COSMO-SKYMED AO PROJECTS – BUILDINGS FEATURE EXTRACTION FROM SINGLE SAR IMAGES

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ABSTRACT

This paper presents the main scientific novel outcomes of the research activities included in the project "Buildings Feature Extraction from Single SAR Images: Application to COSMO-SkyMed High Resolution SAR Images". The project was conceived by the authors of this paper and financed by the Italian Space Agency under the Announcement of Opportunity for the COSMO/SkyMed mission.

Index Terms— Synthetic Aperture Radar (SAR), urban areas, COSMO-SKYMED

1. INTRODUCTION

The project title includes keywords that show, in a very compact form, the main objectives of the project. More specifically, the research work was aimed to explore the possibility of extracting relevant features in an urban area by means of interpretation and analysis of single high-resolution SAR amplitude images acquired by COSMO-SkyMed sensors. It is worth clarifying that for "relevant features in an urban test site" we mean both the characterization of geometric and electromagnetic properties of the main objects present in an urban area (thus, in particular, buildings are under concern) and the explanation of some effects visible only on high resolution SAR images of urban scenarios.

2. TEST CASE AND DATA SET

In fig.1 the Naples business is shown along with sample COSMO/SkyMed SAR images in the medium-resolution stripmap and the high-resolution spotlight modes. It is evident how high resolution images are most indicated for revealing urban features. In the work this visual evidence has been supported by an original electromagnetic model and a quantitative analysis applied to main features like vertical walls, balcony and floor evidence.

Fig.1a Google Earth perspective of the Napoli Business District.

Fig.1b Cosmo-SkyMed amplitude image of area in Fig1a. Stripmap operational mode.

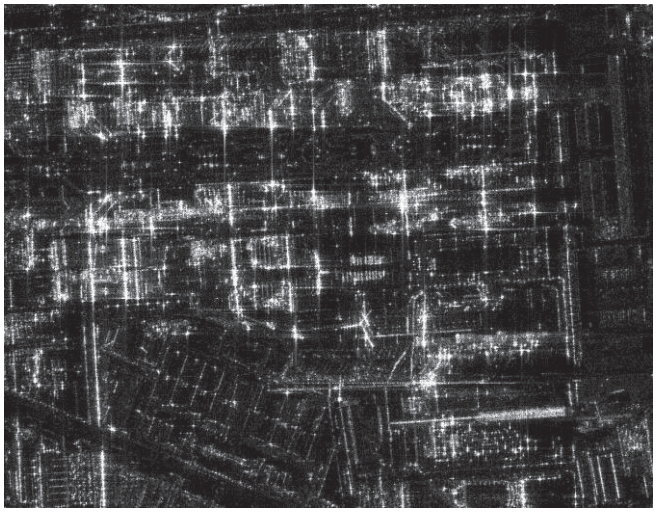

Fig.1c Cosmo-SkyMed amplitude image of area in Fig1a. Spotlight operational mode.

This technique was pioneered by the proposing group that first introduced the theory and verified it, by using airborne SAR data [1,2]. For instance, best case results indicated that the height of some electromagnetically isolated buildings, characterized by simple shapes (prisms with vertical walls), see fig.2a, could be estimated with an accuracy of some electromagnetic wavelengths (actually some centimeters) by using a single SAR amplitude image [3].

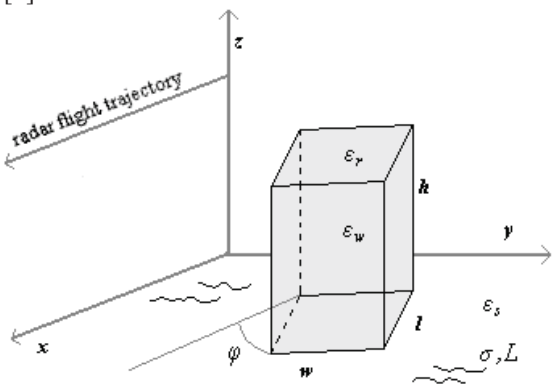

Fig.2a Geometrical and electromagnetic parameters of a canonical "electromagnetically isolated" building.

3. TECHNIQUES

Within the project work a series of new techniques, whose former pioneer versions are in [4,5], have been developed, and are presented here via sample meaningful original maps derived from the SAR images. For instance, in fig. 3 are shown two maps that are used to identify the buildings in the urban area. The fractal map employed to detect the buildings in the business district of Napoli [6,7], and the result of the Pauli decomposition for a polarimetric acquisition relevant to the Collazzone area (therein, buildings characterized by multiple bounce effects are imaged in red). As a first general and key comment, we note that the techniques we introduced in this project are fully innovative and complementary with respect to any other SAR urban monitoring approach: our approach mainly deal with a single SAR amplitude image, whereas other available approaches usually employs a (eventually very) large number of SAR complex images (essentially working on phase differences) within the framework of appropriate interferometry methods.

