# Versatile And Interactive Surveying Methodologies To Provide Specific Topographic Solutions. Case Of Study: Evaluating A Radio Antenna's Prototype

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**Key words**: Geomatics, Surveying, Laser scanner, Total Station, Topography.

## Abstract

Geomatic technologies nowadays offer extremely useful opportunities, however, there are still a lot of cases where surveyors have to overcame with the traditional topographic methodologies integrating different instruments and elaborating numerous data to achieve the final results. In this paper the example of a rather complicated case study is presented to show how a versatile and intelligent use of many surveying instruments, correctly integrated among them was able to brink extremely satisfying results on an experiment where surveying techniques initially seemed not helpful, in particular, this case regards the evaluation of an antenna's prototype developed for identification of bodies trapped under collapses in post-earthquake or other hazard situations. To encounter this case, a number of instruments like laser scanner, total station and GNSS receivers were correctly combined to evaluate the exact position, dimension and orientation of the two prototypes in the three-dimensional local space of the test area. All measurements were appropriately processed to create information that compared with the data received by the antennas could verify its precision, accuracy and efficiency. The test area was a post seismic scenario among the destroyed buildings of Onna, a small village unfortunately wiped out by the earthquake of April 6, 2009. All surveys were curried during the months of June, July and August of 2011. Finally, this case emerged when Geomatica_Lab was asked to evaluate the two prototypes developed by the a researching team in the university of L'Aquila, department of electrical engineering.

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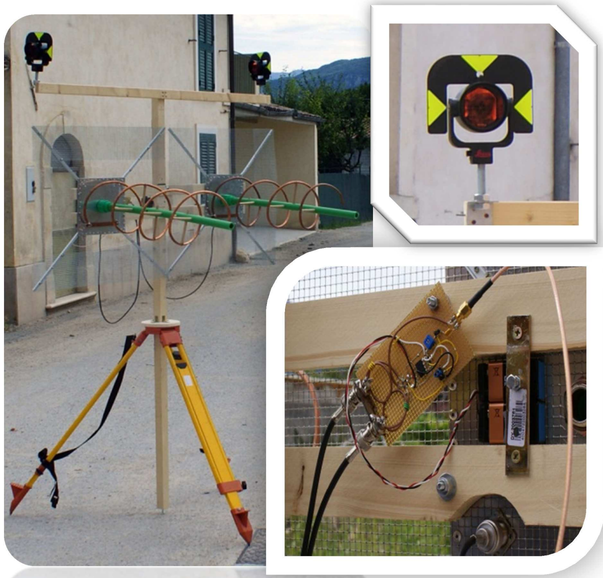
## INTRODUCTION

The wide range of surveying instruments available these days, when integrated correctly among them can provide a lot of valid solutions to overpass many challenges. Even if modern algorithms can now create sophisticated software that enhance the limits for many operations a correct application of the traditional topography is always crucial in order to generate accurate results. An example of both the integration of many instruments and the good application of the surveying principles was represented by this case study that regards the evaluation of a radio antenna's efficiency. This prototype was created after the earthquake that hit L'Aquila three years ago. During this catastrophe more than 300 people lost their life under collapsed buildings; countless people were saved by the rescuers of the civil protection and firefighters that arrived immediately to manage this emergency. Many less fatalities would happen if a system could investigate the space covered by collapses in order to identify trapped persons in need of help. This idea motivated a research team in the Dept. of electrical engineering in University of L'Aquila to experiment a Radio Antenna that would be able to detect signals produced by devices that are buried with the trapped people. The radio antenna would use a localization technique that is based on directional methods, in particular, a continuous wave (CW) system would estimate the Direction of Arrival of the signal radiated by a buried device. The effectiveness of this system mostly depends on the surrounding scenario with its specific propagation phenomena as in most cases many surfaces can reflect the signal distorting the obtained direction by the system. Therefore, an accurate evaluation of the signal's Direction of Arrival by a detailed determination of the antenna's position and the geometric characteristics of the surrounding scenario was a key element for this test. To curry this operation the problem was divided in three parts: the scenario reproduction with a laser scanner, the accurate topographic control network in order to georeference all data and create a numeric layer in all measurements and the angle and distance measurements of the antenna in order to estimate its position over time. In figure 1 the first prototype of this antenna is shown to the test area of Onna, a small village about 5 kilometers away of L'Aquila (figure 2).

