GEOSCIENCE APPLICATIONS WITH POLARIMETRIC SAR

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ABSTRACT

The development of phase preserving processors for radar data has led to the recent availability of polarimentric SAR imagery for geoscience applications. This has also generated the need for a new and updated “tool kit” for the application specialist to apply to the data for processing, information extraction, and displaying the results. This paper describes some of the new tools and techniques useful for the analysis of polarimetric SAR data and presents some results from the agriculture, forestry, geology, hydrology, ice, and ocean application areas.

INTRODUCTION AND BACKGROUND

For the past two decades SAR technology has been successfully applied to a wide range of applications. Notable successes have been reported in vegetation identification and land-cover mapping, soil moisture estimation and hydrological modeling, flood mapping, forest land mapping, ice identification and monitoring, sea surface state evaluation, oil spill monitoring, ship detection, geology mapping and mineral exploration, and stereo-mapping. The recent development of polarimetric SAR’s with phase preserving processors has added another dimension of information for the application scientist (Evans et al., 1988, Ulaby and Elacji, 1990).

The polarimetric SAR data (ie, both magnitude and phase for all linear polarizations) can be used to investigate the scattering mechanisms from a particular target which can then be used in signature studies or modelling efforts. Classification algorithms can also take advantage of the “different” information provided by the phase which can essentially be treated as additional channels available to the classifier. There are thus a number of new analysis techniques and tools available to help the scientist extract the relevant information from the SAR data. These methods of analysis have been reviewed by many authors including Zebker and Van Zyl (1991) and Boerner et al., (1995).

Several examples of how the phase can be used for various geoscience applications have been published in the literature and summarized by Boerner et al., (1995). In general the phase information adds to the dimensionality of the data set and therefore contains unique and useful information. However, the relative benefit and cost associated with fully polarimetric SAR systems has not been adequately investigated and will thus be the subject of future studies as new satellite and/or airborne radar sensors are planned and designed.

This paper will review the analysis tools and techniques used for extracting and displaying information from polarimetric SAR data. Examples will also be presented demonstrating how the phase can be used for geoscience applications in the fields of agriculture, hydrology, forestry, geology, ice reconnaissance, and oceans surveillance.

POLARIMETRIC ANALYSES TOOLS AND TECHNIQUES

One of the more commonly used analysis tools for polarimetric SAR data is the polarization signature graph. This is a three dimensional plot used to illustrate the polarimetric properties of terrain elements for either co- or cross-polarized radar returns. The following conventions are commonly used for these plots:

- the signatures are often normalized to the amplitude range of 0 to 1;
- the horizontal plotting axes are the elipticity angle and the inclination angle;
- the elipticity angle is defined over the range -45 degrees (right circularly polarized) to 45 degrees (left circularly polarized) with 0 degrees being linearly polarized;
- the inclination angle is defined over the range 0 to 180 degrees with those values corresponding to horizontally polarized waves and 90 degrees to vertically polarized waves.

Examples of polarization signature plots for a dihedral corner reflector and a rough surface are shown in Figure 1. Note that inspection of these plots can give a quick evaluation of the target's polarization dependence by evaluating the magnitude of the response as a function of the orientation angle. The height of the pedestal (as related to the ellipticity angle) also gives information about the degree of volume scattering and relative roughness of the terrain or target surface. The higher the pedestal the more volume scattering and the rougher the surface.

The polarimetric properties of various targets (both cultural and natural) can be described in terms of the values of and relations between a large number of parameters extracted or derived from the polarimetric data. Some of these parameters, generally called incoherent parameters) can be derived directly from polarization diversity and thus do not require the phase information. Others require the phase and are often referred to as coherent parameters. These are briefly described below with a full description and details available in Ulaby and Elachi, 1990 or Boerner at al., 1995).

The most familiar incoherent parameters are the radar cross sections and the normalized radar backscattering coefficient. These are often expressed for a particular linear polarization such as HH, VV, HV, etc. with the expression total power used to express the sum of all 4 linear polarization state values. These values can be ratioed as either cross-polarized or like-polarized values to generate additionally derived values, much the same as the approached developed to generate vegetation indices from visible and infra-red responses.

Coherent parameters use the phase information in their derivation and thus require fully polarimetric SAR data sets for their generation. Commonly cited parameters are the co- and cross-polarized phase difference (PPD) and the complex co-polarized correlation coefficient. An example of the co-polarization phase difference for a soyabean canopy versus a stubble field is presented in Figure 2. Note the narrow distribution of the PPD for the stubble field due to the dominance of surface scattering for this target. The plant canopy on the other hand creates multiple scattering and thus a broad distribution of the PPD. Once again the reader can refer to the literature cited for a more detailed discussion of the use of coherent parameters for polarimetric data analysis.

Techniques such as polarization contrast optimization and the use of a polarimetric matched filter can also be used for class recognition and the subsequent classification of polarimetric SAR data. These approaches optimize the dimensionality of the polarimetric responses for efficient class recognition and have been successfully applied to primary cover classifications. The polarimetric matched filter approach was used to generate the classification of the familiar San Francisco Bay scene shown in Figure 3. This approach maximizes the dimensionality of the polarimetric information for an efficient approach to class recognition. Another approach is to use the phase information as additional elements in a multi-dimensional classification to increase the information available to the classifier. This approach was used by Foody et al., (1994) with the results summarized in Table 1. Most studies reported to date have demonstrated that there is additional information in the phase channels but the relative value of this information is not as well understood.

APPLICATIONS REVIEW

Due to the lack of space a review of the applications will not be included in the text of this paper but will be presented at the meeting. In general the research has demonstrated that polarimetric SAR data contains additional useful information about the radar response of both cultural and natural targets. The value of this information with respect to the engineering costs for sensor design and development versus the benefit of the derived information will be the subject of future investigations. A detailed review of geoscience applications of polarimetric SAR data can be found in Boerner et al., (1995).