HyperImage Concept : Multidimensional Time-Frequency Analysis Applied To SAR Imaging

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I. Introduction

This paper suggests a generalization of the HyperImage concept introduced by [1], [2]. Indeed, the HyperImage process only uses the two-dimensional continuous wavelet. This paper proposes extending the concept to other time-frequency transforms in order to highlight some scatterers are anisotropic and dispersive.

II. Set of problems

Classical radar imaging makes the assumption that the scatterers are ponctual, isotropic and non-dispersive. It is the model of ”bright points”. However new very hight resolution (VHR) SAR imaging cannot venture this hypothesis, insofar as it uses a large angular excursion and a wide bandwith. To represent the dispersive behavior of some scatterers, a SAR image is built using three equal subbands centered on the frequencies fc = 8.82 GHz, fc = 9.37 GHz and fc = 10 GHz which are coded in the red/green/blue channels, figure(II). If a scatterer is white in the frequency band, so it is not colored on the image. Otherwise

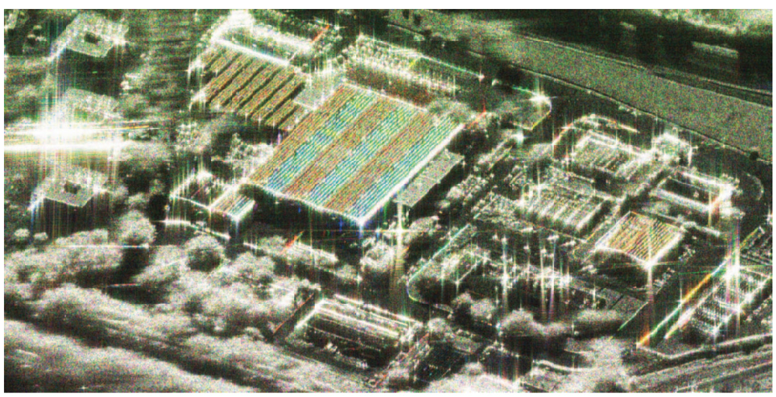


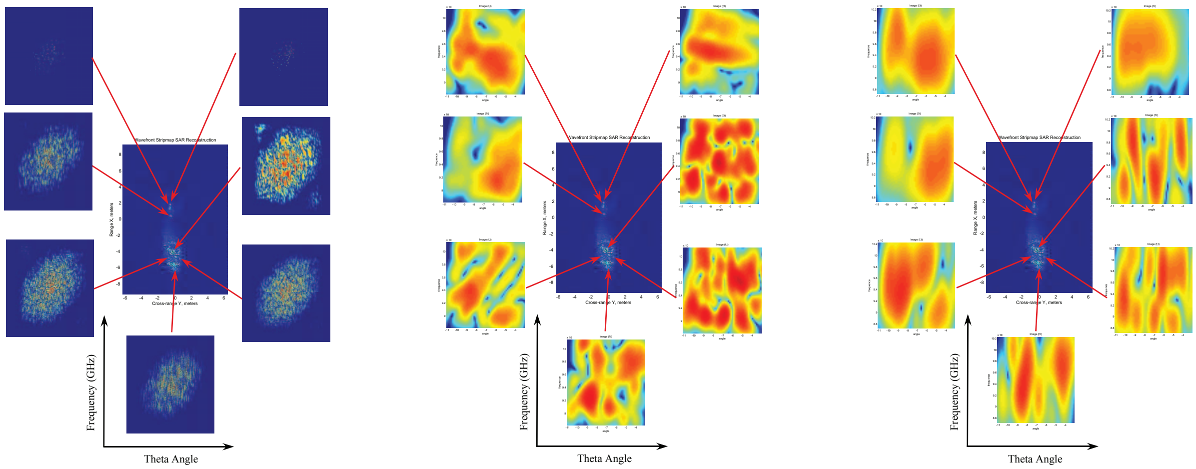
Fig. 1. A SAR image which highlights dispersive scatterers.

if the scatterer is dispersive, so it is colored. On the image (II), the roofs are colored in red and blue, so the scatterers of the roofs are dispersive. The model of bright points is non valid. A same reasoning can be made for the angular behavior. So, the usually spatial repartition of scatterer $I(\vec{r})$ where $\vec{r}$ is the location of the scatterer, depends now of the wave vector $\vec{k}$. This new repartition is noted $I(\vec{r}, \vec{k})$ and called HyperImage.

III. HyperImage construction by multi-dimensional time-frequency transforms

A. Theory

To build HyperImages the only time-frequency transform actually used is the continuous wavelet [1], [2]. In this paper, the Hyperimage calculation can be generalized to the Cohen Class and to the affin class [3], [4]. By applying the two-dimensional transforms of Cohen Class or Affin Class, a HyperImage can be represented according to the properties of the transform. Let us rewritten $I(r, k) = I(x, y, f, \theta)$: for each frequency $f0$ and each angle of radar illumination $\theta 0$, $I(x, y, f0, \theta 0)$ represents a spatial repartition of reflectors which respond at this frequency and this angle. Inversely, for each re?ector located at $r0 = (x0, y0)$, we can extract its feature $I(x0, y0, f, \theta)$ in frequency f and in angular θ. This is this aspect that we decided to point out in order to see if this quantity can be interpretable in terms of target characteristics.



(a) Wigner-Ville (b) STFT (c) Continuous wavelet

Fig. 2. Two-dimensional time-frequency transforms results

B. *Simulation results*

Dispersive and polarimetric behaviors of scatterers have been simulated on a spotlight mode to generate a SAR image. These behaviors are basic mathematics functions which have no physical sense. By applying the multi-dimensional time-frequency analysis, on the one hand the information of anisotropic and dispersive behavior of scatterers is found again, on the other hand this information is dependent of the time-frequency transform properties. For example the wavelet and the short-time Fourier transforms are limited by the Heisenberg incertitude.

IV. Results

Three two-dimensional time-frequency transforms have been tested on a VHR SAR image whose the target is an helicopter. It concerns for the Cohen class : the 2D Wigner-Ville transform, the 2D short-time Fourier transform and for the Affin class the 2D continuous wavelet. The results are presented on the figure (2). The results show some scatterers of the deterministic target are anisotropic and dispersive. However, we can see the limitations of some methods. Indeed, for the Wigner-Ville, the HyperImage is unreadable because of the cross-terms interferences.

V. Conclusion

Multi-dimensional time-frequency analysis allows to build HyperImages. These HyperImages tested in simulation show that the anisotropic and dispersive behavior of scatterers are found again by the HyperImages according to the properties of the used time-frequency transform. The calculation of the HyperImages by the short time Fourier transform, the continuous wavelet and the Wigner-Ville transform on a VHR SAR images whose the target is an helicopter, show some scatterers are anisotropic and dispersive. The future work will use these time-frequency signatures to procees a classification.

References

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