A NOVEL MICROWAVE INTERFEROMETER USED FOR MONITORING STROMBOLI VOLCANO

Linhsia Noferini, Daniele Mecatti*, Giovanni Macaluso*, Massimiliano Pieraccini*, Maurizio Ripepe***

* Department of Electronics and Telecommunications, University of Firenze,
via S. Marta 3, I-50139 Firenze, Italy
**Department of Earth Sciences, University of Firenze,
via G. La Pira, 4, Firenze, 50121, Italy
Email: linhsia.noferini@unifi.it

Stromboli volcano (Eolie Islands, Italy) is one of the most intensively surveyed volcanoes of the world. The huge amount of data collected by a variety of instruments that have been installed nearby for monitoring deformations, gas emissions and seismic activity, has made Stromboli a special test site for researches about unequivocal warning signals (precursors) ahead parossistic explosive events.

In this context, an interferometric radar measurement campaign was arranged on September 2008 in the framework of a collaboration between two laboratories of the University of Firenze: the Laboratory of Technologies for Cultural and Environmental Heritage and the Laboratory of Experimental Geophysics.

The survey focused on exploring the possibility of measuring the terrain deformations with time around the craters even while they were erupting.

A commercially available interferometric radar sensor, which is generally used for structural health monitoring of buildings [1], was adapted for fulfilling the basic requirements of crater monitoring (operative range, sampling, timing). Anyway, because the dynamics and the extent of the deformations were unknown since they hadn't been measured before, the working configuration couldn't be optimized properly.

The radar system used for the reported activity consisted of a radar unit working at 16.95 GHz, a tripod as support and a control unit. The small size of each module made the system easy to be transported. The maximum working distance was up to 2 km, range resolution was about 0.5 m and the viewing angle about 15°. In order to observe fast phenomena occurring within few seconds as volcanic eruptions are, range profiles were gathered at 5 Hz sampling rate.

The system was mounted on top of the volcano (905 m a.s.l.), looking down at the craters that were at about 400 m distance (see Fig. 1 and 2). The resolution cell at that distance was about 50 m2. Data from each bin of the range profile refer to the overall content of the corresponding resolution cell. There is no possibility of distinguishing the reflectors inside a resolution cell.

The system worked for 3 days, the 26th, 27th and 28th of September 2008, in daylight conditions. As it was resulted from seismic and infrasonic recordings, in that period the volcano's activity was characterized by low-intensity explosions (8-10 events per hour) from the North-East crater and the South-West crater with emission of gas, ashes and slag and degassing (puffing) from the central crater.

Radar data were compared with data collected by conventional sensors operated by the Laboratory of Experimental Geophysics.

In particular radar data analysis focused on the investigation of different quantities: the amplitude and the phase of the backscattered radar signal and their rate of variation with time. Radar data were arranged in matrices whose rows corresponded to the bins of the range profiles and columns contained radar data collected at different times. Spatial and temporal information could be appreciated at once.

From the amplitude analysis, information about the time of an explosion and the area affected from the explosion allowing the identifications of the erupting crater could be retrieved. Limitations come from the restricted area illuminated by the radar that couldn't comprise all the three craters at the same time. Generally only two of them could be illuminated. The duration of each event could be appreciated and agreed with that one from the seismic signal.

Phase analysis was particularly interesting because it could provide quantitative information on deformations. From the phase it was possible not only to detect time and location of the explosive events, but also the extent of the generated deformations. It was observed that at each explosion, initially the area closer to the radar with respect to the crater appeared to move toward the radar of some millimetres or centimetres even, according to the strength of the explosion, while the other side of the crater moved departing from the radar. After having reached its maximum deformation, corresponding to the gas emission, the crater appeared to collapse almost elastically to its original size. These movements that were clearly observed at each explosion and at each illuminated crater, involved the all area surrounding the crater (about 50 m far from its center) and seemed to propagate from the bottom to the top of the crater.

Figure 1: radar system and illuminated craters.

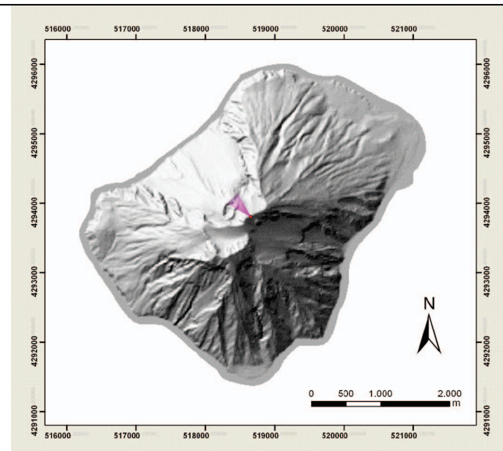

Figure 2: radar position on top of volcano and illuminated area in purple.

[1] M. Pieraccini, F. Parrini, M. Fratini, C. Atzeni, G. Pinelli, “Static and dynamic testing of bridges through microwave interferometry”, NDT and E International, Elsevier, 2007