Synthetic Aperture Radar for Search and Rescue: Polarimetry and Interferometry

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***Abstract*— The use of Synthetic Aperture Radar (SAR) provides an opportunity to assist Search and Rescue (SAR) in the location of downed airplanes in particular in the northern areas of Canada. This paper presents results of examining the detection of crashed aircraft targets using airborne SAR data. Considerations for decreasing the number of "false targets" using a combined polarimetric and interferometric analysis have been tested with results indicating a promising approach for target detection using these SAR techniques.**

Keywords* - *Synthetic Aperture Radar(SAR); Search and Rescue; Polarimetry; Interferometry

I. Introduction

Most of the Canadian landmass is sparsely populated and there are significant northern areas that are in darkness for prolonged periods. Airplane traffic has continued to increase and sadly, there are a number of plane crashes each year. Unfortunately, over the years, although they are improving, operation of Emergency Locator Transmitters on crashed aircraft has not shown the desired success rate [1]. The SAR sensor with all-weather operation has the potential to be an effective search tool for the location of downed airplanes in such circumstances. From the analysis of SAR imagery, it is hoped that potential locations of a crash can be identified so that a concentrated visual search can be made which will reduce search time, risks to Search and Rescue personnel, and costs.

This paper presents results of further studies examining the use of polarimetric C-Band SAR systems for the detection of crashed aircraft. Test data were acquired by the Environment Canada C-SAR in an experiment by Defence Research and Development Canada on the outskirts of Ottawa, Ontario in September, 2002 [2]. This sensor has also been used to obtain a series of images of this previously crashed aircraft target beginning in the spring of 2002 (e.g.[3]). The data have been processed to calibrated interferometric imagery at DRDC-O.

II. Principles

A crash can result in an airplane wreck in any possible configuration. According to the statistics for crashes of small aircraft, the dihedral structure of the tail section, which is often the most readily detected, is the part of the airplane most likely to survive a crash intact [4]. Previous studies have found that the backscatter from the dihedral reflectors can be well separated from that of the adjacent natural areas using polarimetric SAR imagery [3][4][5]. In the analyses carried out by the SAR[2] Project at NASA-GSFC and at CCRS, three methods for detection of targets in polarimetric data have been applied: Polarimetric Whitening Filter (PWF) [6], Cameron Decomposition [7] and Even Bounce analysis [8]. Each of these uses one aspect of the target backscattering characteristics. The PWF can be used to improve the discrimination of bright targets with a magnitude higher than a pre-defined threshold. Cameron Decomposition can be used in distinguishing the symmetric dihedral or narrow diplane reflector from other symmetric reflectors. Determination of the strength of "Even Bounce" interactions can be used to locate targets that result in two bounces on the surfaces of the target. Each of these methods is expected to produce "false targets". To decrease the number of "false targets", the logical AND ("$\cap$") operator can be applied to each image sample so that the target sample is identified as being the location of a potential target only when it is considered to be such by each method (Thus Target = PWF target $\cap$ Cameron target $\cap$ Even Bounce target)[3].

Earlier studies have shown that more than one image is generally required to indicate the presence of a downed aircraft e.g.[9]. The analysis of images acquired by a polarimetric system (as discussed above) employs images acquired at the same time in different polarizations. More than one image can also be obtained when using interferometric pairs acquired by flying of the sensor in repeat passes [9]. In this case, the interferometric coherence can be used to determine the location of non-changing targets: This coherence is expected to be lower for the terrain surrounding a target. The addition of interferometric coherence to the polarimetric analysis is expected to assist in screening out samples that do not correspond to detected targets. This should provide another means of minimizing the number of false targets [5].

Two independent modules are included in the flowchart (of Figure 1) describing the algorithm used in this study: Polarimetric analysis (POL) and inteferometric coherence analysis (INSARCOH). These two modules can be used jointly or independently based on the available input data. The POL module accepts fully polarimetric SAR data as input. The inputs to INSARCOH in this study are images with the same polarizations on transmit and receive (i.e. the HH or VV channels) from interferometric image pairs.