## 1. Test Area and surveying methodology.

As described in the introduction, the effectiveness of this antenna was directly connected to the so called path loss that describes the reduction in terms of the power's density (attenuation) of an electromagnetic wave as it is being propagated through the space.



Figures 1 & 2
The test area evidenced in red on the left and the antenna's prototype with a particular of its hardware on the right.

This phenomena is highly amplified when in the propagation space the signal encounters flat surfaces like buildings that can cause its reflection; this scenario is exactly similar to the post seismic situation of any square in the old city centers around L'Aquila so a test area with similar characteristics had to be used in order to correctly evaluate this antenna. After searching the l'Aquila's surrounding and with the local authorities' collaboration a destroyed square was found in the center of Onna (figure 2). In order to simulate signal that would be emitted by a trapped person and detected by this antenna a radio signal emitter was placed under a pile of rubbles in a known position. (figure 3) The antenna would be placed in surrounding positions and rotated around itself, every time that the antenna's normal direction was passing through the point of the signal's emission a characteristic sound would be reproduced by an onboard speaker to indicate that from that direction of propagation a signal is being emitted. The surveying methodology was based on the determination of the antenna's position and orientation by calculating the position of its two extremities where a couple of surveying reflectors was placed. With simple mathematic procedures, assuming that the antenna's face was vertical, its normal direction in that space could be calculated. And confronted with the real direction of the signal's arrival evaluating the deviation between them. In this way, not only the correctness of the data received by the antenna could be evaluated but also an eventual systematic errors on the antenna's direction could be found.

Figure 3
Placing the emitter under collapses to simulate a trapped body that creates a radio wave.

## 2. Site's topography

The first think to do in the pilot area was creating an three dimensional local reference system that would be used in order materialize all points and certainly to orientate the total stations. To correctly do this, three orientating points where materialized in relatively steady surrounding buildings. The origin of this system was also materialized in a strategic position that would permit the surveying on a great part of the test area with good visibility. As described above the test area was an extremely difficult place with narrow streets and collapse everywhere, thus, in order to be able to cover with surveying all its surface another 5 points where materialized and connected to the origin of this system creating the well triangulated surveying base. The coordinates of all these 5 control points were calculated so that other instruments could make station on each control point and orientate themselves. The distribution of these control points where crucial as the good visual to the whole test area had to be guaranteed. In figure 4 the test area's topography is shown. The three orientation points are evidenced in yellow while the materialized control points are marked in red. In this orientation system, any instrument like total station or laser scanner could make station in any of these points and orientate itself on any of the surrounding points.

