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Security enhancement in small private airports through active and passive radar sensors

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***Abstract*—In this paper we examine the potentialities of an innovative surveillance system composed by passive and active radar sensors for enhancing the security level in small airports and private runways. Specifically we report on the R&D activities carried on within the EU project SOS (Sensors system for detection and tracking Of dangerous materials in order to increase the airport Security in the indoor landside area). These activities included a number of experimental campaigns where both the single sensors and the multi-sensor system have been extensively tested. To this purpose, we employed the WiFi-based Passive Coherent Location (PCL) receiver developed at SAPIENZA University of Rome and a Ku-band frequency modulated continuous wave (FMCW) radar developed by MetaSensing. Both the considered sensors allow a radar coverage suitable for the extent of a small airport area, though providing target measurements with very different accuracies. The experimental results reported in this paper prove the effective applicability of the proposed approach for small airports surveillance.**

Keywords—WIFi-based PCL, FastGBSAR, airport surveillance, multi-sensor surveillance.

I. Introduction

In the last years, the problem of improving security systems for public areas, such as airports, trains station, ports, has been dramatically increasing. In particular, the problem of air transport security has always been a priority for the European Union aviation industry, since airports can be considered a sensible target for terroristic acts.

The ATOM (Airport detection and Tracking Of dangerous Materials by passive and active sensors arrays) project, funded by the EU in 2009-2012, took this perspective and investigated new technologies in order to enhance the security level in the airport terminal areas [1]-[2]. By exploiting the ATOM project results, the EU project SOS (Sensors system for detection and tracking Of dangerous materials in order to increase the airport Security in the indoor landside area), moves another step forward and intends to develop a non-intrusive and pervasive surveillance system for airport and air transport security, based on an innovative combination of passive and active radar sensors operating at various frequency bands, [3]. The project involves three European universities (SAPIENZA University of Rome, Warsaw University of Technology and Deft University of Technology) and two industries (SESM-a Finmeccanica Company and MetaSensing BV).

In [4]-[5] the activities of SAPIENZA University of Rome and MetaSensing BV were jointly focused on the development of solutions for the surveillance of the airport's external area perimeter, in order to prevent threats from people or vehicle that are usually moving around the airport. In particular, the results showed that the X-band frequency modulated continuous wave (FMCW) radar sensor developed at MetaSensing could be used for detection, tracking and imaging of possible threats.

More recently, we considered the monitoring application of very small airports or private airstrips/airfields. With this terminology we refer to open areas designated for the taking-off and landing of small aircrafts, but which, unlike an airport, have generally short and possibly unpaved runways and do not necessarily have terminals. More important, such areas usually are devoid of conventional technologies, equipment, or procedures adopted to guarantee safety and security in large aerodromes. There exist a huge number of small, privately owned and unlicensed airfields around the world which are mainly used for recreational, single-person or private flights for small groups and training flight purposes.

In such scenarios, it would be of great potential interest the possibility to employ low-cost, compact, non-intrusive, and possibly non-transmitting sensors as a way to improve safety and security with limited impact on the airstrips users. Therefore, a dedicated experimental activity has been conducted within the SOS project in order to investigate the potentialities of a multi-sensor surveillance system based on both active and passive radar sensors.

In this paper, we report the results obtained in a test campaign performed in a small private airfield for light/ultralight airplanes by simultaneously employing the WiFi-based passive radar prototype developed at the DIET Department of the SAPIENZA University of Rome [6] and a Ku-band FMCW radar developed by MetaSensing. Aircrafts,