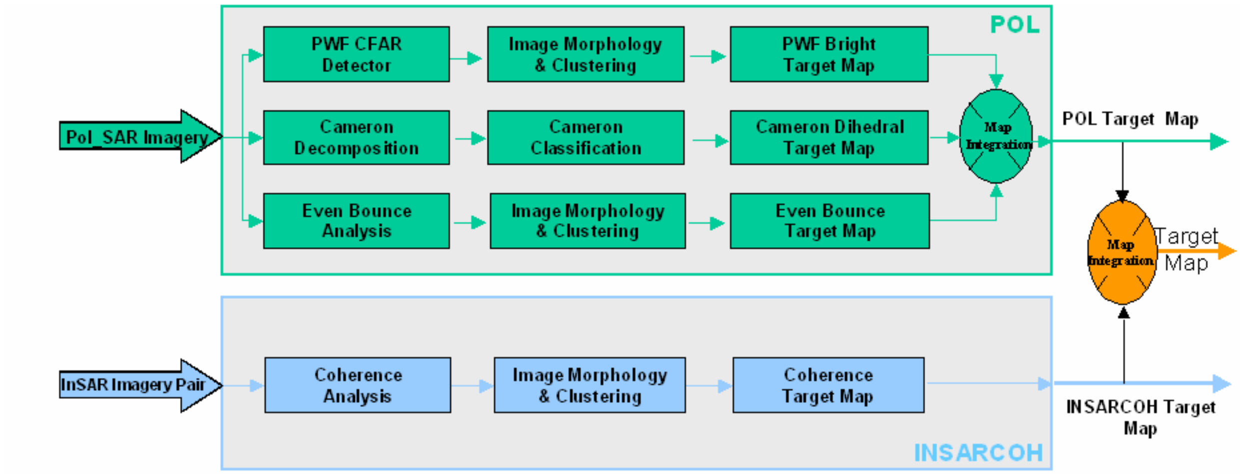


Figure 1. POL∩InSARCOH target detection algorithm flowchart

In analyzing the results for detection, it has been found that man-made as well as natural features can have similar SAR backscatter characteristics to those of a crashed airplane, usually corresponding to sizes larger than such a target. Other false targets can be seen as “spikes” in the radar imagery, but corresponding to fewer samples than would be expected for an airplane. Based on these observations, image morphology and clustering processes have also been employed in distinguishing these false targets from aircraft based on size.

III. EXPERIMENTAL DATA AND RESULTS

One repeat-pass interferometric imagery pair was acquired by the C-SAR on board the Convair-580 on September 24,

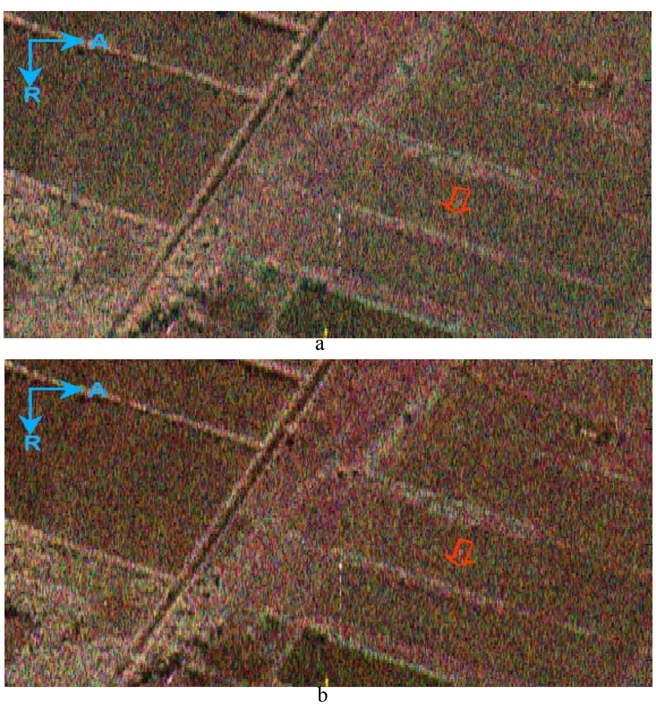


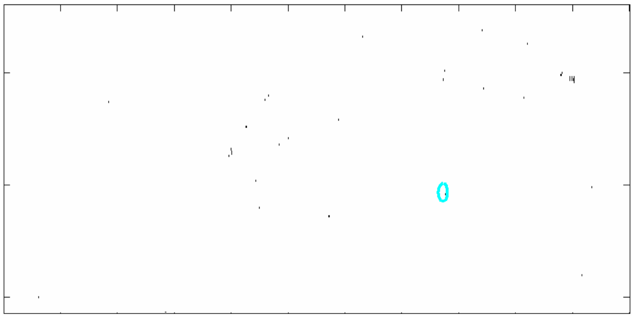
Figure 2. Ground-processed C-SAR interferometric imagery pair of Ottawa test field on September 24, 2002 (R:HH, G:VV, B:HV).The arrows indicates the “heading” of the plane(orange), range and azimuth directions (blue). (a) Line 1 Pass6. (b) Line 1 Pass 8.

2002 with accompanying ground-truth. Imaged targets included calibration targets and the previously crashed Cessna-172. The imagery pair from Line 1 Pass 6 and Line 1 Pass 8 is shown as Figure 2. The three polarizations are displayed as Red: HH, Green: VV, Blue. HV. Arrows indicate the directions of the range and azimuth (blue) and “heading” of the previously crashed aircraft (orange). The target was oriented in the True North direction which is over 60 degrees from the optimum heading for the radar to detect the dihedral structure of the tail [3].

