A Synoptic Visualisation of Fully Polarimetric SAR Data - An Annotated Example

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Abstract— **This paper explores an example SAR data set that has been displayed using a new method of visualising polarimetric data. It is based on an iconic representation of information within a pixel, which allows for the complete polarisation response to be viewed simultaneously across the image. An example from a test site in Sweden is presented, with a detailed description of how such an image can be interpreted. This will be through particular examples of polarimetric responses correlated with features in the landscape.**

Index Terms—**Polarimetry, Visualisation, SAR, Forestry**

I. Introduction

Research spanning the last two decades has shown that radar polarimetry can provide unique information on the shape and distribution of scattering elements within a resolution element. Such information is of potential value to a variety of earth science applications, including geological and ice mapping [1], and in particular forestry and agriculture [2].

Applications of polarimetry have had limited success, and it is clear that some of the limiting factors on its widespread use are the complexity of the data analysis and the inability to successfully visualise polarimetric data in a synoptic (overall) manner. In particular, the mode of data collection (which measures amplitude and phase values), and subsequent synthesis, means that large volumes of data are produced. Such data cannot be adequately represented by one value per pixel. Furthermore, the polarimetric response patterns are difficult to understand by those outside the radar community.

To overcome these difficulties, it is necessary to develop new means of visualising polarimetric data in order to provide an objective and intuitive overview. Such techniques allow large volumes of data to be processed visually by a human observer. This in turn should provide a better understanding of the relationships between polarimetric variables, which can be used to inform the development of models and/or classification strategies. Additionally, it is hoped that such images can be used to help explain the information contained within polarimetric data to a wider audience, thus aiding the development of applications.

The objective of the present research is to describe an example data set visualised using a new technique based on an iconic representation of polarimetric response patterns. This focuses on the re-projection of the polarisation response graph, so that qualities such as ellipticity and orientation can be deduced without the need for an axis. The details of the method are described in [4] and [6]. This representation is then used to generate icons in place of pixels, providing a synoptic overview of the co- and cross-polarised responses, which can be used to visualise variations in response patterns across large areas. Subsequent analysis of such images should improve the understanding of polarimetric datasets, as the distribution of different types of response patterns can be linked to the phenomenolgical patterns within the landscape. This represents an improvement over the analysis of traditional response graphs, which are predominantly single graphs derived from individual pixels or spatial averages.

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II. A Synoptic Approach

The iconic representation is created by first producing a 20x20 pixel image of the normalised polar-projected polarimetric response globe for the co- and cross-pol data for each pixel within the original image. An example of the resulting cross-pol image is shown in Figure 1(a). Note that we also resample the data onto a hexagonal grid. This provides a more "readable" image that is not dominated by the pixel grid when viewed in detail.

Two span (total power) images are also produced — the first span image is resampled so that each pixel is enlarged to 20 square pixels, whereas the second is similar but with zero values for the areas occupied by the polarimetric response globes. An example of the first span image is given in Figure 1(b).

Three of these four images are then combined as an RGB colour composite — the optimum combination depending upon the particular application at hand. Using the first span image produces an image which is dominated by the background intensity, and is useful in terms of overall image characteristics. The second image, however, allows for a more detailed analysis of the polarimetric response patterns.

III. An Example

A portion of an example image is shown in Figure 1. It is taken from a L-band airborne EMISAR image taken as part of the Nopex campaign in 1995 [5]. This particular subset was chosen as it demonstrates a variety of response patterns over a small area, particularly between forested and clear-cut areas. A key which gives the idealised response patterns for the interactions discussed in the text is shown in figure 3. The clearcut area can be clearly distinguished from the forested area due to lower total backscatter values. Only the cross-polarised polarimetric response is shown in Figure 1(a) as it exhibits greater visual contrast between response types, and is therefore easier

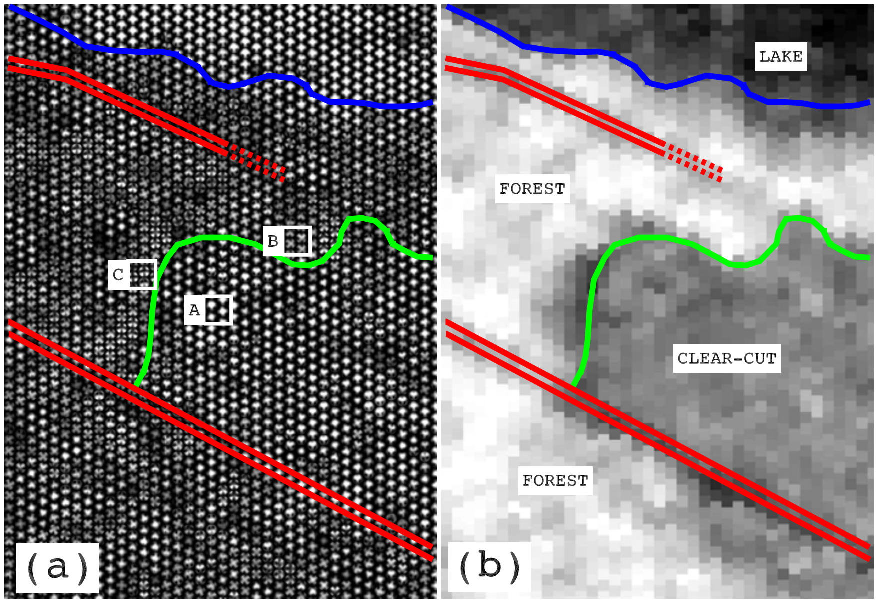

Fig. 1. Variation in polarimetric response for different land cover types.