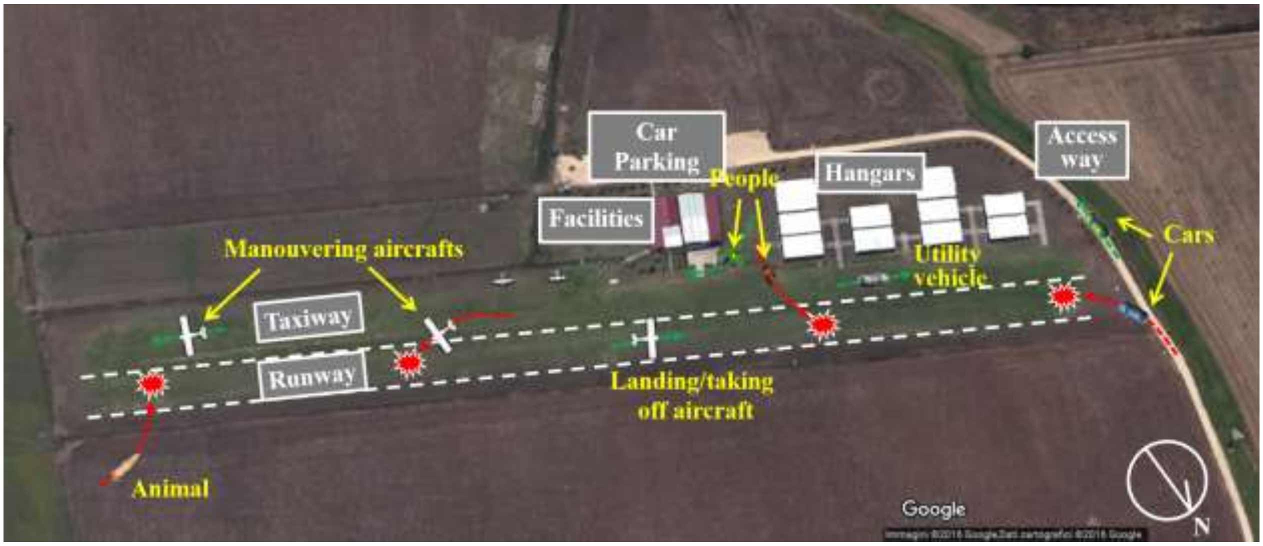


Figure 1. Scenarios of potential interest in small private airfield monitoring application.

cars, and people have been employed as targets of opportunity to simulate different operative conditions of interest.

The results obtained with the employed sensors support the practical applicability of the conceived system concept for improving safety and security of small private airfields and demonstrate its suitability to be usefully employed in such scenarios in the near future.

The paper is organized as follows. Section II illustrates the performed test campaign and the set-up of both the employed sensors. The experimental results are reported in section III. Finally, our conclusions are drawn in Section IV.

II. Acquisition campaign and receivers architecture

In this section we report the results obtained in the test campaign performed in a small airfield named "Aviosuperficie Monti della Tolfa" [7] located in Santa Severa (about 60km North of Rome). Figure 1 reports an aerial view of the airfield area. The airfield is only used for recreational and training flight purposes. It features a single runway, 520 meters long and 20 meters wide, with a grass surface. Depending on wind direction, take-offs and landings are performed with heading 120° or 300° w.r.t. North.

In the performed test campaign, we employed the experimental PCL receiver developed at SAPIENZA University of Rome, [6]. It consists of four parallel rx channels providing a fully coherent base-band down-conversion of the input signals; these are then synchronously sampled at 22 MHz and stored for off-line processing.

A commercial WiFi Access Point (AP) is used as transmitter of opportunity. Its output is connected to the transmitting antenna (TX) that is located at the point represented with the coordinates $(x_{TX}, y_{TX}) = (0,0)$ m; a directional coupler is used to send a -20 dB copy of the transmitted signal (the reference signal) to the first rx channel of the four-channel PCL receiver. The router was configured to transmit in channel 7 of the WiFi band (2442 MHz). It was set up to roam for connected devices emitting a regular Beacon signal exploiting a DSSS modulation at 3 ms intervals.

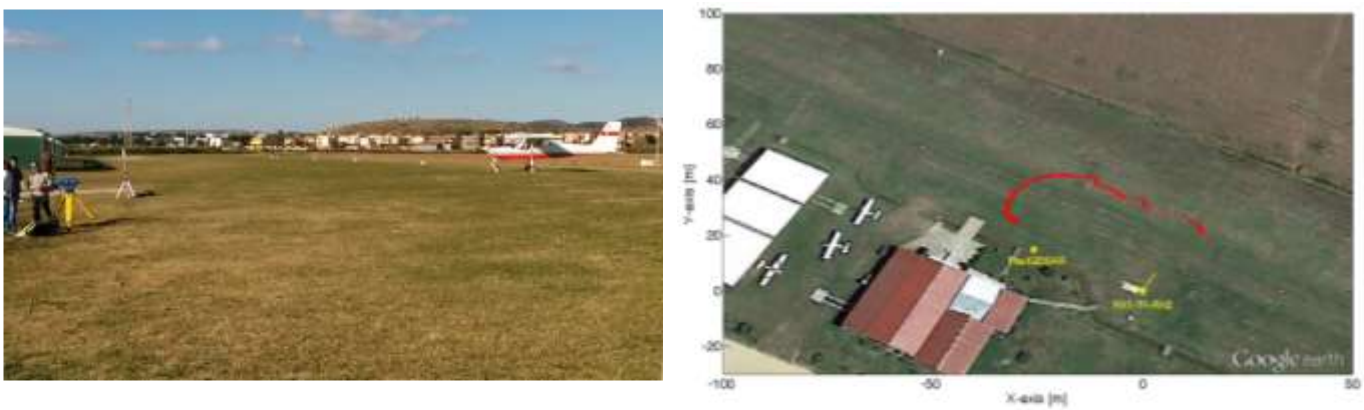
Other two rx channels are connected to commercial WiFi panel antennas to collect the surveillance signals; the employed antennas are characterized by a gain of 12 dBi, a front-to-back ratio of 15 dB and beamwidths equal to about 80° and 23° on the horizontal and the vertical plane, respectively. The surveillance antennas were mounted at a height of about 1.6 meters from ground, about 40 cm below the transmitting antenna, in a quasi-monostatic configuration, and they were pointed at 345° w.r.t. North. Moreover, they were displaced in the horizontal direction by 12 cm, which gives a 45° ambiguity for the target DoA estimation, based on an interferometric approach.