The “POL Target Map” of each image from Polarimetric analysis and the “INSARCOH Target Map” from interferometric coherence analysis using both images are shown in Figure 3. Bright image samples that correspond to the locations of a dihedral or narrow diplane with high degree of Even Bounce are retained as possible locations of a crashed airplane on the “POL Target Map”; and image samples with high coherence are retained as possible locations of a crashed airplane on the “INSARCOH Target Map”. Blue ovals indicate the true location of the airplane.

All three of the target maps in Figure 3 show detection of the crashed aircraft within the blue ovals for nominal global parameters in the analysis. At the same time, the selection of parameters in the analysis has generated quite a few “false targets” in each case. These “false targets” could arise in two major ways: In the first of these, man-made targets are correctly identified, but these are not crashed aircraft. In the second, man-made targets are identified in the image where there are, in fact, no such targets. In a Search and Rescue scenario, this would require a visit by Search and Rescue personnel. By careful setting of the values of the parameters used in the algorithm (e.g. a higher threshold for the PWF), it is possible to decrease the number of “false targets” although this may occur at the risk of losing the “desired target” location.

It may thus be preferable to decrease the number of “false targets” by use of another technique. This type of “false target” can be largely decreased by the use of the combined algorithm because of the random nature of the backscatter from the clutter. The detection result using the combined algorithm is shown as Figure 4 and shows only the crashed aircraft inside



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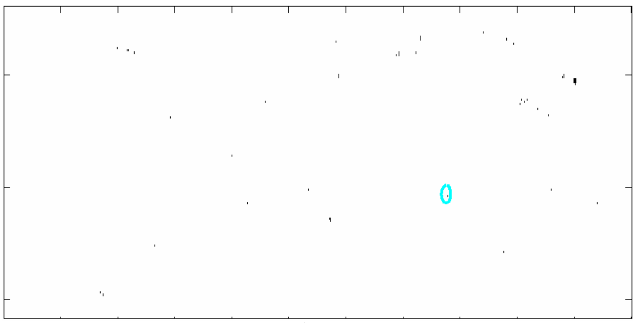
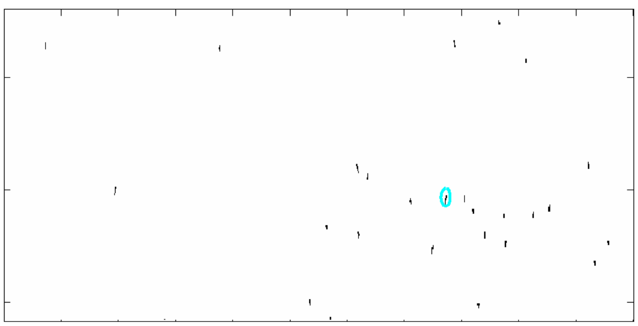


b



c

Figure 3. Target Maps. Blue ovals indicate the location of the crashed aircraft target. (a) Line 1 Pass 6 from POL. (b) Line 1 Pass 8 from POL. (c) Line 1 Pass 6 and 8 from INSARCOH.

the blue oval, with no other potential targets remaining on this target map. When compared to the number of detected potential targets in Figure 3, it is seen that this combination of methods of Figure 4 can be used for significant improvement to assist in the Search and Rescue task.

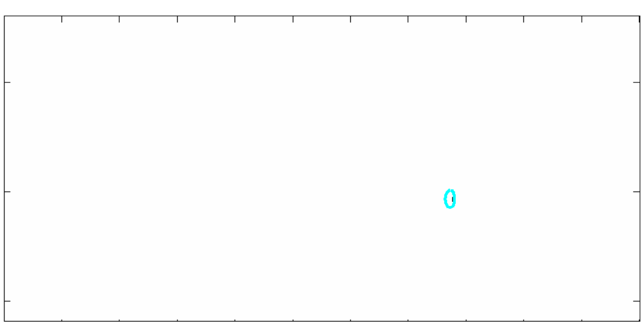


Figure 4. Combined Target Map from POL∩InSARCOH. Blue ovals indicate the location of the crashed aircraft target.

IV. Conclusions

The success of these studies (detection of crashed aircraft with minimal false alarms) continues to support the potential use of SAR systems for detection of crashed aircraft, to assist Search and Rescue in Canada, particularly in the northern regions of the country.

There will soon be an increase in available spaceborne SARs (such as RADARSAT-2) with more complex operating modes and better resolutions than to date. It is hoped that preparatory work such as this will show how such systems can be of assistance in improving the possibility of saving lives and mitigating the effects of aircraft crashes.

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