

## Projection Pursuit Classification Methods Applied to Multiband Polarimetric SAR Imagery

Dennis B. TRIZNA, Charles Bachmann, Mark Sletten,  
Nick Allan  
Naval Research Laboratory, Code 7255  
4555 Overlook Avenue  
Washington, DC 20375  
USA  
tel: 202-404-7891  
fax: 202-767-3303  
e-mail: [triznad@ccf.nrl.navy.mil](mailto:triznad@ccf.nrl.navy.mil)

Jakov Topokov  
Sachs Freeman, Inc.  
Largo, MD

Raymond Harris  
Metrotek, Inc  
Fairfax, VA  
(703) 293-9040

**ABSTRACT** -- Results are presented for an experiment utilizing land calibration targets imaged by the NRL ultrawideband synthetic aperture radar (NUWSAR). Projection Pursuit statistical analysis tools were applied to a set of simultaneous L and X-band polarimetric images of dihedrals and trihedrals to determine optimal and minimal combinations of polarization and radar bands for identifying different scatterers. The normalized mutual information function (NMIF) was used as a quantitative optimization measure. It was calculated for a series of combinations of frequencies and polarizations, beginning with the maximum set of all six elements (HH, VV, and HV for each of X and L-bands), then continuing with successive elimination of single elements, then pairs, and so on. In principle, this will produce 6! (or 720) of such combinations. To illustrate the principle, only a subset of element combinations were eliminated, and it became clear that the NMIF decreases rapidly as one goes beyond 2 members. Results presented suggest that a 'spectral' display of these NMIF results correlates with scale size and shape of targets, and that different types of targets in the scene display a robust NMIF spectral signature. This leads one to hypothesize that such an approach may lead to NMIF library signatures for classification of natural and man made targets similar to the way optical hyperspectral library signatures are utilized, but using microwave radar band and polarization combinations instead.

### INTRODUCTION

The Naval UltraWideband Synthetic Aperture Radar (NUWSAR) is a new synthetic aperture radar system under development by the Office of Naval Research (ONR) for ocean and land remote sensing research. Several features enhance its operation: (1) pulse-to-pulse multi-channel operation, allows interleaving combinations of radar frequency and polarization; (2) small package, deployment capability on either a P3, light aircraft, or UAV; (3) 1.2 to sub-meter spatial resolution; (4) >40 MByte/s data recording speed; and (5) full motion compensation using a Litton LN100G INS system.

The NUWSAR antenna system design and layout for a Piper Navaho aircraft is shown in Figure 1. One dual polarized L-band and a set of three 3-15 GHz antennas is shown, mounted in the doorway behind a fiberglass skin.

The two lower antennas are elements used for along-track interferometric data; the upper right antenna is use for cross track INSAR operation, and the lower right antenna is used for transmission for all cases. We discuss here polarimetric data collected with both X and L band, switched pulse-to-pulse, and is effectively simultaneous after SAR processing.



*Figure 1. Polarimetric antennas for AT & CT INSAR work, with LN100G INS mounted below, on light aircraft.*

### Projection Pursuit Methodologies:

Projection Pursuit (PP) methods are powerful techniques for extracting statistically significant features from remote sensing data for automatic target detection and classification. Remote sensing applications, especially those related to the analysis of imagery, are typically characterized by a very high number of effective dimensions. PP techniques automatically determine the low-dimensional projections of such data sets that best highlight any inherent structure or clustering, which can then be used to detect and classify the targets or clutter associated with it. Principal Component Analysis represents one member or subset of this more general PP family (Bachman & Donato, 1999). PP analysis was applied to the polarimetric images of Figure 2 below for this work, and additional imagery will

