Passive Radar as a Part of Critical Infrastructure Protection System

Selected Results from SCOUT Project

Piotr Samczyński, Mateusz Malanowski, Grzegorz Krawczyk, Janusz Kulpa, Marcin Żywek
Warsaw University of Technology
Institute of Electronic Systems
Warsaw, Poland
p.samczynski@elka.pw.edu.pl

***Abstract*— This paper presents the concept of using passive radar sensor as a part of critical infrastructure protection system. This work has been done within the framework of FP7 European Union project on Multitech SeCurity system for intercOnnected space control groUnd staTions (SCOUT). In the paper the system design is shown along with selected results from the SCOUT project trials during which the protection the infrastructure of the Italian Space Agency has been analyzed.**

Keywords—passive radar; critical infrastructure; PCL; passive coherent location; PBR; passive bistatic radar.

I. Introduction

SCOUT (Multitech SeCurity system for intercOnnected space control groUnd staTions) was a project founded by the European Union whose aim was to develop a system for protection of the ground segment of the satellite link infrastructure [1-4]. Protection of the critical infrastructure from threats such as terrorist attacks is increasingly important, and it is one of the priorities of the European Union [1, 4-6].

Within the project two classes of threats were investigated: cyber attack and physical attack. In case of cyber attack, the critical infrastructure has to be protected at the network level. In case of physical attack, potential threats such as pedestrians, cars, drones or airplanes have to monitored. One of the sensors used for monitoring moving target is a passive radar, which is the focus of this paper.

The main advantage of using the passive radar technology in this applications is its silent operation, as the radar does not emit own energy and uses existing net of transmitters of opportunity for target illumination. Furthermore, lack of own transmission means that there is no need to allocate the spectrum for transmission, which puts this sensor in the category of 'green technology'. Moreover signal reception can be realized using commercial off-the-shelf (COTS) antennas, installation of which on the protected infrastructure is relatively easy, and also does not reveal the real use of antennas for radar application. This is because antennas for passive radars can look almost the same as antenna installation used to capture the radio or TV signals for user entertainment. This feature played an important role in selection of passive radar as one of the sensor to protect the critical infrastructure in the SCOUT project.

In the paper the general description of the project is provided. Next, passive radar sensor is presented. The results from the measurement camping are shown at the end.

II. SCOUT System Architecture

The general SCOUT system architecture is shown in Fig. 1. The system consist of three subsystems [1-4]:

- SENSNET, which is responsible for the detection and identification of the physical threats within the surveilled area and the perimeter of the protected infrastructure;
- CYBERSENS, which is responsible for the identification and neutralization the cyber attacks via the network infrastructure of the protected zone;
- RECOVER, whose main task is to recover the most important functionality of the protected critical infrastructure after an intrusion.

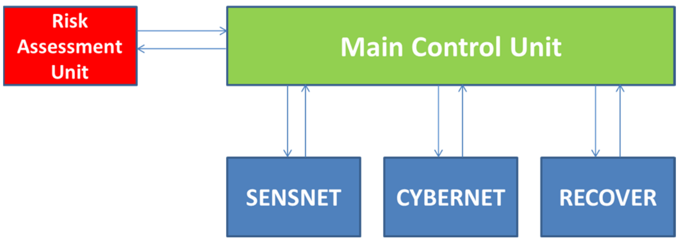

Fig. 1. Block diagram of SCOUT system

Passive radar described in this paper is one of the sensors used in the SENSNET subsystem. This subsystem consist of several sensors including: noise radar, Ka-band ground based noise SAR (synthetic aperture radar), Ku-band radar, optical camera and RFID (radio-frequency identification) sensors. The goal of the SCOUT project was to use sensors that guarantee the day and night operation in all weather conditions. In addition, the sensors should emit no power or emit very low power to ensure low probability of intercept (LPI). The information collected from all sensors is fused in the main control unit (S-MCU) and then passed to the higher level SCOUT main control unit (MCU). The main functionalities of the S-MCU is to manage and control all SENSNET sensors, fuse the detection information obtained from all sensors, and then classify the target, identify type of physical attack and manage communication from/to SCOUT MCU. The Risk Assessment Unit analyses the threats based on the fused data from the MCU.