The WiFi-based passive radar processing scheme reported in [8] is applied against the collected surveillance signals separately at each channel. In particular, the removal of undesired contributions is performed with the sliding version of the extensive cancellation algorithm (ECA-S), [9], over a range of 600 m with a batch duration equal to 0.2 s whereas the filter update rate is equal to the beacon emission rate of the exploited AP. A Coherent Processing Interval (CPI) of 0.3 s is then used to evaluate the bistatic range-velocity map over consecutive portions of the acquired signals with a fixed displacement of 0.1 s and target detection is performed by resorting to a standard cell-average CFAR threshold with probability of false alarm equal to 10^{-4}. Then, a conventional Kalman tracking algorithm over the bistatic range/velocity plane can be applied to reduce the false alarms while yielding more accurate range/velocity measurements. The target 2D localization in local Cartesian coordinates is finally obtained by exploiting the range and azimuth measurements provided by the two horizontally displaced surveillance antennas, [10]. Acquisitions of about 20 s are performed.

The Ku-band FMCW (named FastGBSAR) active sensor developed by MetaSensing is located in (x, y) = (-26, 15) m. FastGBSAR is a Ku-band ground-based interferometric radar system designed for the deformation monitoring, vibration measurement and stability assessment of natural slopes and man-made structures, [11]. It has been used in Real Aperture Radar (RAR) mode; thus, it allows target detection over the

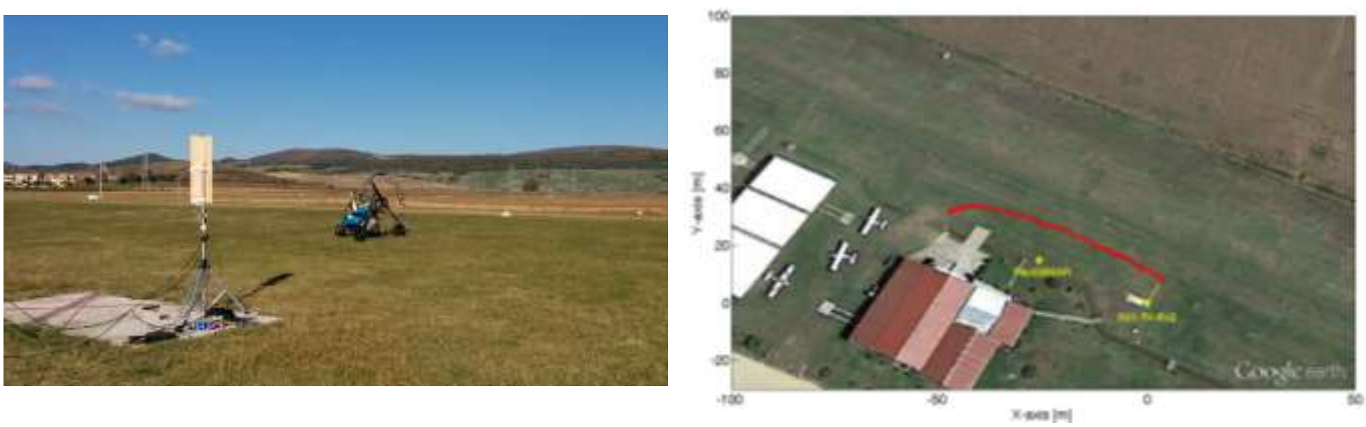
(a) (b)

Figure 2. Test against a landing aircraft: (a) picture of the performed test; (b) WiFi-based PCL localization results.



(a) (b)

Figure 3. Test against a maneuvering aircraft: (a) picture of the performed test; (b) WiFi-based PCL localization results.