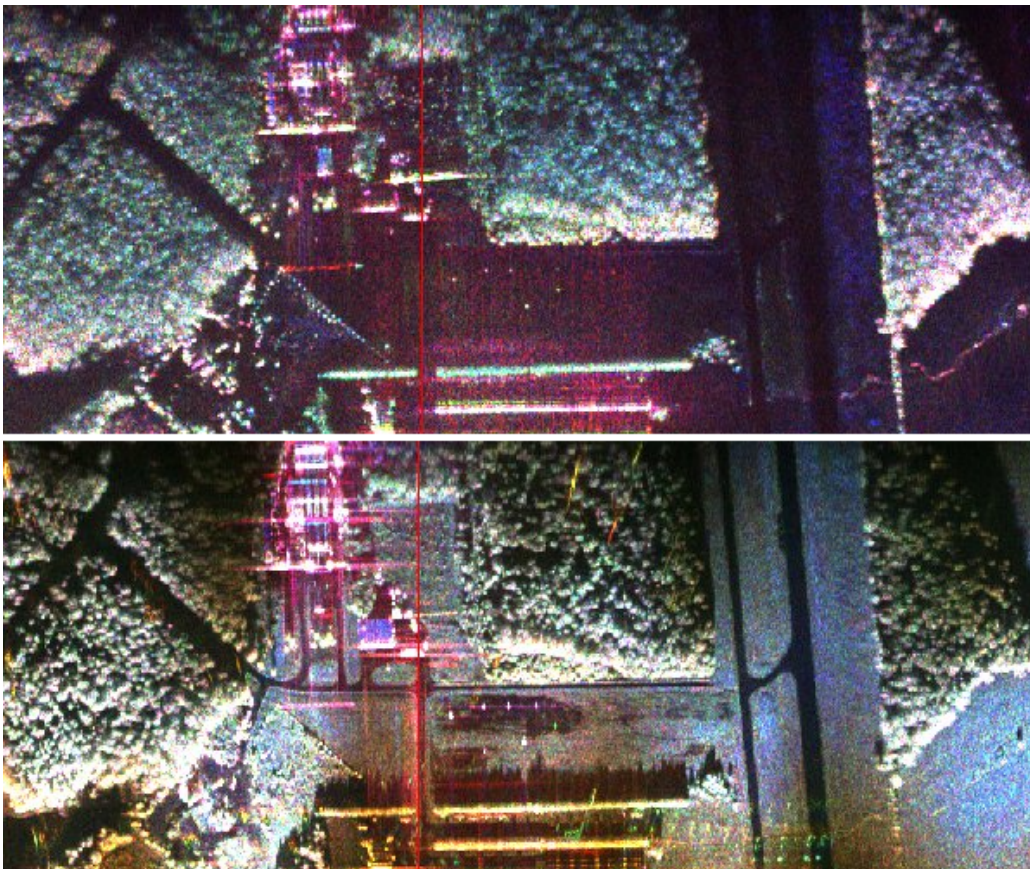


Figure 2. Warrenton VA Airport is shown for L and X-band polarimetric RGB images (HH/HV/VV) at 1.2-m resolution; calibration targets lie in the ellipse in the image center. Note the L-band green tree color, indication strong HV relative power, suggesting double bounce scatter from tree limbs and penetration of the foliage.

be analyzed for presentation at IGARSS'00. Here we demonstrate the principles of our analysis, as applied manmade targets, with the calibration targets seen in a row in the middle of the image.

Targets included three trihedrals in the far left of the line, a dihedral to the far right aligned vertically, and a dihedral to the lower right (green color) aligned at  $45^\circ$ . Another trihedral completes the group at lower center. All are located in a clear clay surface area, accounting for the dark ellipsoid, with low grass providing the surrounding color. A rather small wooden peg showed up as a strong echo, and is located to the left of the last trihedral identified, just out of the grassy area, and will be discussed later. Deciduous trees dominate the scene, with a line of pine trees just above the road bounding the targets from above. The brightest line across the very bottom are metal airplane hangars, and the second line just above is a tree line, the shadows of which can be seen above them at X band. A few aircraft can be distinguished in a row between the hangars and the tree line. A small moving van sits to the lower right of the hangar. A creek runs diagonally in the lower right corner, most strongly observed in the L-band image. The inverted-V line of spots lower left of center in each image are evidence of an aluminum road safety rail, the metal

anchors into the ground providing the strong echoes, with virtually no echo little coming from the horizontal rails. It is particularly strong at L-band.

A projection pursuit analysis was run on the data, using the first three targets on the left training as a training set. The polarimetric RCS properties of the cal targets were then applied to a variety of other man made targets in the scene. The analysis consisted of calculating the mutual information function, first using all six image planes of data ( $L_{hh}$ ,  $L_{hv}$ ,  $L_{vv}$ ,  $X_{hh}$ ,  $X_{hv}$ ,  $X_{vv}$ ,). In the training set, one defines a set of categories,  $y$ , and the SAR power values or gray level in each pixel as  $x$ , and the joint probability of category and gray level as  $P(x|y)$ , then the entropy is defined as

$$H(x|y) = -\sum_i P_{ij} \ln (P_{ij}/P_{*j}) \quad (1)$$

Correspondingly, the mutual information function (MIF) is defined as:

$$U(y|x) = [H(y) - H(y|x)]/H(y) \quad (2)$$

This quantity was calculated over all six planes of data, (labeled as  $L_{123}X_{123}$ , where 1,2,3 refers to HH, HV, VV), then again with single polarizations dropped, creating a set of six new MIF values, then again dropping polarizations in various combinations. Results are shown in Figure 3 below.

