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# A FIRST TEST ON PERMITTIVITY INVERSION OF A DOUBLE BOUNCE IN A SAR IMAGE

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## ABSTRACT

We study the possibility of extending a ratio method developed for real aperture radar to be used in a SAR, that can retrieve complex permittivities from a double bounce. We include the technical hurdles in the extension and then present the first results of a test using Airborne X-band data obtained by ONERA.

*Index Terms*— SAR, Double bounce, Permittivity

## 1. INTRODUCTION

THE sensitivity of microwave scattering to the dielectric properties and the geometric structure of surfaces makes radar remote sensing both a powerful tool and at the same time a challenge to solve the inverse scattering problem, and moreover, recovering surface parameters from remote sensing data (far field measurements) has been of vital importance for many applications. For a specular surface, analytical inversion of permittivity is possible by using specific configurations such as the pseudo-Brewster angle or in general by using the co-polarized Fresnel coefficients [1]. The available comprehensive theory of electromagnetic wave scattering from random rough surfaces are based on integral equations themselves and hence the inverse multipath scattering problems are without doubt highly non-linear. For a polarimetric real aperture radar, permittivity inversion of a double bounce caused by a perfect dihedral has been extensively studied in [2, 3, 4] while assuming specular reflection at each surface.

Since recent decades, Synthetic Aperture Radar (SAR) polarimetric data-sets are being widely available and are being used in the detection and classification of urban areas. The double bounce is a prominent feature available in almost all polarimetric SAR image decompositions and is widely present in the vicinity of both natural and man-made structures where the principal geometry of a resolution cell can be approximated by a dihedral which causes a strong backscatter. Hence, we present here an interesting first test, in an attempt to extend the validity of the inversion method proposed in [2], to double bounces in SAR images using X-band Airborne data from SETHI-ONERA.

## 2. THE RATIO METHOD

It is very convenient to use the ratio method developed upon the work of [2] since considering the ratio  $\rho$  as following removes the dependencies on fine calibration requirements in measurements,

$$\rho(\phi, \epsilon_1, \epsilon_2) := \frac{R_{Vv}^{DB}}{R_{Hh}^{DB}} \approx \frac{\sqrt{\sigma_{Vv}}}{\sqrt{\sigma_{Hh}}} \quad (1)$$

where  $\phi$  is the incident angle and  $\epsilon_1, \epsilon_2$  correspond to the complex permittivities of the surfaces. Hence, very accurate co-registered (sub-pixellic) polarimetric data from two incidence angles are needed as measurements. Furthermore the extension of the ratio method to a double bounce in a SAR image can be justified by using the radar cross-section of a wall-ground structure modelled as a dielectric corner reflector as mentioned in [5]. The inversion can be summarized as follows;

1. Using co-registered SLC (Single Look Complex) data for two incidence angles, calculate  $\rho_1, \rho_2$  for pixels that pass a double bounce criteria.
2. Inversion using the ratio method to obtain solution pairs  $\{\epsilon_1, \epsilon_2\}$ .
3. In order to be interpretable, filter the solutions using the following criteria,

$$\epsilon_1, \epsilon_2 \in \{\epsilon \in \mathbb{C} \mid [1 < Re(\epsilon)] \ \& \ [Im(\epsilon) < 0]\}$$

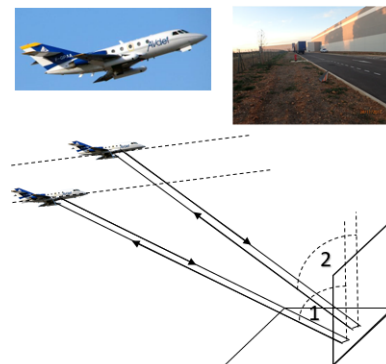


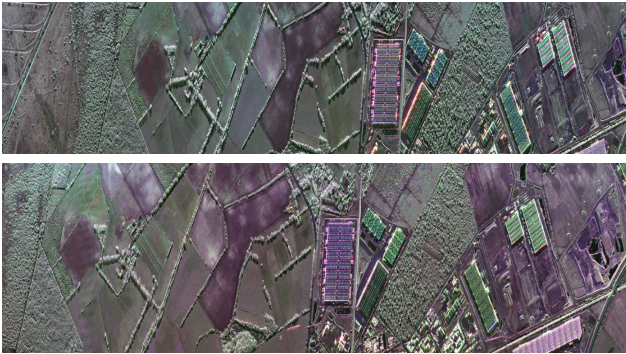
Fig. 1. Acquisition geometry

### 3. THE DATA SET

Since the ratio method requires data from two acquisitions (Fig.1) with different incidence angles and two polarizations Hh and Vv, we have identified a data-set meeting these conditions from an acquisition campaign done by SETHI-ONERA [6]. The data-set had been acquired over Saint Martin de Crau, France. They were acquired with two look angles of 45° and 60° in a full polarimetric mode at X band.