III. PASSIVE RADAR SYSTEM

The passive radar used as a SENSNET subsystem component in the SCOUT project is based on DVB-T transmitters. DVB-T is a digital television standard used mainly in Europe, Asia, Africa and Australia. It usually operates in the UHF band, approximately from 400 MHz to 900 MHz. The power of the transmitters can reach over 100 kW, which provides potential of long range detection [7].

The bandwidth of the DVB-T signal can vary depending on the standard version, however, usually the 7.6 MHz bandwidth is used. This provides bistatic range resolution of approximately 40 m. When passive radar is used to detect aircraft at ranges of tens of kilometers, this range resolution is satisfactory. In case of surveillance of area around critical infrastructure, where targets are expected at ranges of several hundreds of meters, finer range resolution might be required. In such a case, several adjacent frequency channels from the same transmitter can be used [8]. Fig. 2 shows signal spectrum measured at the trials site. As can be seen, multiple DVB-T transmissions are present in adjacent frequency channels. These signals can be used jointly, providing better range resolution. It must be also noted, that in many places the single frequency network (SFN) is being used, which may require multi-hypothesis tracking module.

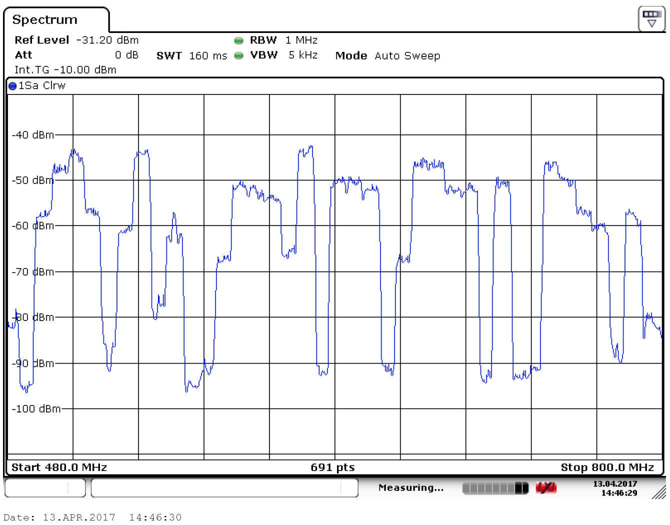

Fig. 2. Measured signal spectrum from 480 MHz to 800 MHz. Several adjacent DVB-T channels are visible

If slowly moving targets are considered, for example pedestrians, the velocity resolution of the radar becomes very important. The bistatic velocity resolution can be calculated as:

$$\Delta V = \frac{\lambda}{T}, \quad (1)$$

where λ is the wavelength and T is the integration time for which the crossambiguity function is calculated. This means that in order to obtain finer velocity resolution higher frequencies or longer integration times have to be used. In case of passive radar the frequency range is determined by the type of transmitter used for target illumination. However, the integration time T can be changed almost arbitrarily.

Fig. 3 shows the bistatic velocity resolution versus integration time calculated using formula (1). Different curves correspond to various frequencies approximately covering the DVB-T band. In order to distinguish the target from the clutter, the target echo should be at least in the second or third velocity resolution cell. Let us consider a person walking with the velocity of 1.5 m/s and a car moving with 30 m/s. That corresponds respectively to 3 and 60 m/s of the bistatic velocity, assuming the quasi-monostatic scenario. Therefore, the integration time for correct detection of pedestrian requires at least 0.5 s of integration time, whereas the detection of vehicle – only 25 ms. If multiple classes of targets are considered, the integration time has to be adjusted to the slowest target.