(a) (b)

Figure 4. Test against a small maneuvering aircraft: (a) picture of the performed test; (b) WiFi-based PCL localization results.

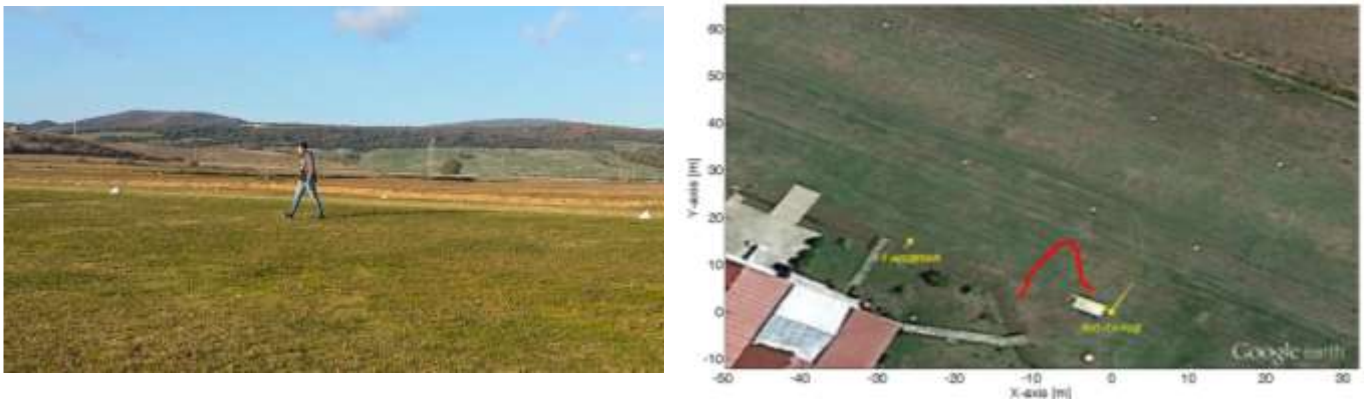
range/velocity plane only. Specifically, a maximum range equal to 4 Km is achievable.

Several tests have been performed against different targets of interest aiming at assessing the suitability of the conceived multi-sensor system with reference to typical operative conditions. Some examples are reported in the following section.

III. EXPERIMENTAL RESULTS

The experimental results reported in this section refer to the following test type:

- small aircraft moving on the runway for landing/taking-off;
- small aircrafts maneuvering in different areas of the airfield;
- a man walking around the airfield.



(a) (b)

Figure 5. Test against a human target: (a) picture of the performed test; (b) WiFi-based PCL localization results.

Figures 2-5 report the sketch of the performed tests and the target localization results of the WiFi-based PCL receiver. In Figures 2-5(b) the positions of the receivers and the main beam angular coverage of the PCL antennas are sketched in yellow.

We observe that the PCL sensor is able to detect the small aircrafts along their trajectory at least when they are included in the receiver antennas beamwidth. Specifically, aircrafts that moved on the runway just after landing are monitored up to 110 meters away from the receiver location [Figure 2(b)]. As expected, the target localization accuracy rapidly degrades as the aircraft gets far away from the PCL receiver; basically this is due to the decrease in the target echo power level and to the widening of the uncertainty x-y area caused by a given DoA error.

From Figures 3-4(b), we note that the passive sensor can also be used to monitor aircrafts activities in the proximities of the runway in order to avoid accidents due to intentional/unintentional runway incursions.

Moreover, in typical operative conditions, many people might be walking around different airfield areas (i.e. club house, restaurants, etc.). Therefore, aiming at improving safety and security in such scenarios, the capability to reliably detect, localize and track human targets might be crucial. This possibility is proved in Figure 5 where the PCL sensor is operated against a man walking in the proximities of the airfield facility.

Figure 6 shows the range-Doppler analysis of an aircraft during the landing phases carried on with the FastGBSAR active sensor [Figure 6(a-l)]. From Figure 6(f) can be also noticed the deceleration of the aircraft when approaching to the ground. The measurements were performed with a PRF of 763Hz, obtaining a maximum range of 1800 m and an unambiguous radial velocity of 3.32 m/s.

Despite the fact that the PRF used is low and it covers a long range, the results of the Ku-band radar show a suitable sensitivity to the aircrafts during the phases of landing and maneuvering around the airport's external area perimeter.

The reported results prove the effective applicability of the proposed multi-sensor system for small airports surveillance. Obviously, better results could be obtained by jointly exploiting the measurements provided by multiple sensors properly dislocated on the area to be surveyed, [10].