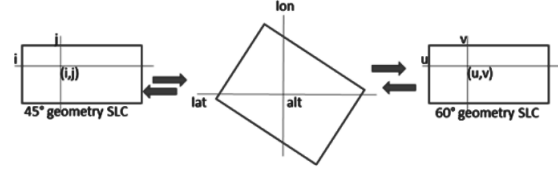
Accurate geolocation is of vital importance since we're working with two incidence angles of the same double bounce and the SLC images should be well co-registered. Accurate geolocation of SAR images for azimuth axis depends on the trajectory measurement accuracy, the quality of the inertial measurement unit and on its data post-processing. Along the slant range axis, geolocation also depends on the internal radar electronic delay estimation. To estimate accurately the electronic delays, the difference of location between the GPS ground measurement of a corner reflector and its position in the SAR image had been calculated. Then the electronic delay had been tuned to correct the miss-location.

For the two data-sets acquired with different incidence angles, we use the same corner reflector for geolocation purpose. Taking into account all these factors, the data had been re-processed to improve the geolocation and the resolution. The resolution for these images is 0.20m in range and 0.50m in azimuth with a pixel size of 0.15m and 0.4m in range and azimuth respectively.



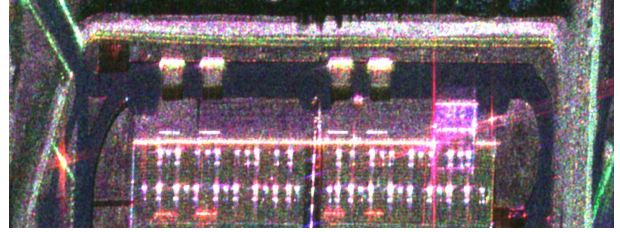
**Fig. 2.** Top: look angle 45° Bottom : look angle 60°

Once the SAR image is processed by taking into account the geolocation constraints, the coordinate of a pixel had been obtained using a terrestrial referential like WGS84 by knowing the position of the aircraft, the SLC SAR image coordinate of the considered pixel  $(i, j)$ , the squint and the local incidence angles, and vice versa. Then to find a corresponding SLC pixel coordinates from an acquisition geometry  $(i, j)$  into another one  $(u, v)$  an intermediate terrestrial referential had been used Fig.(3).



**Fig. 3.** Coordinate transformation between two acquisition geometries

### 4. FIRST TESTS ON REAL DATA AND DISCUSSION



**Fig. 4.** ROI with double bounce scattering

A  $3 \times 3$  windowing was applied on the amplitude of the region of interest of both SLC images. This serves both as a preliminary speckle filtering and as a filter that makes regions with uniform permittivity more prominent. However, the presence of speckle in a region with a double bounce should be taken into account with more caution and more modelling of it needs to be done.

The criteria for checking the presence of a double bounce in a pixel was taken to be the following,

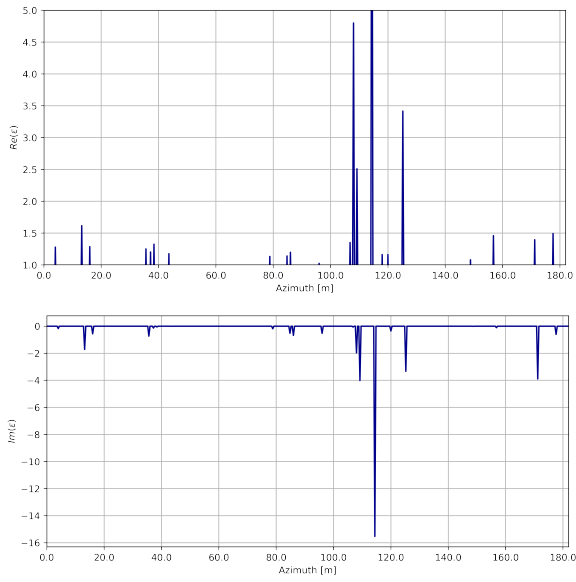
$$10\text{db} < 20 \log \left( \frac{|S_{Hh}|}{|S_{Vv}|} \right)$$

The local incidence angles on the ground near the double bounce were 43.3966° and 58.8918°.

