CAPON/APES BASED SAR PROCESSING: PRACTICAL CONSIDERATIONS

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1. INTRODUCTION

Traditionally, most research in SAR focusing algorithm has focused on the implementation of efficient and accurate approximations to a matched filter in range and azimuth, with some appropriate fixed tapering to mitigate range and azimuth side lobes. In order to somehow separate the compression in range and azimuth these algorithms need to deal with the range cell migration and with the fact that the azimuth phase history is range dependent. While efficient implementations of matched filter based SAR processors are still relevant in the context of batch-processing of large amounts of SAR data, the ever increasing available computing power should be taken as an invitation to explore alternative processing approaches.

Several authors have recognized that SAR focusing can be casted as a spectral estimation problem and that, therefore, a wide range of spectral estimation methods can be applied to it [1]. Of these methods, non-parametric adaptive methods such as Capon's Mimimum Variance Method [2] and APES seem some of the most promising approaches [1, 3, 4]. While other authors have focused primarily on the signal processing side of the problem, treating SAR focusing primarily as a nice application, this work studies the practical aspects and caveats of SAR focusing using these algorithms.

2. PROBLEM FORMULATION

Lets us consider the point-target response of a reference target, $p_0(t_r, t_a)$. The received signal for a target in the vicinity of this reference target, $z(t_r, t_a)$, is a slow- and fast-time delayed replica of the point target response. A matched-filter approach to process this received signal is to calculate its convolution with the time reversed conjugate of the point target response,

$$s(t_r, t_a) = z(t_r, t_a) * p_0^*(-t_r, -t_a). \quad (1)$$

In the frequency domain, the processed image is given by

$$S(f_r, f_a) = Z(f_r, f_a) \cdot P_0^*(f_r, f_a), \quad (2)$$

where $Z(f_r, f_a)$ and $P_0(f_r, f_a)$ are the 2-D Fourier transforms of the received signal and the point-target response. Since the received signal is a time delayed replica of $p_0(t_r, t_a)$, this can be rewritten as

$$S(f_r, f_a) = |P_0(f_r, f_a)|^2 \cdot a_1 \cdot e^{-j2\pi(t_{r,1}\cdot f_r + t_{a,1}\cdot f_a)}. \quad (3)$$

This resulting expression is that of a 2-D complex harmonic function in the frequency domain windowed by the spectral density function of the point-target response. Thus, the step of taking the inverse Fourier transform of (2) to obtain (1) can be considered as a the simplest implementation of a spectral estimator which may be replaceable by more sophisticated ones.

3. CAPON AND APES RATIONALE

Both APES and Capon algorithms construct a bank of adaptive band-pass FIR filters. In Capon's case, these filters are designed to minimize the output power of each one with the constraint that the filter must have unity gain at the selected frequency [2]. In the presence of a small number of dominant frequency components (or a small number of bright targets), the filters used to

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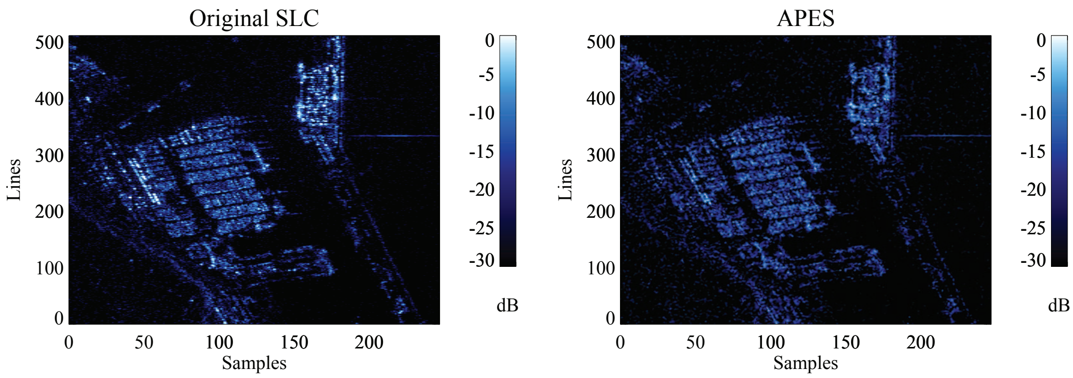

Fig. 1: Left: original RADARSAT-2 SLC image. Right: image reprocessed using APES algorithm.

estimate spectral components will tend to place nulls at those dominant frequencies. In contrast, the filters are allowed to have a large frequency response (or side lobes) at those frequencies at which there is little interfering signal. The apparent *resolution* increases because of the ability of the algorithm to place a null suppressing spectral spill-over from a nearby object. The power minimizing criterion results in a tendency to underestimate the spectral power. As a proposed solution, the APES estimator minimizes the mean squared difference between the filter output and the estimated harmonic component at each frequency [3].

4. IMPLEMENTATION

The processing chain implemented follows the chip-image processing scheme proposed in [1], extended to deal with multi-channel (interferometric, polarimetric) data sets. The processing uses focused Single Look Complex (SLC) data as input, and refocuses the data dividing it into relatively small rectangular regions. Thus, it is easy to select small regions of interest for reprocessing. The APES estimator has been implemented following the approach in [4], extended to the multichannel case.

5. RESULTS

First, the algorithms have been tested first on a wide range of simulated data. These simulation show that for scenes consisting of a limited number of point targets, APES and Capon offer a significantly improved resolution and outstanding side lobe rejection. In fact, the improvement in resolution can easily result in the apparent loss of targets if the output image is not sufficiently up-sampled. As the target density increases or the SNR decreases, both resolution and side lobe rejection degrade gracefully, approaching those of windowed matched filter implementations. This is because the impossibility to implement FIR filters that simultaneously suppress a very large number of targets.

This behavior is confirmed in the case of real SAR data. Refocused ERS-2 and RADARSAT-2 data shows significantly better defined scatterers in scenes corresponding to the Barcelona Harbor. Figure 1 shows a comparison of a region RADARSAT-2 SLC image (VV channel corresponding to a Fine Quad Polarization acquisition), and the same image reprocessed applying the APES algorithm. It can be observed how bright scatterers appear better resolved.

6. REFERENCES

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