TERRESTRIAL SAR INTERFEROMETRY MONITORING OF A CIVIL BUILDING IN THE CITY OF ROME

fringe 2011 workshop
19-23 September 2011
Frascati (Rome) Italy

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1. INTRODUCTION

During the excavation of tunnels in urban areas the monitoring of ground and building deformation is a key requirement in order to prevent damages to structures and utilities at the ground surface [1]. Therefore, innovative remote sensing monitoring techniques able to overcome the limitations of conventional techniques are welcome. Among these techniques Terrestrial SAR Interferometry (TInSAR) is particularly promising.

Instrumentation view

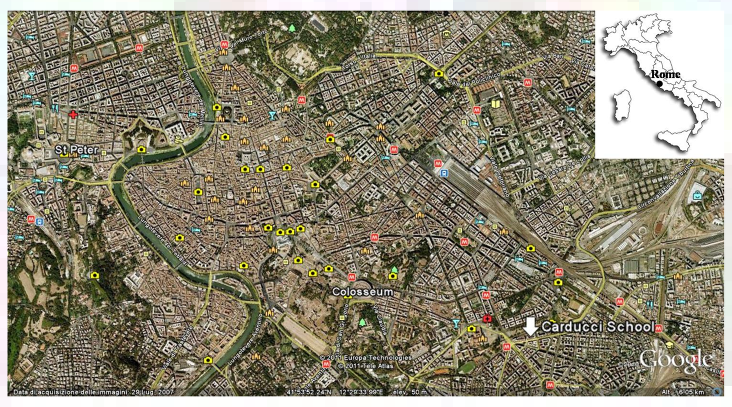
In the last years the city of Rome is affected by the excavations for the realization of the third Metro line (Line C). In this paper the activities, the results and the future developments of the monitoring of a civil building along the Line C route by TInSAR technique is presented.

2. TERRESTRIAL SAR INTERFEROMETRY

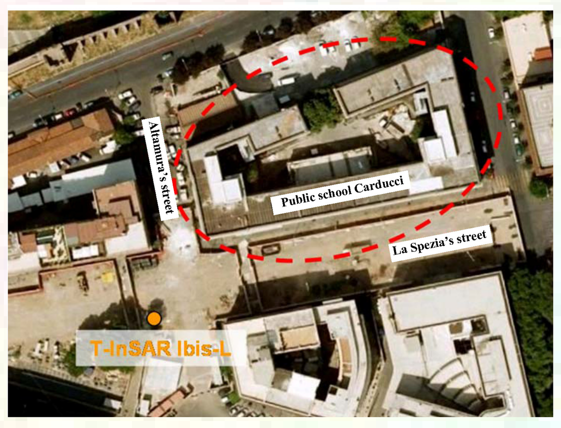
TInSAR [2] is a ground based radar monitoring technique based on the same operational principles of satellite SAR Interferometry [3].
The TInSAR technique it is based on an active radar sensor that emits and receives electromagnetic wave in the micro-wave Ku band while moving along a rail. TInSAR is characterized by the following main features: i) 24/7 efficacy under any weather and lighting conditions; ii) range of operability up to 4 km; iii) max range (direction sensor-target) and cross-range resolution (direction perpendicular to the range) up to 4.52 mrad, respectively; iv) high accuracy in displacement measurement; v) high image sampling rate (up to 5 minutes); vi) widespread monitoring capabilities [4, 5].

3. MONITORING OF A BUILDING IN ROME

One month continuous monitoring of a building, located at the intersection between La Spezia and Altamura streets (near the historical centre of Rome), was performed from March 6th to April 4th, 2009 by using an IBIS-L equipment by IDS S.p.A. By setting 5 minutes sampling rate a total amount of 7229 SAR images were collected.