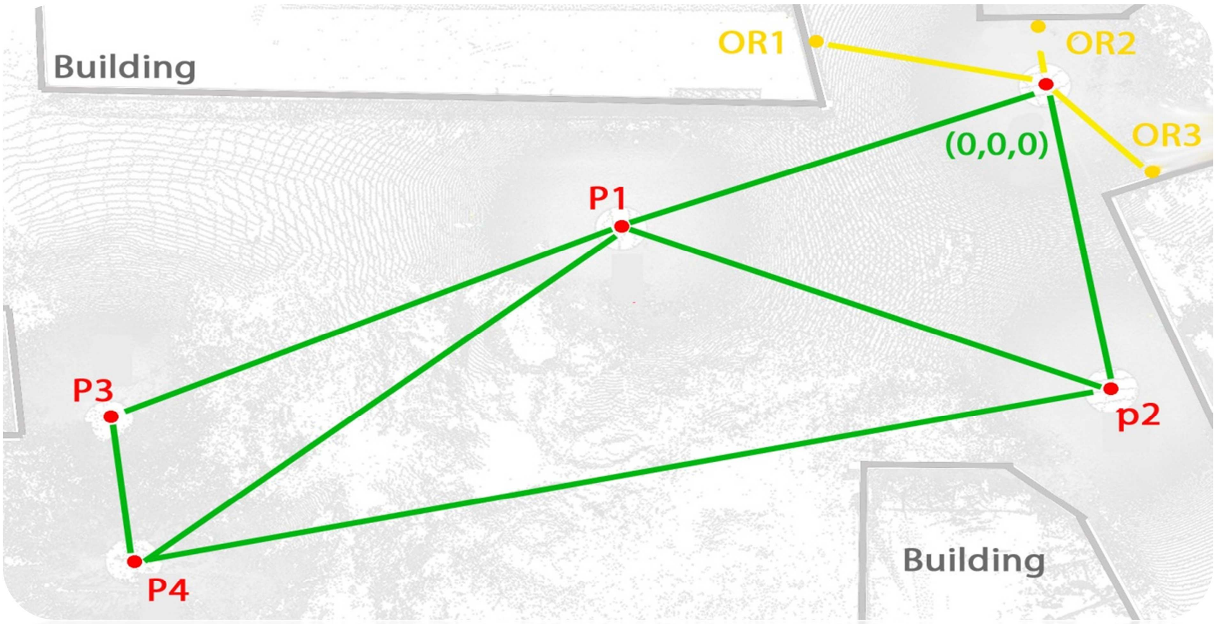
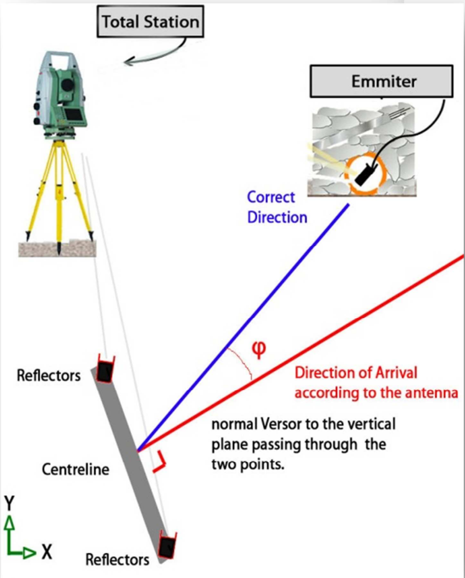
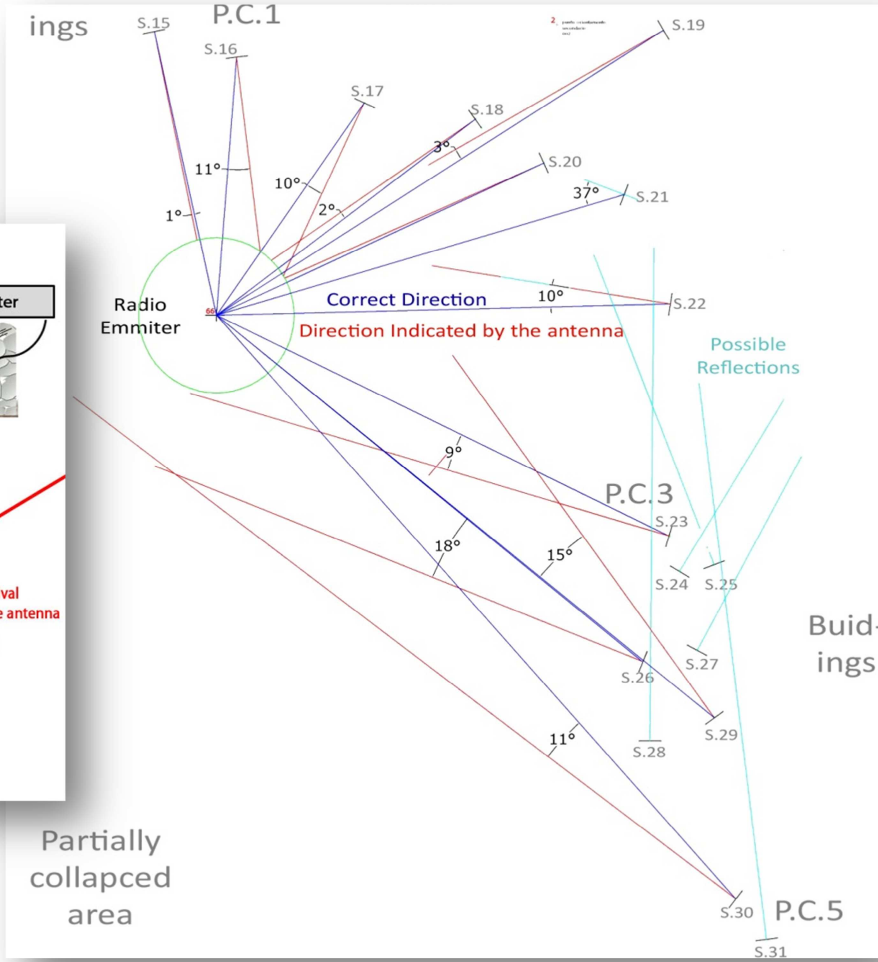



Figure 4
The local topography features the origin (000), three orientating points to enhance the networks accuracy (yellow) and 5 materialized vertexes to be used by any instrument (red).

