ARTIFICIAL SCATTERERS FOR S.A.R. INTERFEROMETRY

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ABSTRACT.

The evaluation of land displacement using SAR interferometry becomes often very difficult if we consider areas characterized by limited coherence. In this cases it is necessary the use of artificial scatterers. Presently, it is possible to utilize different kinds of reflectors: mirrors, dihedrals, and trihedrals, i.e. corner reflectors. We try to develop new generations of artificial scatterers with better properties. The possibility to use the same reflector for ascending and descending orbits would be a very powerful instrument to better characterize landslides, subsidence or other displacements. Exploiting the experience achieved with Corner Reflectors a new object is proposed to pursue this objective.

1. INTRODUCTION.

SAR interferometry is a good tool to measure topography or crustal deformations; however, changes in reflectivity properties of the area of interest can compromise its utility. If we consider urban areas concrete structures work as good scatterers, but if we have to analyze areas characterized by fields or vegetation it could be impossible to find good scatterers to estimate ground motion. In these cases it is necessary to use artificial scatterers. There are several types of artificial scatterers, the mirror, the diherdral reflector and the corner reflector, plus poles, etc. Each of them has its own characteristics to exploit in different situations. The main object of our studies has been the Corner Reflector. This object is composed by three metal plates (usually of triangular shape), joint together using their sides in order to build a corner. Its main advantages are the high Radar Cross Section granted and the installation that results to be easier than the other artificial reflectors.

2. CORNER CUBES.

The typical Corner Reflector utilized for calibration or as permanent scatterer, is made of triangular plates. However it has been shown that, to optimize the scattering surface, other shapes could be used to build this object [1]. If we consider a Corner Reflector built with squared plates and simulating its behavior using geometrical optics, it's easy to notice that all the surface of the object is exploited (Fig.1, Fig.2), if properly pointed.

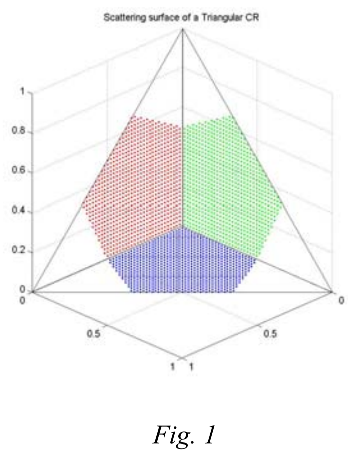

Fig. 1

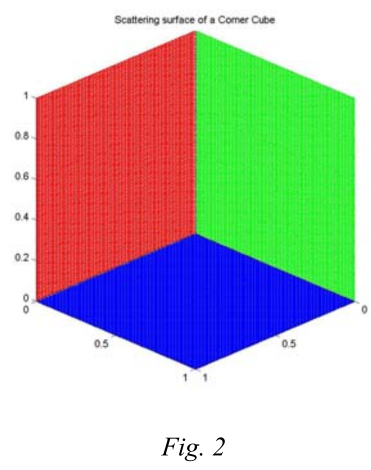

Fig. 2

This explains the different Radar Cross Section formulas (1), (2).

$$R.C.S._{tria} = \frac{4\pi l^4}{3\lambda^2} \tag{1}$$

$$R.C.S._{cube} = \frac{12\pi l^4}{\lambda^2} \tag{2}$$

3. ASYMMETRICAL CORNER CUBES.

The aim of the work was the project of new corners that could be as much as possible independent from the pointing, in order realize a multi-platform reflector**.** A square based corner cube with a longer vertical side has been designed. In this way it is possible to avoid the elevation pointing without loosing too much RCS. A Corner Cube with 1m x 1m base plate and two 1m x 1.5 m lateral plates can be placed sitting on the ground and giving to it only an approximate azimuth orientation. The RCS that can be obtained from this object depends from the platform's look angle (Fig. 3, Fig.4). The Corner could then be seen from different platforms but with different RCS.