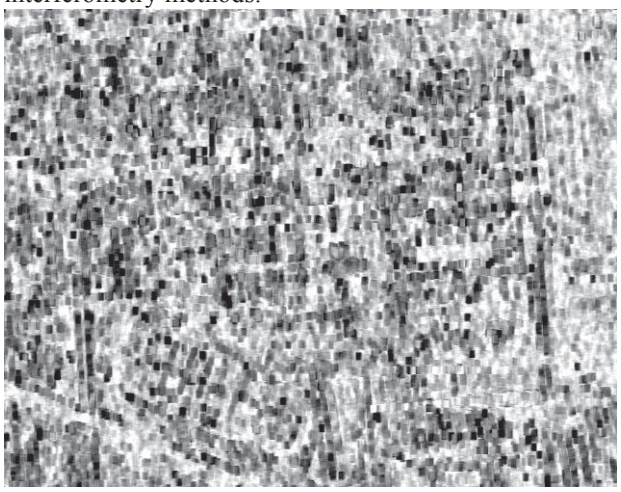

Fig.2a Fractal map derived from the Cosmo-SkyMed spotlight image of the business district in Napoli, Italy.

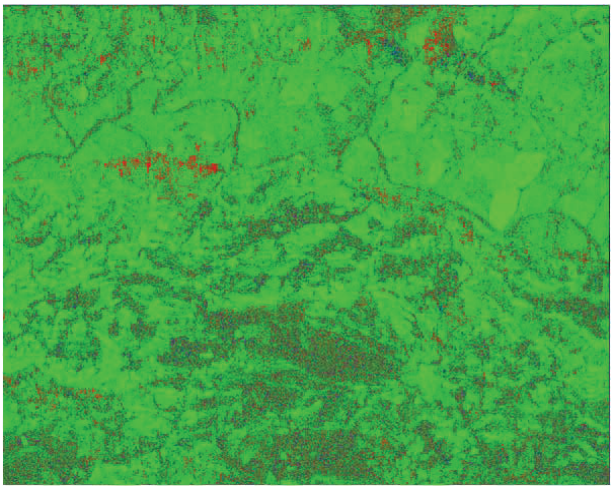

Fig.2b Pauli decomposition applied to the area of Collazzone, Umbria, Italy: buildings are imaged in red as characterized by multiple bounce effects.

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A second comment is relevant to the employed methodology. We did not use heuristic, phenomelogical or empirical methods: we developed original closed-form

analytical methods for estimating the backscattering coefficient in the phasor domain [1,2]. In a SAR image let us define a building as "electromagnetically isolated" if its radar returns, after SAR processing, do not overlap (but for the SAR impulse response sidelobes) to any return from other buildings in the scene; then, single, double, triple backscattering contributions relevant to an "electromagnetically isolated" building are evaluated in closed form. Stratified walls were also considered for the electromagnetic backscattering in the spotlight SAR modes, see Fig.4a.

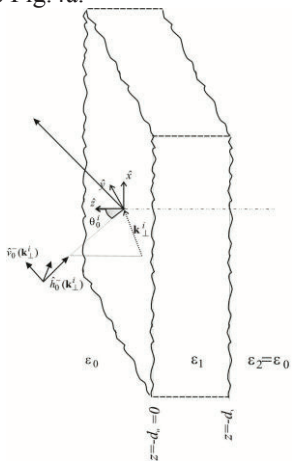

Fig.4a Fig.4a Rough-layered model for walls imaged in high-resolution SAR.

Moreover, as far as multiple interactions between different buildings are concerned, conditions for the occurrence, position in the SAR image, and backscattering coefficients were also evaluated in closed form, see fig.4.

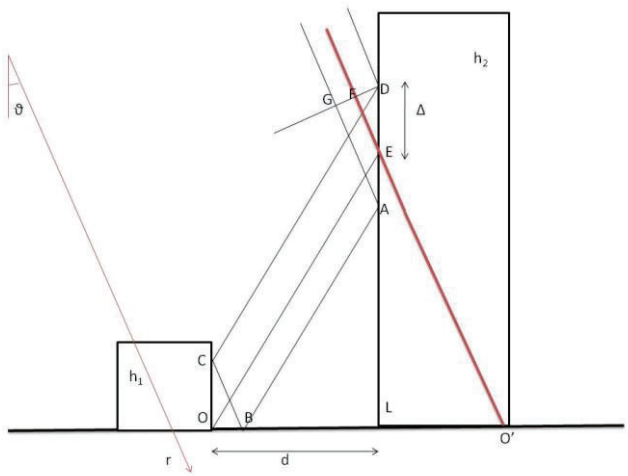

Fig.4b Geometry for the four-fold interaction.