## 3. First Surveys.

When the test area's topography was ready the first measurements could begin. For this case the main instrument was a total station TS30 with ultra millimetric accuracy. This instrument was initially made station on point 0. The radio transmitter started emitting a signal and the testing antenna was placed in the area. In order to evaluate the direction indicated by the antenna two very accurate reflectors where statically fixed in the antenna's extremities as shown and described above. Moreover, a spherical level was also installed to the antenna in order to prove its perfect verticality during all surveys. The coordinates of the two reflectors where surveyed by the total station, assuming that the antenna was vertical these two information permitted to calculate the vertical plane passing through the two points of the antenna that in fact is perfectly coincident to the antenna's face. With simple geometric operations the centerline between these two points was find and in that point the normal to the surface versor was calculated. This was the direction of the signal's arrival according to the antenna. The same procedure was operated many times moving the antenna around the emitter and determining continually the direction of the signals arrival. With the total station, the coordinates of each station with the antenna where saved to be compared during the elaboration with the effective signal's direction. In the figure 5 the estimation method for the signal's direction is shown while in figure 6 the plot of the first 50 stations are drown.




Figures 5 and 6

On the Left the DOA’s estimation method while on the Right the first 35 stations are plotted.

Evaluating the first results, as was expected, the fact that immediately emerged was regarding the completely wrong directions revealed by the antenna (marked in light blue in figure 6) that certainly had to do with reflections. Studding better the test area about 40 possible elements that could generate reflections were found, these elements were the building’s doors and windows, metallic garage doors and especially the building’s facades themselves. The only correct way to evaluate these apparently wrong directions was either control every possible flat surface that as described could generate reflections or to operate a geometric three dimensional survey in order to detect and represent all surrounding elements present in the test area. The last solution could be very useful so a laser scanner survey was decided.

## 4. Laser Scanning Survey.

The impotence of an accurate and detailed topography was immediately evidence when the use of a laser scanner was decided. In fact, the non-optimal visual due to the presence almost everywhere of collapses and other reported materials made needed at least three or four point clouds to entirely cover the whole test area. All scans where operated making station to the initial points that where materialized for the preliminary triangulation network. Finally 5 point clouds where curried in order to perfectly cover the square. These point clouds where combined during the elaboration creating a unique point cloud of about 7.5 million points. Having the coordinates of each station the integration between each single scan was extremely accurate, finally some parts of the final scan were deleted in order to lighten the final data made of 4.5 million points distributed in useful areas. In figure 7 the first orthophoto of the final point cloud is presented both in view from top mode and in a manual point of view to evidence the dimensions of the test area.