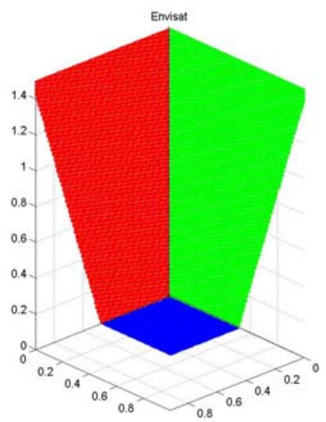

Fig. 3

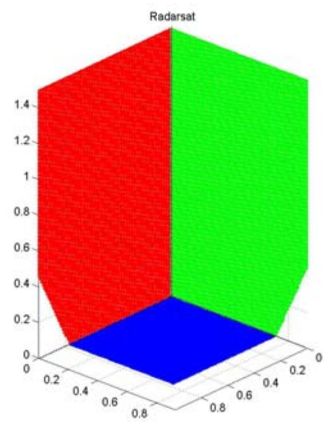

Fig. 4

4. THE HOLED PLATES.

The corner reflectors are objects that must be exposed to atmospheric phenomena at times for many years. The impact of wind and water should be then taken into account. The simplest way to solve this problem is the use of holed plates: wind forces are lower and water can filter through the base avoiding problems due to the accumulation of rain.

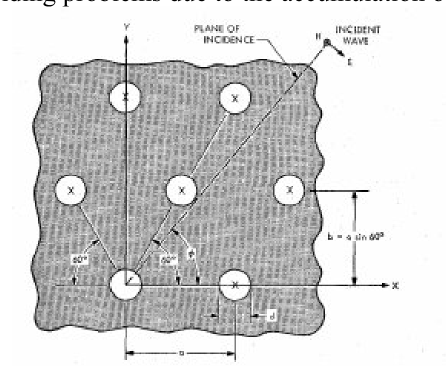

Fig. 5

Moreover, the weight of the object can be reduced. Now the only parameter to define is the holes' dimension: typically the dimension of the hole should be less than $\lambda/8$. However, considering that incidence on the plates it is never 0^o and the different scattering properties at different frequencies, it can be shown that in the case of C-band but also of X-band the holes in the plates can reach a diameter of 1 cm, with a respective filled/vacuum ratio of the plates of 60%, preserving a good RCS. It has been shown in [2] that the trasmittivity through holes is given by the following formula:

$$T_{db} = 20Log_{10}\left(\frac{3ab\lambda_0}{2\pi d^3 \cos(\theta_{inc})}\right) + \frac{32t}{d} \tag{3}$$

Where the dimensions a, b, d are shown in the above figure (Fig. 5). (F/V) is the filled/vacuum ratio and t is the thickness of the plates. Considering the dimensions of the object, it is necessary to reinforce the rigidity of the structure with one or more rods between faces. Geometrical optics simulation of the scatterer showed that a rod between the two corners of lateral faces does not create significant RCS losses, because of the small incident angle: however with increasing off-nadir angle some losses may occur but at the same time RCS increases very fast and so their effect can be considered negligible. Two prototypes of this artificial scatterer, with holes in the plates respectively of the diameter of 0.5 cm and 1 cm, has been tested in Milan firstly (Fig. 6, Fig. 7) and then the design has been used in other test sites.