The corner reflectors show a strong MIF for all six planes of data, as seen in the first data point, as well as the next three combinations which drop out Lhh, then Lhh and Lhv, and finally all three L-band polarizations. As confirmed by their weak returns in the L-band RGB display, they do not provide as much information as do each of the 3 X-band planes. The 5<sup>th</sup>-7<sup>th</sup> MIF values keeps all L-band planes, but drop out Xhh,

Xhv, and Xvv in succession, and the MIF drops in each case. The 8<sup>th</sup> MIF drops both X and L VV

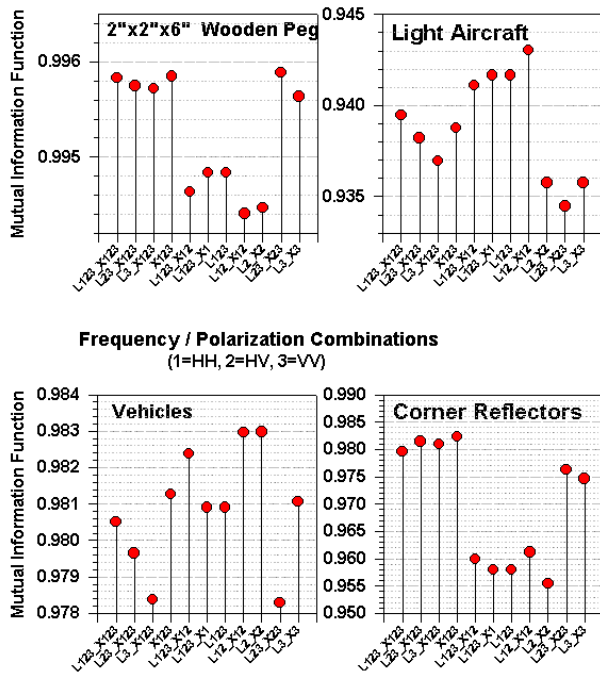


Figure 3. The mutual information function is plotted for different combinations of polarization and frequency image planes, left-most using all 6 (L&X, hh, hv, vv for each).

image planes, and the 9<sup>th</sup> consists only of HV for both X and L. All of these MIF values are smaller than those using all X-band planes. An interesting result is seen for the 10<sup>th</sup> and 11<sup>th</sup> MIF values that drop first both L and X HH planes, then the HV. Note that these analyses used a 4x4 matrix of data surrounding the targets, so that the local texture was also accounted for. This will be important in scene classification with similar single pixel RCS's, but with different area characteristics.

This type of analysis was repeated for an additional three different types of targets: a wooden peg, the light aircraft identified earlier, and the two vehicles. The peg has a MIF response for this set of image combinations remarkably similar to the corner reflectors, in part due to the similar texture. Conversely, the MIF sets are quite different for the light aircraft and the vehicles in the scene.

With such a characterization, one could consider this analysis as equivalent to a spectral analysis, in effect. We did not analyze any other combinations, up to 6! being available, which might be considered equivalent to broadening the spectral bandwidth. One might find, for example, that the wooden peg might in fact be differentiated from the calibration targets were this done. Nonetheless, this appears to be a powerful tool for assisted target and scene classification. This methodology will be applied to attempt to do scene classification of the natural cover, including tree

types, grass, etc. These more comprehensive results, including additional imagery will be presented at the oral session, and published in a more comprehensive article.

## SUMMARY

We have applied Projection Pursuit analysis to multiband polarimetric radar data, using only the RCS characteristics from one band-polarization image plane to the next for a set of man-made targets. Land classification results will be presented at the IGGARSS session.

## REFERENCES

1. Bachmann, C. M. and T. F. Donato, 1999. Mixtures of Projection Pursuit Models: An Automated Approach to Land-Cover Classification in Landsat Thematic Mapper Imagery. Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS99), Hamburg, Germany, June 28-July 2, 1999, pp. 339-341.
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