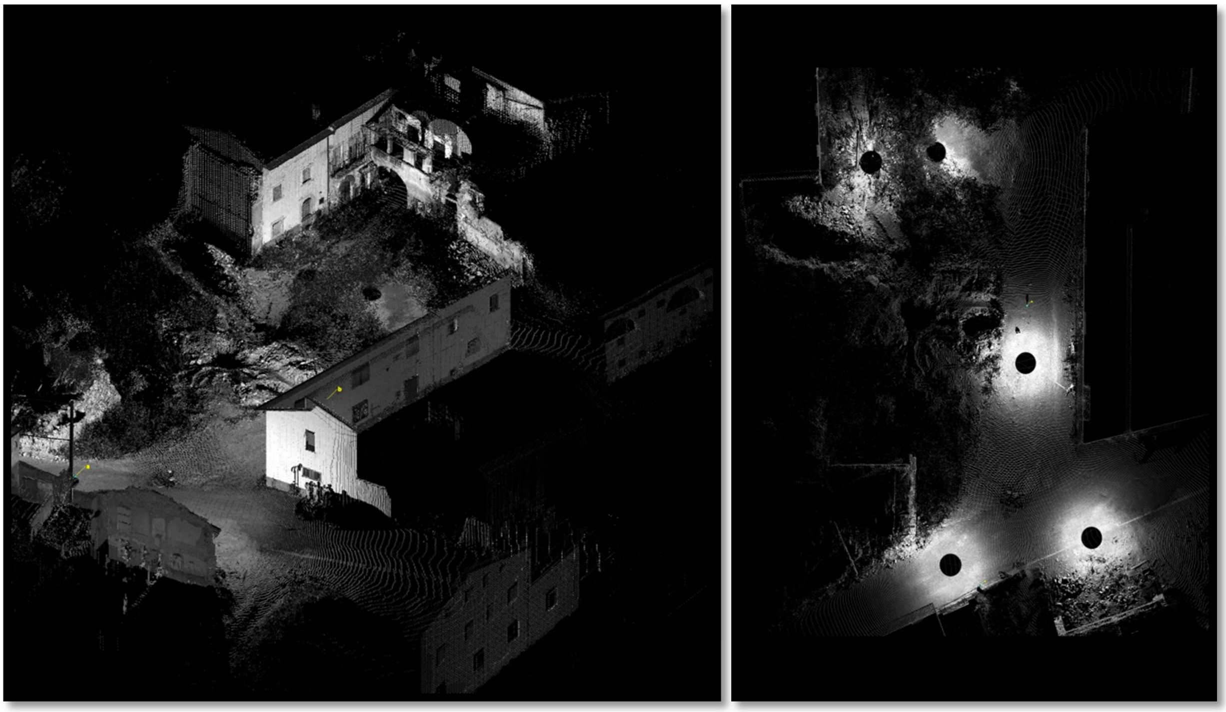


Figure 7
Exports of the final point cloud. The 5 points where the instrument made stations are visible in black (no data). On the Right in view from top mode.

Having this three dimensional representation of the test area the individuation of all materials, elements or any other kind of obstacles presented in the test area could be at least geometrically identified in order to evaluate any strange direction found by the antenna and examine weather depends on a reflection or not. Firstly, using some filters of conventional image editing software, the view from top image, from now on called map, was cleaned in order to better evidence all walls, building and especially metallic elements as windows or garage doors that can in a particular way affect the signal's propagation. (figure 8) After the image's adjustment, using the control points and their known proportions the map image was reported in the same scale of the other measurements made by the total station. Having both data in the same scale an ulterior evaluation of each direction detected by the antenna was possible by overlapping the two data.

