SAR Data Analysis:
An Useful Tool for Urban Areas Applications

M. Ferri, A. Fanelli, A. Siciliano, A. Vitale

Dipartimento di Scienza e Ingegneria dello Spazio “Luigi G. Napolitano”
Università degli Studi di Napoli “Federico II”
P.le V. Tecchio 80 - 80125 Naples, Italy
Tel: +39 – 081 7682352
Fax: +39 – 081 5932044
E-mail: fermario@unina.it

Abstract
C-band SAR and InSAR data has been widely used for several Earth related studies (topography, volcanology, forestry etc.). Nevertheless, not much attention has been paid to urban areas and coherence imagery has been used for classification purposes only. So, urban areas and other built-up environments present great challenges for SAR (Synthetic Aperture Radar) interferometry processing. In fact, SAR and InSAR parameters acquired in C-band can be useful for urban oriented studies as they provide valuable information about the shape of a city and its main structures; the determination of elevation models of buildings could be an important topic too.

In this paper we have analysed the potential benefits connected with the combination of SAR and InSAR signatures (intensity image, 1-day and long term) for urban oriented applications. In particular we have analysed the causes of decorrelation over urban areas. It is well known that coherence can be divided into five components: spatial, temporal, thermal noise, processor and volume. We focused the attention on volume scattering decorrelation. The effects of volume scattering in terms of estimated coherence can be explained by the Van Cittert Zernike theorem: volume coherence is the normalized Fourier transform of the backscattering coefficient as function of height. Moreover, a model for backscattering coefficient of urban areas has been defined. This model allows to get theoretical coherence values.

In this paper several test sites have been considered in the surrounding of Naples, in Italy. Theoretical and experimental values of tandem coherence are compared and the mean heights of buildings are extracted. In situ measurements are in agreement with values of the buildings height obtained from coherence comparison.

The described procedure seems to be promising also considering the interest to compare this kind of data with those of SRTM mission; better results may be achieved using fine resolution coherence images.

Introduction
Urban areas, with their complex structure composed of buildings of different shapes and kinds, infrastructures and green areas, and phenomena like shadowing, layover, height discontinuities, multipath reflections, multiplicative noise from sidelobes and so on, present great challenges for interferometric SAR processing. Since the largest part of the world population is already settled in towns and cities, it is important to develop a set of tools for the analysis, monitoring and planning of urban environment[1]. SAR remote sensing is an efficient and relatively cheap means to acquire...
information on a timely and consistent basis, and several studies have successfully demonstrated that SAR interferometric coherence images can be useful to this aim [2, 3, 4, 5]. In this work we examine the source of decorrelation in urban areas. Then we focus on layover and its influence on interferometric coherence (volumetric coherence). At last, we estimate the buildings height applying Van Cittert Zernike theorem to coherence maps and validate this technique comparing estimated heights with in situ measurements.

**Data set and methodology**

In this paper we have examined 10 SAR images acquired in C band and with polarization VV, from the satellites ERS-1 and ERS-2 in tandem mode. All images are descending and in slant range geometry. The dimensions of a ground-pixel correspond to about 4 meters and 20 meters along azimuth and range, respectively. All the possible couples to produce coherence images have been considered; only those having normal component of baseline smaller than 300 meters can be considered interesting. They are characterised by a time interval - between the two observations - varying from 1 to 1261 days. The selected couples have been reported in Tab. 1, with the relative values of baseline and the temporal interval of acquisition. The components of the baseline are furnished by the European Spatial Agency.

<table>
<thead>
<tr>
<th>Master</th>
<th>Slave</th>
<th>Time interval [days]</th>
<th>Baseline ⊥ [m]</th>
<th>Baseline // [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-12-1995</td>
<td>14-12-1995</td>
<td>1</td>
<td>-213</td>
<td>-79</td>
</tr>
<tr>
<td>13-12-1995</td>
<td>09-10-1997</td>
<td>666</td>
<td>-163</td>
<td>-15</td>
</tr>
<tr>
<td>13-12-1995</td>
<td>27-05-1999</td>
<td>1261</td>
<td>-121</td>
<td>37</td>
</tr>
<tr>
<td>14-12-1995</td>
<td>09-10-1997</td>
<td>665</td>
<td>50</td>
<td>64</td>
</tr>
<tr>
<td>14-12-1995</td>
<td>27-05-1999</td>
<td>1260</td>
<td>92</td>
<td>116</td>
</tr>
<tr>
<td>21-05-1997</td>
<td>22-05-1997</td>
<td>1</td>
<td>97</td>
<td>26</td>
</tr>
<tr>
<td>21-07-1997</td>
<td>30-07-1997</td>
<td>70</td>
<td>-4</td>
<td>79</td>
</tr>
<tr>
<td>30-07-1997</td>
<td>31-07-1997</td>
<td>1</td>
<td>139</td>
<td>-30</td>
</tr>
<tr>
<td>08-10-1997</td>
<td>09-10-1997</td>
<td>1</td>
<td>282</td>
<td>206</td>
</tr>
<tr>
<td>08-10-1997</td>
<td>22-05-1997</td>
<td>139</td>
<td>-215</td>
<td>63</td>
</tr>
<tr>
<td>08-10-1997</td>
<td>14-12-1995</td>
<td>664</td>
<td>232</td>
<td>142</td>
</tr>
<tr>
<td>26-05-1999</td>
<td>09-10-1997</td>
<td>594</td>
<td>-123</td>
<td>-100</td>
</tr>
<tr>
<td>26-05-1999</td>
<td>14-12-1995</td>
<td>1259</td>
<td>-173</td>
<td>-164</td>
</tr>
<tr>
<td>31-07-1997</td>
<td>22-05-1997</td>
<td>70</td>
<td>-38</td>
<td>-23</td>
</tr>
</tbody>
</table>