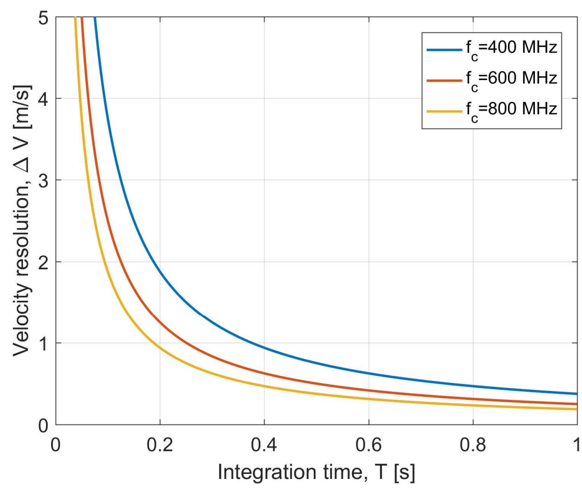

Fig. 3. Bistatic velocity resolution vs. integration time

IV. PASSIVE RADAR SETUP

Passive radar system hardware used in the presented SCOUT project consists of:

- Directional antennas
- Amplifiers and filters
- Software defined radio receiver (Ettus X310)
- Computer with GPU

Two directional antennas are used, one pointed towards the transmitter that provides the reference signal, and one pointed towards the surveilled area. The signals from two antennas are amplified and filtered. The signals are down-converted and sampled using software defined radio receiver (SDR). Here Ettus X310 has been used [8-10]. The effective sampling frequency (after decimation in the SDR) is 10 MHz, which is enough to process a signal corresponding to a single DVB-T channel. However, if more than one channels is required in order to improve range resolution, the sampling frequency can be increased. The sampled signals in digital form are sent from SRD to computer using 10Gbit Ethernet. The whole processing is performed on computer in real time.

The signal processing, which is a typical passive radar processing, consisting of:

- Clutter cancellation
- Crossambiguity function calculation
- Target detection
- Tracking in the bistatic coordinates

First the reference signal is used to remove the direct signal leakage to the surveillance channel. Then the cross correlation between the reference and surveillance signals is calculated, providing range-velocity surface, known also as crossambiguity function. The targets are detected by thresholding the absolute value of the crossambiguity function. Then, the plots that result from the detection are used to establish tracks in the bistatic coordinates.

In order to localize a target in Cartesian coordinates, more transmitters or receivers have to be used. In such a case, the target can be located by intersecting bistatic ellipses corresponding to different transmitter-receiver pairs. Another approach is to use the azimuth angle measurement, which, together with bistatic ellipse, provides 2D target position.

In the SCOUT project trials there was no requirement for localization of the target in the Cartesian coordinates. The aim of the project was to test the potential of different sensors to detect threats of various types, and not to deploy a fully operational surveillance system. For this reasons the bistatic data from the passive radar was fed to a centralized fusion module, which, based on ground truth data (GPS track from cooperating target), decided if given sensor was or was not capable of detecting a target.

V. MEASUREMENT CAMPAIGN

The measurement campaign took place in September and October 2017 in the Italian Space Agency (ASI – Agenzia Spaziale Italiana) in the south of Italy. The premises of ASI are an ideal place to test different scenarios concerning protection of the ground segment of satellite infrastructure. Fig. 4 shows the optical image from Google Earth of the surrounding area. The buildings of ASI are surrounded by shrublands. There are a few roads around the ASI area, which are to be monitored with passive radar.

Fig. 4. Satellite image of Italian Space Agency

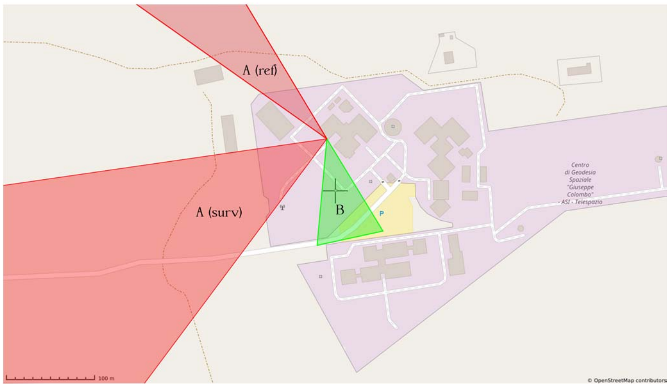

Fig. 5. Map showing surveillance area around Italian Space Agency

Fig. 5 shows a detailed map of the area with marked antenna beams of the passive radar: A (ref) – the reference beam of passive radar, A (surv) – the surveillance beam of passive radar. Beam marked with B denotes second sensor – an active noise radar, which has been also used in this trials as one of the component of SENSET subsystem [1-4].