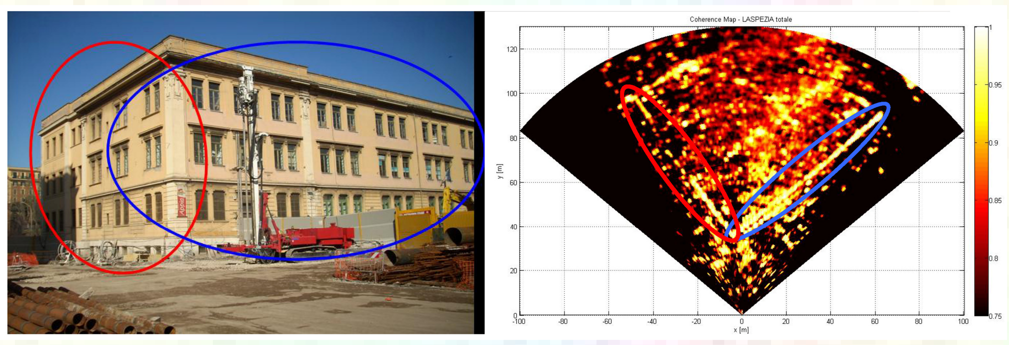


Location of the Carducci School



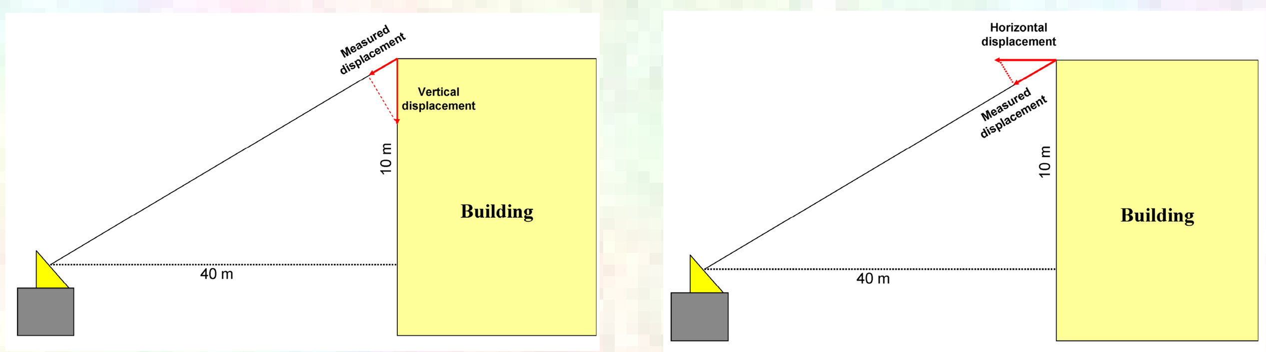
Aerial view of the monitoring area

The monitoring platform, made of a concrete basement of sizes 2,10x0,6x0,9 m and covered by a wood roof, was located inside the Metro C yard at a distance of 40 m from the building's corner facing the intersection from the La Spezia and Altamura streets. A power connection was realised in order to guarantee a 24/7 power supply, thus allowing the continuous operability of the equipment.



Comparison of a digital image and a coherence radar map

The scenario illuminated by the interferometer IBIS-L covered an area of 130 x 200 m (i.e. 0-130 m in range direction and ±100 m in cross-range direction).
It is worth to note that TInSAR monitoring is able only to collect the displacement along the instrument LOS (Line Of Sight), hence the measured displacement is always a component of the total displacement along a predefined direction. In the present case study the components of the total displacement acquired from the monitoring position range from the 10% to 90 % of the real displacement for the vertical and horizontal displacement, respectively.