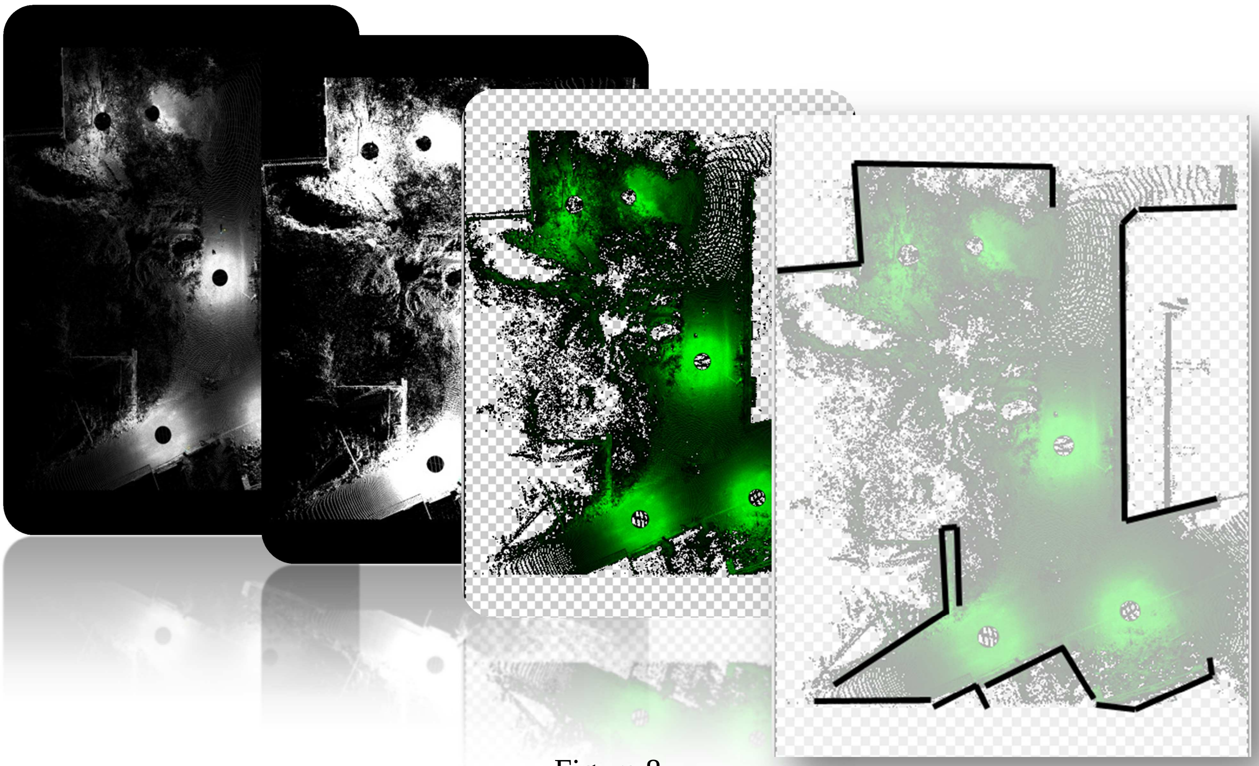


Figure 8
Editing the view-from- top point cloud export to evidence flat surfaces that can generate reflections. This adjustment was made by widely used conventional software for image editing.

In fact, most of the apparently strange directions were proven to be reflation caused by surrounding walls or even results of multiple reflections of a long multipath among vertical planes.

## 5. Final elaboration and integration

With this information the exact origin for each signal's direction of arrival was easily calculated even in cases that the resulting direction was a fruit of long multipath. (figure 9) Some statistical considerations were possible as all stations were resolved. In particular, the average diversion expressed as the formatted angle between each indicated and each correct directions was used to determine the standard deviation (σ). Thus, an estimation of the success percentage and the probability to correctly identify the origin of a signal that is being propagated under the collapses was calculated. In figure 9 also the eclipse average error is drown to show that in 99.5% of the cases the antenna was able to correctly detect the signal's origin within a metric error. As the antenna was only a prototype the values of the final results cannot be published in this paper, however, the final map containing most of the stations are shown in figure 9.