*Table 1*

The evaluation of the urban parameters has been made using only five tandem coherence images. Instead long term coherence was used for distinguishing urban areas from other types of coverage present in the observed zone. The attention has mainly focused on the territory belonging to Caivano, a small town situated in the northern part of the city of Naples. An other area of interest has been the historical centre of the city of Naples.

The interferometric couples, constituted by the SAR SLC images, have been processed by ATLANTIS EarthView InSAR 1.1 software. Every couple is co-registered with an accuracy of the fraction of pixel. The coherence images have produced by using the maximum likelihood estimator, valued in windows of dimensions 15x3 pixels, along azimuth and range, respectively. These dimensions seem to be a good compromise
between resolution and accuracy. The correction of topographical phase, considered in the evaluation of the coherence, is linear [6]. The bias is not compensated. Finally, we average on 5 pixels along the azimuth obtaining a “square” resolution.

The spectra of the two images are filtered with band-pass filter; in this way the uncommon parts of the spectra are suppressed [7]. Such operation has realised for eliminating the spatial decorrelation. We can hypothesise that:

1. \( \gamma_{\text{processor}} \) is close to 1;
2. \( \gamma_{\text{noise}} \) is equal to 1 for urban areas, because in this zones the SNR is very high;
3. \( \gamma_{\text{temporal}} \) is equal to 1 for tandem coherence and urban areas, which are very stable in time;
4. \( \gamma_{\text{spatial}} \) is close to 1 after spectral shift filtering.

For these reasons experimental decorrelation is only due to volumetric phenomena. According to the Van Cittert Zernike theorem the normalised Fourier transforms of the volumetric backscatter coefficient is the volumetric coherence [8]. Then we can compare experimental and theoretical values of coherence and find buildings height in the backscattering model (see Fig. 1) for which we have the best fit, in least mean square, of the two coherence curves.

\[ \text{Fig. 1 – Volumetric backscatter model.} \]

**Result and discussion**

The estimation of the height has been carried out in way that the theoretical curve reproduces as much as possible the functional course of the experimental data; the exact overlap of the two curves is impossible, in accord with the approximation of the defined theoretical model and the presence of a bias in the experimental coherence estimator.

The first area taken in examination is Caivano. This area is characterised, primarily, from rural typical architecture, with houses of two or three plans. In this case we use a backscatter model with only two rectangles; the first one has centred at 8 meters from the ground. The second rectangle has the centre at a distance of 4.8 meters from the first one. Fig. 2 illustrates the results obtained in this area.

The height of 50 randomly selected buildings has been measured in situ [9]. Only two criteria of selection have been used: the horizontal extension of the buildings, never less than 100 square meters and their uniform distribution in the area. Besides, all the measured structures are perfectly visible from east, which is the direction of illumination of the satellite.

Fig. 3 shows the histogram of the heights so obtained. The distribution of the heights of the buildings is of bimodal type; the first mode is in correspondence of \( h = 8 \) meters, the second one is introduced at \( h = 12 \) meters. The values of the heights provided by the theoretical model to reproduce the course of the experimental data are in good agreement with those measured in situ.
For the others zones of interest aren’t available precise measures acquired in situ. However, we know the urban characteristics of the observed areas. For the historical centre of Naples, the urban characteristics are completely different in comparison to the areas till now examined; particularly, the height of the buildings is notably greater. We again use a backscatter model with only two rectangles; the first one centred at 18 meters from the ground. The second rectangle has the centre set at a distance of 4 meters from the first one. Fig. 4 illustrates the results obtained in this area. The difference between the two curves, theoretical and experimental, is, in average, slightly greater than the previous cases. Greater errors were for small values of the baseline. The justification of this phenomenon is analogous to that given before. Anyway, once more, the theoretical model reproduces with good approximation the experimental data.
Conclusions
We tried to extract information related to the height of the buildings in the observed areas through the comparison between the experimental values of the coherence, calculated by using images from the satellites ERS-1 and ERS-2 and the theoretical values, got by a model, previously introduced.
For one of such zones, the area of Caivano, 50 “in situ” measurements have been carried out; the results obtained by the theoretical model are in good agreement with the “in situ” measurements.
For other analysed areas, the obtained information are qualitatively correct.
The available experimental data have a limit: SAR images and the maps of coherence have a rather coarse resolution. This limit has allowed the determination of the mean height of buildings present in the observed area rather than the height for single urban structures. Even so, this procedure seems to be promising also considering the interest to compare this kind of data with those of SRTM mission; in fact, better results may be achieved using fine resolution coherence images. So, the next goal will be the application of the defined technique to coherence images with high resolution. Besides, in the urban areas great attention must be pointed out to the influence of meteorological phenomena on the coherence.

References


