursuit(BP) which is
$$\text{minimize} \ \ \|\mathbf{h} - \mathbf{Ba}\|_2^2 + \lambda \|\mathbf{a}\|_1,$$
where $\mathbf{B}$ is an overcomplete representation in terms of all possible delays and Doppler frequencies.
- (For multiple time samples) The cost function is
$$\min \|\mathbf{H}_{SV} - \mathbf{BA}_{SV}\|_f^2 + \lambda \|\tilde{\mathbf{a}}^{(l_2)}\|_1$$
where the Singular Value Decomposition (SVD) is applied to the matrix $\mathbf{H} = [\mathbf{h}(t_1), \dots, \mathbf{h}(t_M)]$. The objective is to decompose the matrix into the signal and noise subspaces. This algorithm deals with the reduced dimensions regarding the signal subspace only.

Simulations & Conclusion



The simulations show that all of the techniques applied in this work can provide satisfying target detection ability. One time sample basis pursuit presents low level of direct path interference as only one snapshot is included. l_1-svd, though combines as equal number of snapshots as the MUSIC, can display lower amount of direct path leakage. The algorithms can be extended to multiple transceivers system in the future work.