The balcony where different radar sensors were mounted during the trails is shown in Fig. 6 with passive radar antennas (green) mounted at the pole (visible on the left of the standing person).

Fig. 6. Picture of the antennas of different radar sensors

VI. MEASUREMENT RESULTS

During the trials different types of targets were observed: small passenger cars, trucks, pedestrians and drones. The processing was performed in real time, so the performance of the radar was monitored during trials. In Fig. 7 a truck echo on the range-velocity plane is shown. The truck was moving on a road several hundred meters away from the ASI area. The truck echo visible in Fig. 7 at around 20 m/s bistatic velocity and 500m bistatic range.

In Fig. 8 a more challenging target is visible – a small drone, which is shown in Fig. 9. Passive radar was capable of detecting and tracking the small drone up to several hundreds of meters.

The data from the passive radar has been sent to the fusion center and merged with data from different sensors and correlated with onboard GPS trackers. It has been confirmed that the vicinity of the critical infrastructure can be successfully monitored using passive radar.

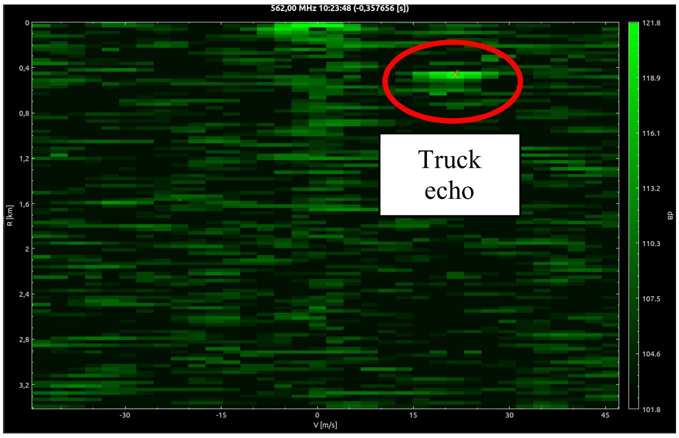

Fig. 7. Example of range-velocity map with a truck echo

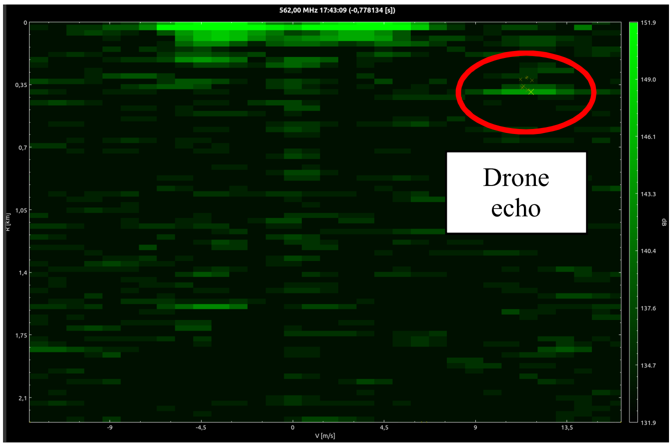

Fig. 8. Example of range-velocity map with a drone echo

Fig. 9. Picture of a small drone

VII. CONCLUSIONS

Results presented in the paper shows that passive radar sensor can be successfully used in the future as one of the novel sensor technology to protect the critical infrastructures against physical threats. The passive radar is able to detect and track wide spectrum of targets including ground moving object such as vehicles or human being as well airborne targets including planes, rockets and targets with relatively small radar cross section (RCS) such as small drones [11-18]. The potential of this technology is vast and authors believe that in the near future the demonstration phase will come to more mature stage, where the real operating passive radar will be used as a sensors to protect various types of critical infrastructure.

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