IV. Conclusions

In this paper, the potentialities of an innovative multi-sensor system that integrates active and passive radar sensors for enhancing the security level in small airports has been examined. Specifically, a WiFi-based passive radar developed at SAPIENZA University of Rome and a Ku-band FMCW developed by MetaSensing have been employed. The proposed system is studied within the European project SOS. The tests performed in a small airfield have proven the capability of the multi-sensor system to detect and accurately track typical users of the airfield (such as small aircrafts and people).

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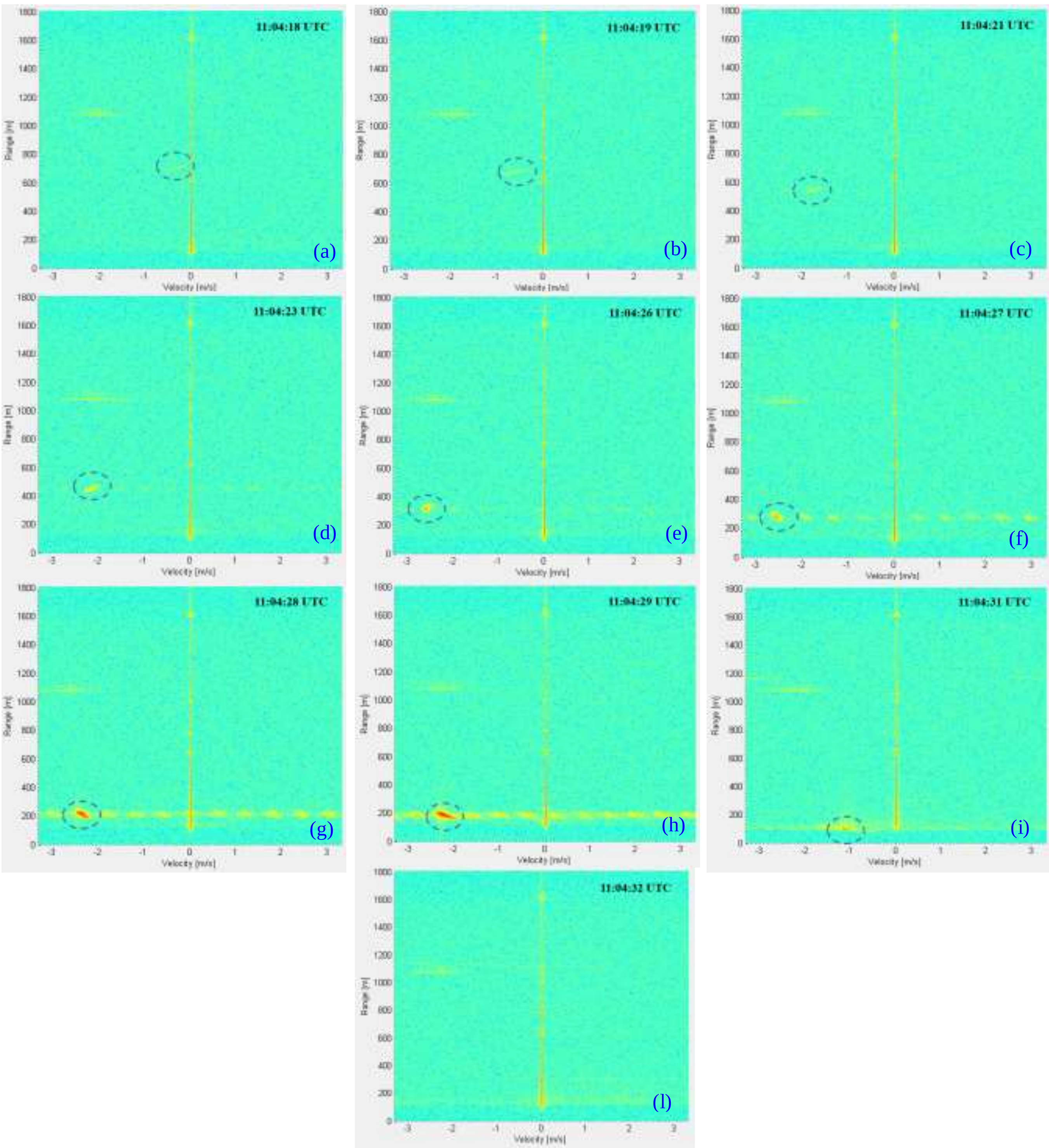

Figure 6. Range-Doppler analysis of a small aircraft during landing phases.