Preface

Ground-based/terrestrial radar interferometry (GBRI) is a scientific topic of increasing interest in recent years. The GBRI is used in several field as remote sensing technique for monitoring natural environment (landslides, glacier and mines) or infrastructures (bridges, towers).

These sensors provide the displacement of targets by measuring the phase difference between sending and receiving radar signal. If the acquisition rate is enough the GBRI can provide the natural frequency, e.g. by calculating the Fourier transform of displacement.

The research activity, presented in this work, concerns design and development of some advanced GBRI systems. These systems are related to the following issues: detection of displacement vector, Multiple Input Multiple Output (MIMO) and radars with 3D capability.

The conventional GBRI measures only the component of displacement along range direction. A GBRI operating in monostatic and bistatic modality is presented in this work. The sensor detects the first component of displacement as the conventional GBRI (monostatic) and an additional component through a transponder (bistatic).

The radar has been successfully tested in controlled environment using a basic transponder (two antennas and an amplifier). The transponder has

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been improved in order to increase the gain of the amplifier and to solve some issues of the basic version. Finally, the system is used in real application for measuring the natural axis of a telecommunication tower.

The most advanced GRBI system can measure the direction of arrival of scattered signal by exploiting the movement of the antenna on an axis (Ground Based Syntetic Aperture Radar - GBSAR). The step between two position on the axis has to be smaller than a quarter of wavelength.

The emerging Multiple Input Multiple Output (MIMO) technique can be used to reduce the mechanical movement parts and the problems related to these. Also for MIMO radar the spacing between two closer phase center has to be smaller than a quarter of wavelength for the Shannon theorem.

In this work a Compressive Sensing (CS) MIMO radar is described. Indeed the CS is a technique able to reconstruct signal without the constrain of Shannon theorem. The signal has to be sparse and randomly sampled in order to use the CS.

The CS technique can be applied for increase the scan-length of a MIMO system of $40\% \div 50\%$. Therefore, by using the same number of antennas, the CS allows to increase the angular resolution of a MIMO radar.

A prototype of interferometric CS MIMO radar has been developed and tested on some bridges. The results were compared with a conventional GBRI with a good agreement. The CS MIMO radar was able to discriminate the left-right movement of bridges. Unfortunately the repetition rate of this prototype was not enough to retrieve the spectra of natural frequency.

Since the movement is along a single axis the obtained radar image does not have angular resolution in the plane orthogonal to the scan axis. In other words, if the radar head scans along the x-axis the radar image cannot have resolution in elevation angle. This is not a serious problem when the scenario is a slope, where the elevation (z-axis) can be reasonably considered an unambiguous function of the (x,y) position. Unfortunately there are cases where the geometry of the structure under test is much more complex, i.e in urban environment.

In this thesis two radar systems with three dimensional resolution are reported. This two systems synthesize the two technique previously described. Indeed the first sensor uses the bistatic principle by exploiting the movement of an additional antenna in vertical axis for obtaining the resolution in elevation. The second system exploits the movement on an horizontal axis of the CS MIMO with phase center positioned on a vertical axis.

In order to test the capability, the two radars were located in a urban scenario in front of a 7-storey building. Both systems were able to provide a 3D image of the building.