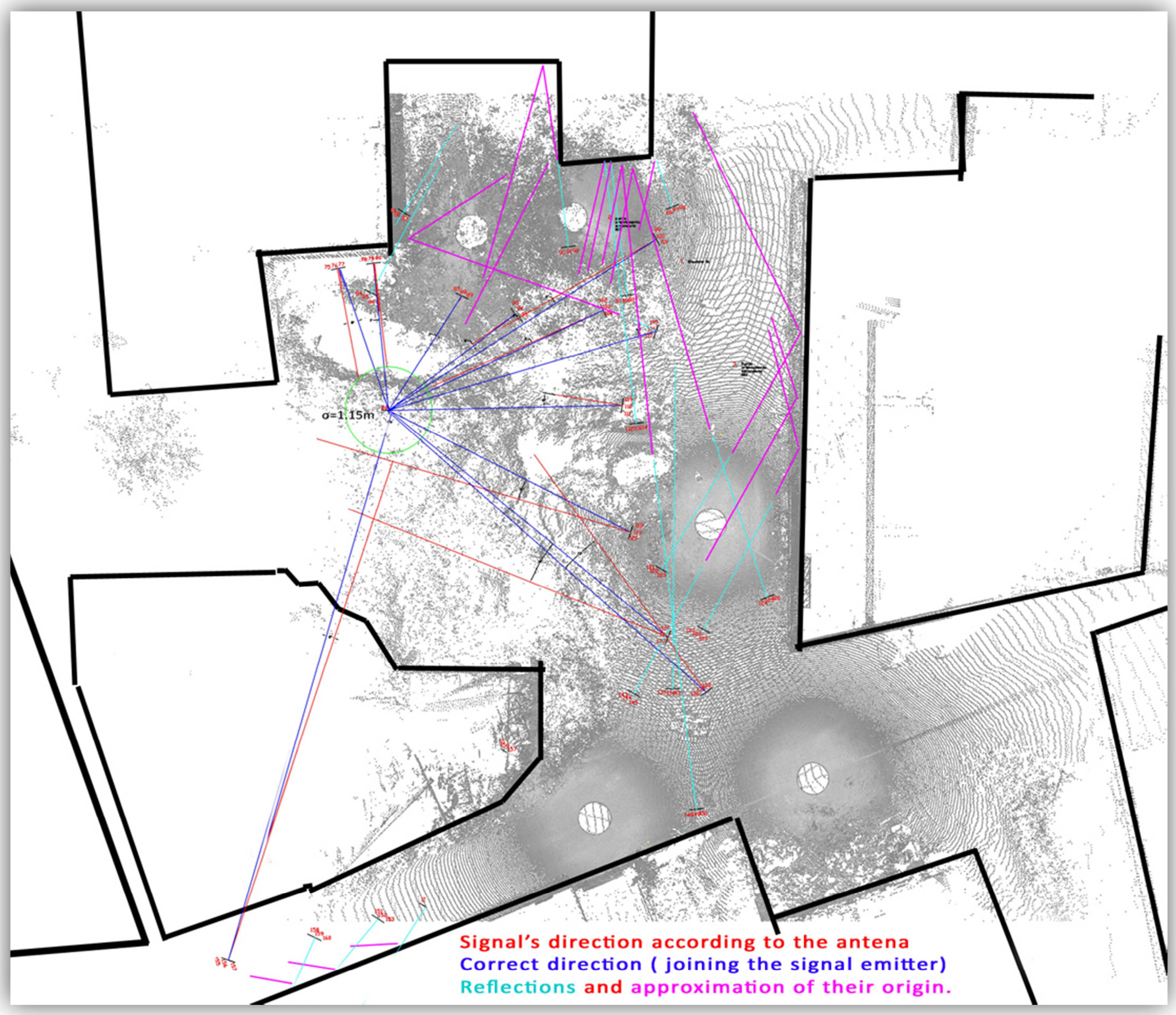



Figure 9

Final elaboration: overlapping the laser scanner scenario, the detected limits for all buildings and a part of the antenna's measurements. With all these data an evaluation of all reflections was possible, in fact, the correct detected direction are marked in blue, the deviations are marked in red, finally all reflection and an estimation of their origin is plotted in light blue and magenta respectively.

## 6. Conclusions and future operations.

This paper aimed to present the evolvement of this case using a wide range of different instrument and techniques. The real motivation for this work was to evidence that there is no need of searching particular and specific methodologies to overcame each apparently complicated situation as the integration and the intelligent use of the existing instruments and methodologies can surely work for many purposes. In future, the same methodology will be ulteriorly enhanced by using GNSS receivers in RTK mode in order to continually track the position of the antenna's both extremities over time. The simple geometrical equations needed to elaborate these coordinates can be loaded in an algorithm that will be able both to track these data in real time and to calculate these results in any needed form. In this way a further automation both for the testing of similar antennas and for their future applications can be possible.

## Biographic notes

**Donatella Dominici**

Donatella Dominici is an associate professor in Engineering's Faculty - University of L'Aquila where teachs Surveying, Satellite Geodesy and Remote Sensing. She obtained a Ph.D.in Geodesy and Surveying in 1991 from Bologna University. Her areas of expertise are GPS analysis data and design network The latter includes design and materialization of GPS permanent network for Abruzzo Regional Council , monitoring with high resolution satellite images Abruzzo's coastline. She is the coordinator of Laboratory of Geomatics in Faculty of Engineering of L'Aquila, member of editorial board of Applied Geomatics and member of AFCEA 's council.

**Elisa Rosciano**

Elisa Rosciano is currently a PhD student under prof Galeota in structural engineering Dept and Prof Dominici in Architecture and Ciry Planning Dept. She has participated in numerous research projects mainly with laser scanning surveying and other geomatic tecniques. Currently deals with the application of laser scanners for surveying in the post seismic recovery of the old city center of L'Aquila.

**Michail Elaiopoulos**

Michail Elaiopoulos is a graduating student in civil engineering under Prof Dominici. During the last months deals with structural monitoring of masonry monumental building using geomatic techniques for his thesis in Geomatica_LAB - University of L'Aquila.

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