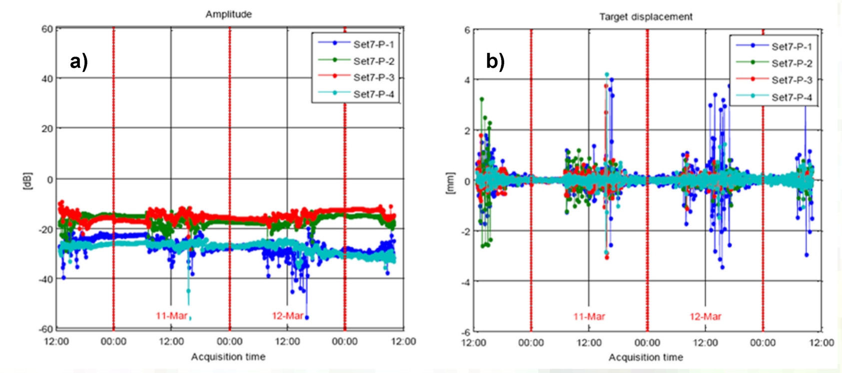


Scheme of geometry aquisition

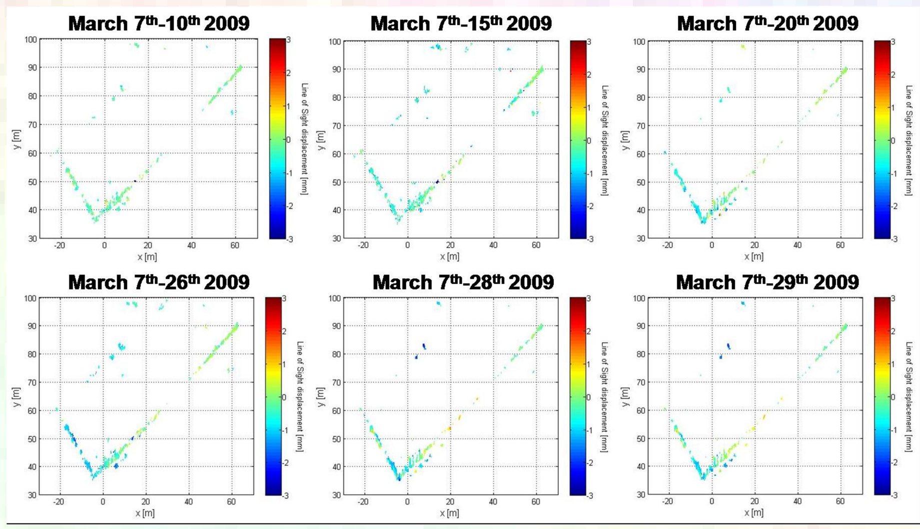
IBIS-L configuration	
Center frequency	16.75 GHz
Polarization	VV
Bandwidth	300 MHz
Length of track (utilized)	2 m
Max number of single image for SAR focusing	401
Inter scan delay	6 s
Range resolution	0.5 m
Cross-range (azimuth) resolution	4.5 mrad (0.5 m at 110 m)
Accuracy	0.1 to 1 mm
Maximum distance	130 m
Vertical beamwidth	17° a -3 dB and 34° a -10 dB
Cross-range beamwidth	17° a -3 dB and 34° a -10 dB (200 m at 130 m in range)
Sampling rate	5 min

4. DATA ANALYSIS

Both D-InSAR (Differential-Interferometric Synthetic Aperture Radar) analysis by couples of images collected at different times and multi-stack analysis were performed by using the large dataset available.
The accuracy of the data during the day was significantly lower than during the night, of at least one order of magnitude, mainly due to the presence of working activities. In order to remove the noise, images affected by the transit of vehicles were identified and removed from the stack by a specific algorithm based on the identification of anomalous back-scattering values.
Then, the displacement was computed by applying suitable phase screen procedures.



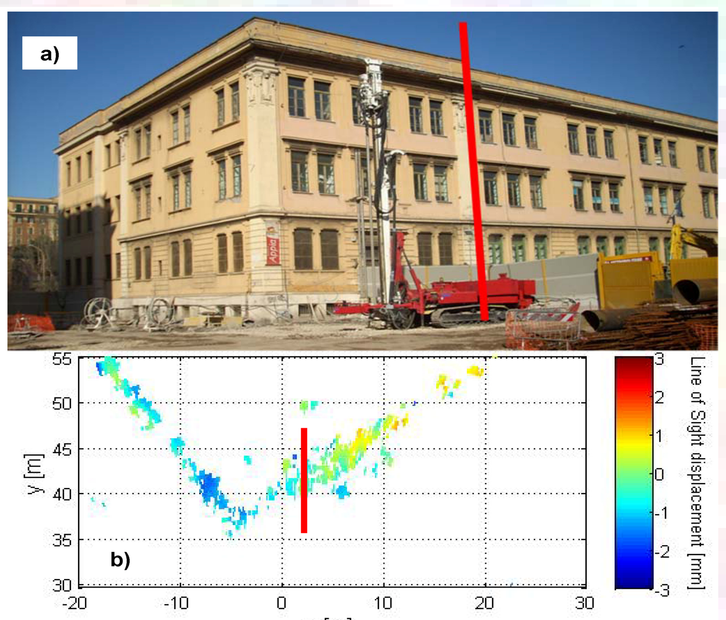
Comparison, for the same temporal period and pixels, of the amplitude of back-scattering signal a) and displacement b)