(a) Iconic representation of the cross-polarised response patterns over Siggefora example area. (b) Span image of the same area showing the relative backscattered power for each of the land cover types.

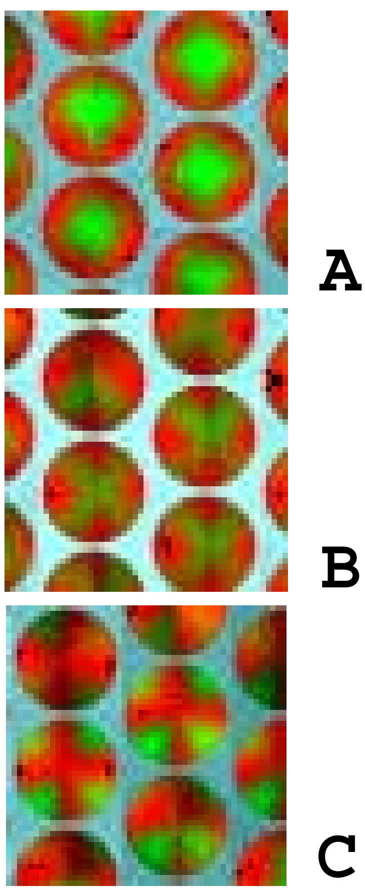

Fig. 2. Distinctive polarimetric response patterns for areas given in figure 1(a). Red = co-pole response. Green = cross-polarised response Background = relative intensity

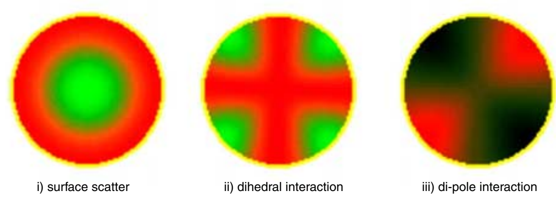

Fig. 3. Idealised response patterns for three interaction types as referred to in figure 2.

to "read" when unfamiliar with the colour composite representation.

It is immediately apparent that the polarimetric response patterns do exhibit a degree of spatial correlation. This is very distinct for the clear-cut area where the dominant response is similar to that found across the lake i.e. it is dominated by surface scattering which appear as symmetric icons with a bright circular centre. This can be seen more clearly in figure 2(A), in which the cross-polarised response (in green) is overlain by the co-polarised response (in red), both of which are then added to a grey scale background image.

Within the forested area, the variability of polarimetric response patterns is far greater. This is to be expected, as the incoming radar wave will interact with and propagate through several different layers before being backscattered. However, several interesting patterns are apparent. For example, figure 2(B) correlates with an area that exhibits high backscatter in the span image, and a polarimetric response pattern that suggests interaction with horizontal and vertical dipoles [3]. Such a polarimetric response is typical for the kind of coniferous forest found in this area, and is related to the interactions with branches, trunks and ground. However, what is more interesting is that these double-dipole responses appear in “clusters” throughout the forested region, rather than forming a uniform area of identical responses. These clusters are only weakly correlated with the intensity image, implying that there is useful information in the spatial patterning of the polarimetric response.

A further notable feature that is apparent in the imagery is that there are also clusters of pixels exhibiting a dihedral-type response, as can be seen in figure 2(C). This might be expected for a forest imaged at L-band, whereby we should have some penetration through the canopy resulting in a trunk-ground interaction, but the intensity of the response may not be large enough to be observed above the dominant canopy signal. However, many of these dihedral responses occur along the “shadow-edge” of the forest/clearing boundary (the image being illuminated from the left). Usually such areas are considered to contain little in the way of useful information, but in this case the extra slant range path length between crown and ground results in the ground-trunk scattering being located within the shadow area. The lack of crown scattering in this region results in the trunk-ground scattering being dominant. This is apparent in a number of locations along the shadowed edge of the forest.

IV. Conclusions

The iconic representation presented here has great potential for visualising multi-dimensional remotely sensed data sets. The example discussed illustrates how the method can be used to view spatial correlations in the polarimetric response, something that is not possible using traditional visualisation methods. This synoptic view allows the data to be explored in a more straightforward manner and patterns that are not apparent in the intensity data are visible within the polarimetric response. We hope that such visualisations will encourage exploration and explanation of these patterns, thus promoting a deeper and wider understanding of polarimetric SAR data.

Future research will consider how to optimise this technique for forestry applications, and potentially to include multi-frequency responses.

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