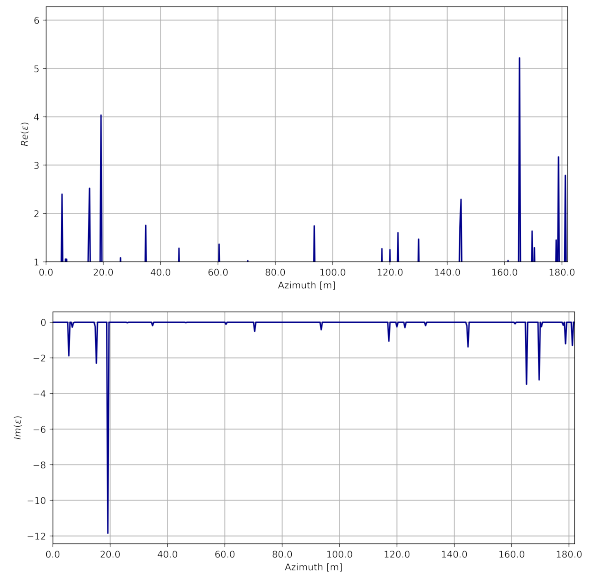


**Fig. 5.** Pixels on which the ratio method successfully executed

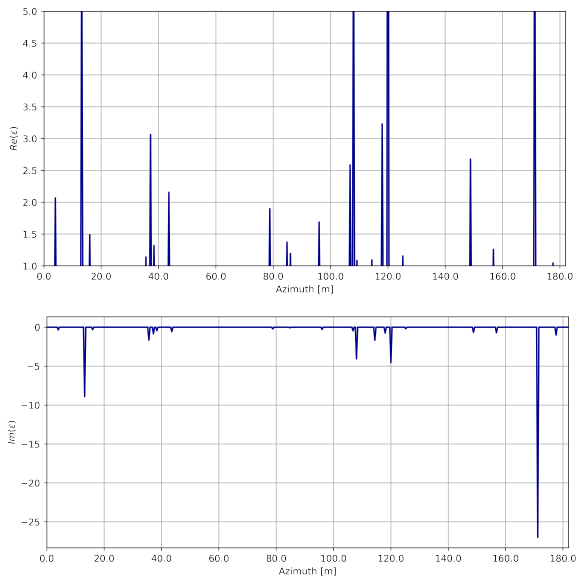
By observing the distribution of points along the range direction in Fig.(5) it can be suggested that more work should be done when modelling the radar cross-section in order to interpret the successfully executed pixels. We plot below the recovered permittivity distribution along the azimuth direction for two different range values depicted in Fig.4.



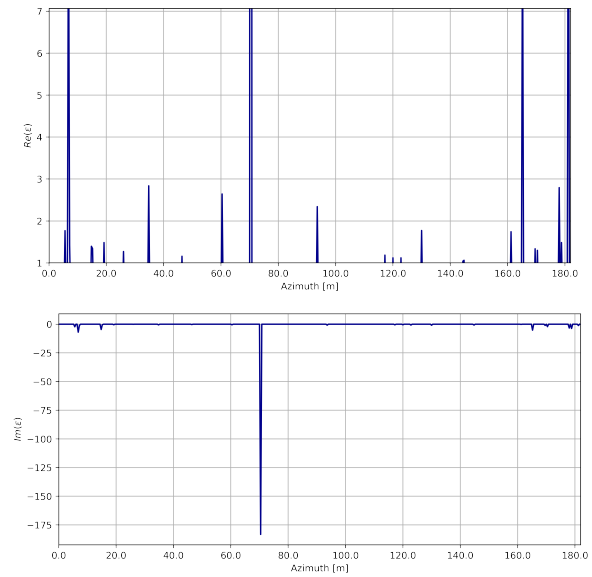
**Fig. 6.** Retrieved permittivity of the wall for range position 1



**Fig. 8.** Retrieved permittivity of the wall for range position 2



**Fig. 7.** Retrieved permittivity of the ground range position 1



**Fig. 9.** Retrieved permittivity of the ground for range position 2

By considering the relatively high peaks appearing along the azimuth direction, a first conclusion one can theoretically arrive is that they could correspond to a back-scatter from a metallic structure. Once more ground truth is available from the site, these locations will be compared to find the compliance.

A first comment on results that seem to possess low dielectric can be speculated to be a consequence of material mixing in the back-scattered signal. In any case, more ground truth is needed for the interpretation for these results. Moreover, it is difficult to find an answer at this stage of the test because of high sensitivity to roughness of X band signals.

## 5. CONCLUSION

The results of a first tests on real data of retrieving complex permittivities of both surfaces of a double bounce on a SAR image was presented.

## 6. REFERENCES

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