Fig. 6

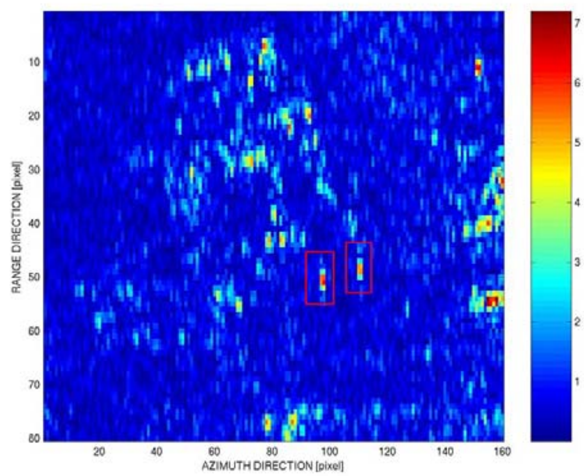

Fig. 7

5. A PROPOSED ASCE/DESCE CORNER REFLECTOR.

The next step in developing artificial scatterers is to design an object that could be seen from both ascendant and descendant orbits. Knowing displacements in different directions permits to understand not only one but two motion components helping the interpretation of data. The solution proposed here exploits the experience achieved from the Corner Reflector proposed before. The idea is to merge two of the corners to create an object that works in two different directions as a corner reflector but with just one scattering center. The main problem to face is related with orbits directions. Ascendant and descendant directions cannot be considered parallel and the angle between them varies changing the latitude of the test site. In Milan, for instance, angles are 26^0 for ENVISAT and 16^0 for RADARSAT. According with this observation it is necessary to optimize the reflector's geometry in order to maximize the RCS in both directions. This can be obtained modifying the ratio between lateral plates (Fig. 8, Fig.9).

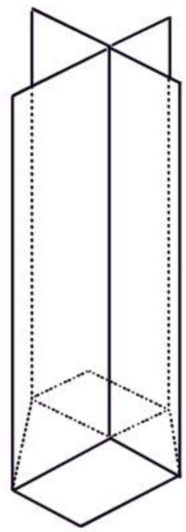

Fig. 8

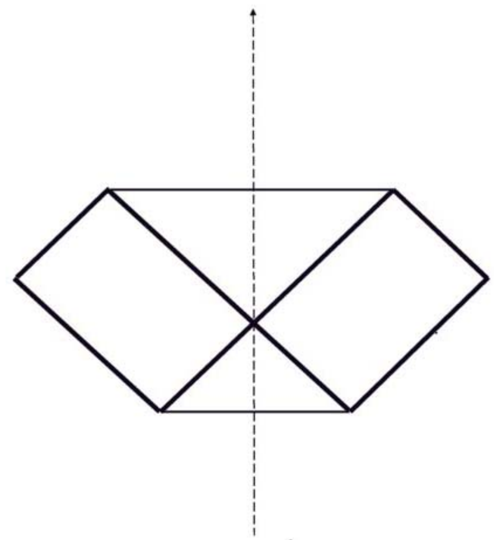

Fig. 9

Some simulations have been done to evaluate this design, plotting the RCS as a function of the difference (X) between the dimension of the two lateral plates. In the figure below we show an example of a simulation using Milan dataset acquisition geometry. It is possible to observe that optimizing sides' proportion the object could be seen by four different orbits each with RCS greater than 2500 m^2 (Fig. 10, Fig.11).

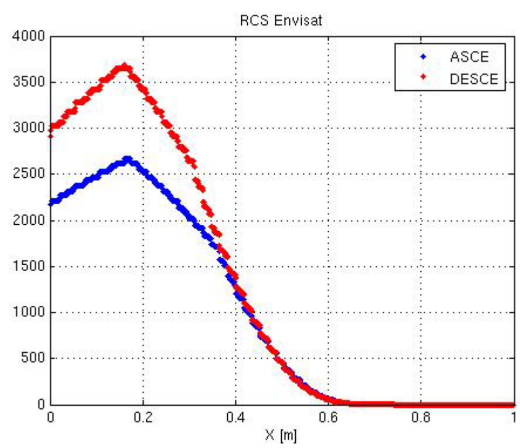

Fig. 10

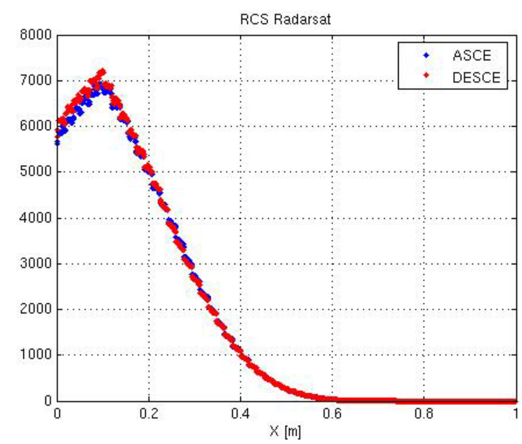

Fig. 11

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[2] T.Y .Otoshi. A Study of Microwave Leakage Through Perforated Flat Plates. *IEEE Trans. Microwave Theory and Techniques,* v. 20, pp. 235-236, March 1972.