A signal sub-space based approach for mitigating wind turbine clutter in fast scanning weather radar

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***Abstract*—Removing turbine clutter from weather radar observations has become an essential problem in the community since wind turbine clutter signals (WTC) cannot be filtered using traditional clutter filtering. This paper addresses the problem of mitigation of WTC using knowledge of local precipitation and WTC signals to retain the maximum amount of precipitation and retrieve the filtered radar IQ data. The proposed algorithm uses the Generalized Likelihood Ratio Test (GLRT) to detect the range gates affected by WTC, and signal subspace estimation to mitigate the turbine clutter. The performances of the turbine clutter identification and suppression algorithms are also studied by a common evaluation technique of combining clear air wind turbine data and precipitation data.**

I. Introduction

Due to presence of both stationary and movable parts of wind turbines, WTC can be very difficult to distinguish from ground clutter or precipitation from standard weather maps like PPI (Plan Position Indicator). Standard clutter filters like Gaussian Model Adaptive Processing (GMAP) [1] filter or a standard zero Doppler notch filter [2] can be used for suppression of the returns from the stationary parts but cannot suppress the returns from blades of wind turbine produce echoes which are dynamic in nature and appear at non zero Doppler region in the power spectrum. Many of the previous researches depend on finding solutions for fixed pointing scans [3]. But these are not applicable for fast scanning radars where the time varying properties of WTC cannot be captured. Thus, WTC mitigation for the PPI scan strategy which are used for operational purposes for monitoring rapidly growing precipitation must be addressed. This paper addresses the wind turbine clutter mitigation solutions for fast scanning strategies. In this paper, a generalized likelihood ratio test (GLRT) is done for the detection of WTC which is similar to the ground clutter identification procedure proposed by Li et al.[4]. The clutter detection step is followed by the suppression step which is based on signal subspace estimation which is similar to sea clutter suppression as proposed by Sira et al. [5]. This algorithm is implemented on a data-set recorded by the CSU-CHILL radar. Finally, it is concluded that GLRT with the clutter sub-space estimation method gives better results.

II. WTC detection via Generalized Likelihood Ratio Test and suppression by signal subspace estimation

The proposed framework has an initial step of detection of turbine clutter range bins followed by precipitation estimation. In Step I, the detection process is done by using a Generalized Likelihood Ratio Test. Step II is the filtering process which is estimation of the precipitation field that involves estimation of signal subspace. A neighborhood around the clutter range bin is considered followed by estimation of the signal covariance matrix. It is then decomposed to find the eigen vectors that can span WTC or precipitation signal subspace depending on neighborhood under consideration.

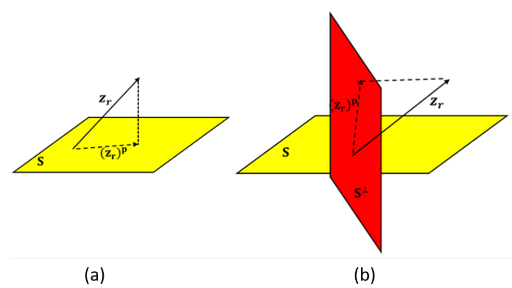
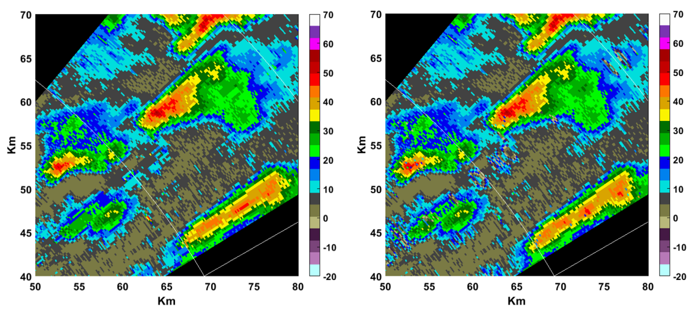


Fig. 1: Precipitation signal subspace shown in (a). WTC subspace shown in (b). Clutter suppression is done by projection onto the required subspace.