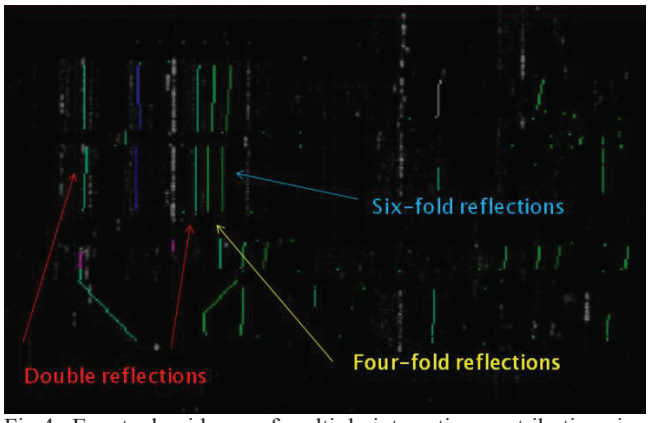

Fig.4c Eventual evidence of multiple interaction contributions in a close up of the Spotlight image.

The proposed closed form methods have been implemented in a numerical code to simulate the SAR images relevant to a prescribed urban scenario characterized by building of known shape and material superimposed on a macroscopic profile of known roughness and complex dielectric constant, see fig.5. The simulated COSMO/Skymed images can be used as a knowledge database in the interpretation of actual SAR images. Finally, connection between the backscattering coefficient and the reflectivity function relevant to a single SAR image (a realization of the stochastic process whose mean square value is the backscattering coefficient) has been also modeled.

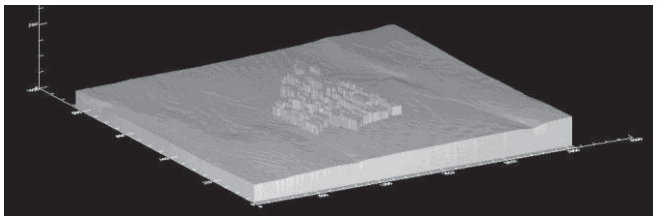

Fig.5a DEM of an urban area including topography and buildings.

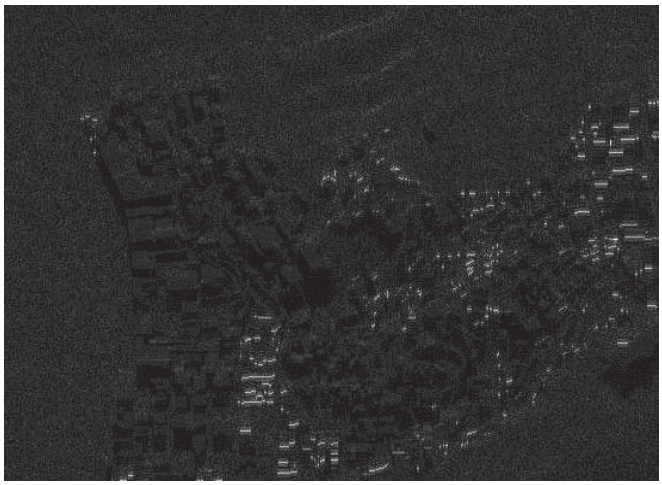

Fig.5b SAR simulated stripmap image adopting the DEM in fig.5a

and COSMO/Skymed parameters (only isolated building are here considered).

Inversion of the closed form models has been studied. Calibration, error budget and multilook issues have been analyzed to assess the proposed inverse methods reliability. Design of feature extraction techniques has been also considered.

Fig.6a Aerial photograph of the business district: a relevant building is emphasized.

An example of the achieved results is shown in fig.6. For a building (see fig.6a) in the SAR image (see fig.6b), the portion of the SAR image relevant to its façade has been extracted and presented in an appropriate new framework (see fig.6c).

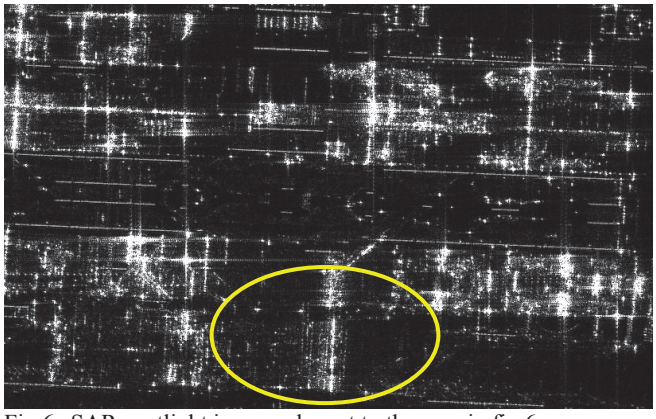

Fig.6c SAR spotlight image relevant to the area in fig.6a.

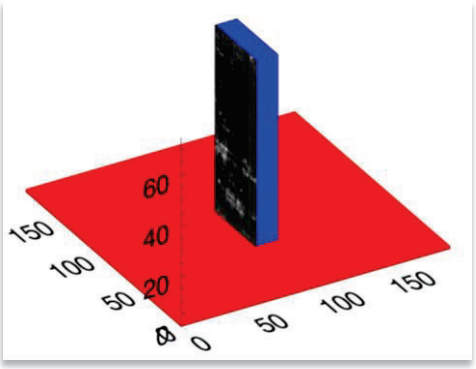

Fig.6b A new framework to propose SAR images of buildings.

5. REFERENCES

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