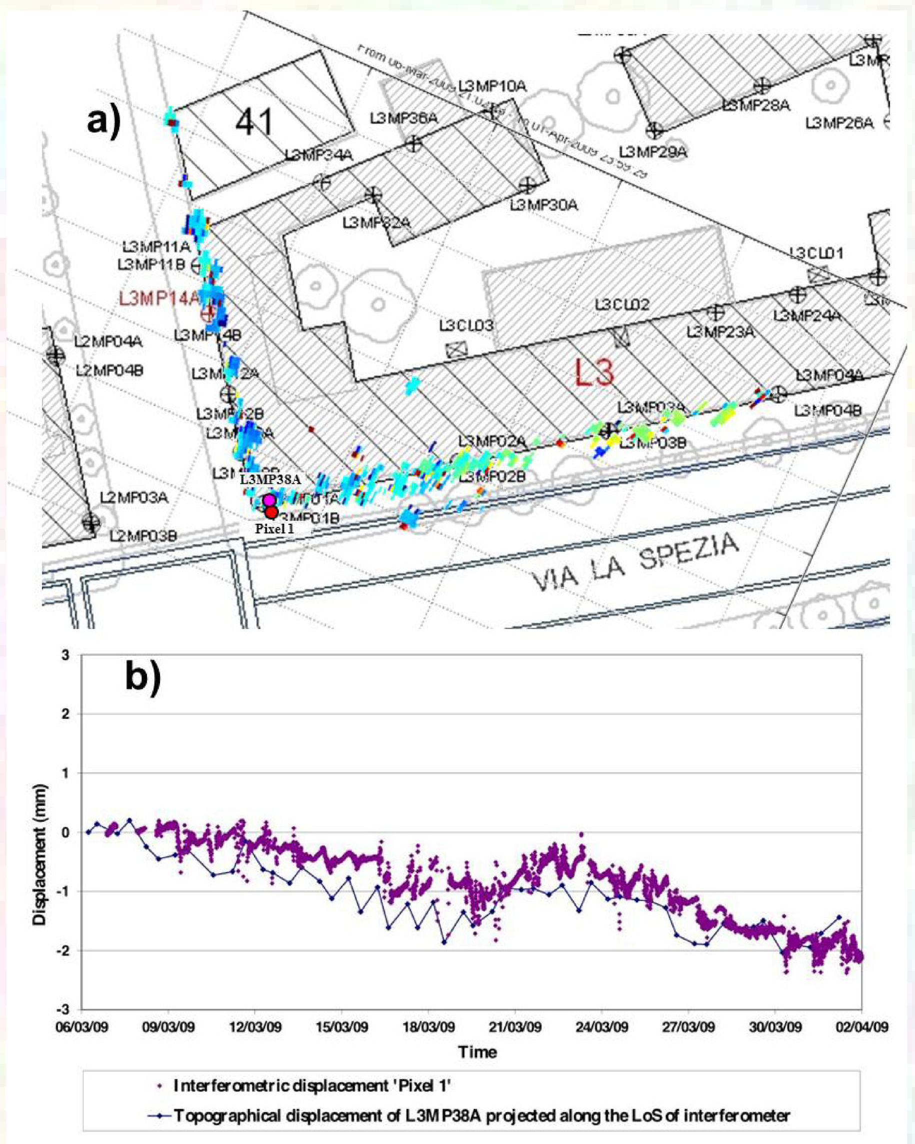
Series of cumulative displacement map

5. RESULTS AND COMPARISON WITH CONVENTIONAL MONITORING

A total amount of displacement toward the instrument ranging from 1 to 2 mm was observed in the portion of the slope facing the Altamura Street and the intersection between Altamura and La Spezia streets. Differently, no displacement was observed in the other portion of the building.
In order to rightly compare Total Station (TS) and TInSAR data, achieved in the same period, the TS displacement along the LOS of TInSAR has been computed by the combination of the three direction data. Projection of TS displacement collected during the same period along the TInSAR LOS direction allowed to confirm the same values measured by Terrestrial SAR monitoring.



a) picture of the building (red full line identifies the boundary between stable and unstable parts; b) displacement image from March 7th to March 28th, 2010



Comparison of topographic and TInSAR displacement time series of the same point

6. CONCLUSIONS

TInSAR can be a very useful technique for the monitoring of buildings in urban areas especially in the following cases: 1) emergency conditions that require high sample rate and do not allow a suitable planning and installation of targets; 2) investigation monitoring in order to map in detail the areas affected by displacement with respect to stable ones.
However, suitable planning and processing procedures have been demonstrated to be very important in performing effective monitoring.
The correction of atmospheric noise by using weather data and the rigorous projection of TInSAR data on Terrestrial Laser Scanner derived point clouds seems to be very promising to improve the efficacy of TInSAR monitoring.

REFERENCES

1. Ng, C.W.W. (2008). Geotechnical aspects of underground construction in soft ground: proceedings of the 6th International Symposium, (IS-Shanghai 2008), Shanghai, China, 10-12 April 2008.
2. Massonet, D., Fiegl, K.L. (1998). Radar Interferometry and its application to changes in the earth's surface. Reviews of Geophysics 36(4): 441-500
3. Mazzanti, P. (2011). Displacement Monitoring by Terrestrial SAR Interferometry for Geotechnical Purposes. Geotechnical instrumentation news, p. 25-28, June 2011.
4. Taylor, J. D. (2001). Ultra-wideband radar technology, CRC Press.
5. Bozzano, F., Mazzanti, P. & Prestininzi, A. (2008). A radar platform for continuous monitoring of a landslide interacting with an under-construction infrastructure. Italian Journal of Engineering Geology and Environment, 2, 35-50.