In the clutter neighborhood case, we either have only clutter signals or both clutter signals and very weak precipitation echoes. The clutter suppressed signal is given by the projection of the signal vector under consideration onto the subspace orthogonal to the turbine clutter subspace. Therefore, the subspace that provides suppression is shown as the red subspace in Fig.1(a). In case of precipitation neighborhood, the clutter vector is projected onto the signal subspace to find the equivalent precipitation signal vector corresponding to it which is the turbine clutter suppressed signal. The precipitation signal subspace is shown as the yellow subspace in Fig.1(b).The mixed neighbourhood considers presence of both strong turbine clutter and precipitation signal which can be solved either by one of the above two cases depending upon nature of the neighborhood.

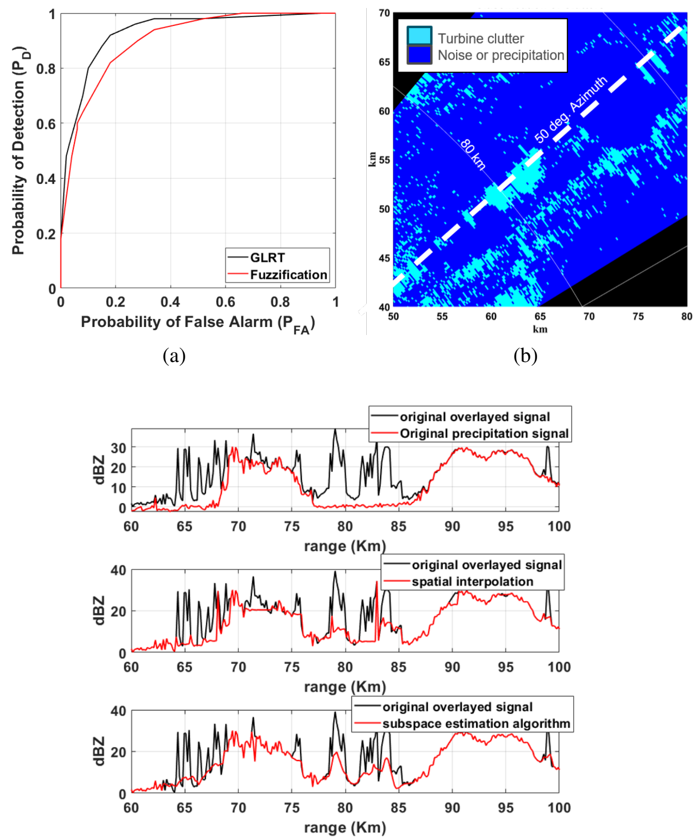
III. IMPLEMENTATION ON CSU-CHILL OBSERVATIONS

For evaluation, clear air PPI scan containing turbine signal was collected on 27th August 2018 at 21:11:51 UTC and overlaid over a precipitation scan. This superposition of data is similar to the method presented by Uysal et. al [6]. The results in Fig 2a and 2b show that both the filtering methods can effectively mitigate the clutter data. Fig. 3a shows that the GLRT has better WTC detection performance than fuzzy logic identification. Fig. 3c shows the profiles of overlaid precipitation with turbine clutter (black) and the WTC filtered (red) data respectively along 50 degree azimuth.The turbine clusters are located approximately around 65 to 70 km and 75 to 85 km respectively.The signal subspace estimation algorithm maintains profile continuity and gives better suppression.



(a) (b)

Fig. 2: PPI scans showing Reflectivity field of estimated precipitation after filtering using spatial interpolation (a) and using signal-clutter subspace estimation filter (b) respectively.



(a) (b) (c)

Fig. 3: ROC curve for performance analysis of WTC identification shown in (a). Classification field obtained using GTRT shown in (b). The white dotted line is the 50 deg. azimuth on which ray profile analysis has been done as shown in (c).

IV. SUMMARY

A solution for wind turbine clutter mitigation has been presented for fast scanning weather radars. For evaluation purposes, a coincident data set was created by overlaying a clear air turbine scan over a precipitation data set. The proposed algorithm using GLRT for WTC detection and signal subspace estimation for clutter suppression has been compared with a real-time WTC identification and mitigation [7] based on fuzzy logic inference and standard spatial interpolation techniques. The proposed algorithm has been observed to perform better than the standard WTC mitigation technique.

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