Electronic Countermeasure for OFDM-based Imaging Passive Radars

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***Abstract*—Passive radars are notoriously robust to jammer because the receiver location cannot be detected. Furthermore the use of OFDM based signal as reference signal further improve the robustness against jammers. Nevertheless this paper aims at proposing an electronic countermeasure for OFDM-based passive radars. In this paper a target-on-board deception jammer is proposed that aims at protecting the target itself from detection, localization and identification. The proposed system is required to operate in real time, which could be seen as a quite challenging objective. However the recent technological advances make the realization of a system able to sample a broadband signal, modulate it in amplitude and phase and retransmit it with a very short time delay, likely and possible.**

Keywords—passive Passive radar; radar imaging; ISAR; OFDM; Countermeasure.

I. Introduction

Radar imaging systems are used to obtain e.m. images of targets for the purpose of ATR (Automatic Target Recognition) especially for military applications. In battle scenarios, enemy combatants may attempt to use Electronic Counter Measures (ECM) to confuse such radars or to intentionally corrupt the received echo signals resulting in a poor radar image quality.

Passive radars are notoriously robust against such kind of ECM, either because the receiver does not transmit and hence cannot be intercepted, and because they use broadcast sources operating in frequency bands where it is usually forbidden to transmit for different purposes [1],[3],[4]. Therefore, conventional electronic jammer, such as “spot jammer” or “barrage jammer” cannot be used to interfere with the receiver operation.

Deception jammers can be a viable solution to be investigated as possible jammer against imaging passive radars [2]. Deception jamming senses the incoming radar signal and generates false echoes that emulate other targets thus hindering the receiver ability to identify the true target.

In this research activity, we will focus on digital broadcast signals and specifically on OFDM-based waveforms. We will analyze the case in which the jammer is installed on the moving target itself. Following this approach, the target is equipped with a Commercial Off-the-Shelf (COTS) transceiver able to generate and transmit omnidirectionally multiple echoes, each one corresponding to a moving target of similar shape of the real one, which will appear in the range/Doppler map at different range and Doppler coordinates. The false target echoes may be generated by sampling the received reference signal and by modulating the complex samples both in amplitude and phase according to the shape, RCS (Radar Cross Section) and motions of the false targets.

Transmitting false echoes gives a twofold advantage:

1) Conversely from the “spot and/or barrage jammer”, a low power false echo is sufficient to confuse the receiver. The false target echo power should be comparable to that of the true target echo which generally is many tens to even over a hundred dB lower than the reference signal power. This allows the average power on board of the platform to be shared for transmitting multiple signals, and therefore, several spatially distributed false targets to be generated.

2) Even though the target-born transmitter emits a low power OFDM signal, this signal cannot be intercepted since it is hidden by broadcast transmissions. Therefore, the transmitter on board of the platform cannot be intercepted.

To reproduce a false target, a point-like model of the target may be used. The low spatial resolutions generally achievable with passive radar imaging represents in this case an advantage since they contribute to make the range/Doppler image of a point-like target model similar to those of a true one. This contributes to further confusing the receiver in case it will try to identify the target through its ISAR images.

There are however some issues that should be taken into account during the system design phase.

The first one concerns the maximum allowed transmitted power. The target-borne transmitter should not interfere with broadcast transmitters. Considering the low power level of target echo at the receiver, it is sufficient to transmit low power signals to confuse the passive radar receiver.

The second one concerns the maximum allowed delay time in order to guarantee that a false echo well cross-correlates with the direct signal. The false target echo delay time is due to both the artificial delay time of the false target and the processing time needed to generate the false echo. The last one should be as small as possible in order to both guarantee a high integration gain at receiver and the possibility to generate multiple spatially distributed false echoes.

The remainder of the paper is organized as follows. Section II describes and gives the high-level concept of the electronic jammer on board of the target. Section III shows the simulation results and Section IV reports the main conclusions.

II. THE ELECTRONIC COUNTERMEASURE CONCEPT AND ARCHITECTURE

The target on board jammer aims at sensing the incoming signal and at generating false targets so as to hinder a receiver to identify the true target.

The block scheme of the target-on-board jammer is represented in Fig. 1 and Fig. 2.

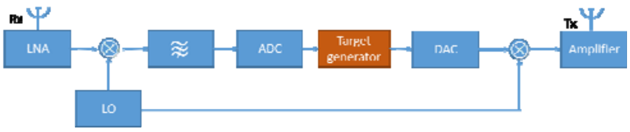

Fig. 1. Deception jammer block scheme.

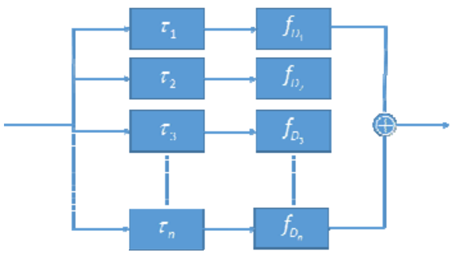

Fig. 2. Target generator block scheme.

The incoming signal is first amplified through a large bandwidth Low Noise Amplifier (LNA). A Local Oscillator (LO) is used to both down and up convert the signal. The base band signal is then filtered with a low pass filter and finally sampled at Nyquist rate in order to obtain the signal samples. At this stage a false target echo is generated by the target generator block. This block emulates the amplitude and phase history of a moving target by using the a priori known or estimated shape and RCS of the target itself and a false trajectory. The false echo signal modulates in both amplitude and phase the base band signal samples. The analog version of the generated signal is then amplified and transmitted.

The target generator generates more than one target as depicted in Fig. 2, where the first blocks introduce a fictitious delay for each false target and the second blocks introduce a time-varying phase term which depends on fictitious target radial velocities.

When this signal cross-correlates with the reference one at a receiver, each of the targets (either true and false) will appear at a delay-time and Doppler bin that depends on their motions with respect to the radar.

If the jammer a priori knows the transmitter of opportunity location, the target shape and mean RCS, together with its trajectory, then it is able to produce false targets with the desired RCS and trajectories different from that of the true target. Such false target will appear in the RD map at similar or even higher power level of the true target.

The false target power level in fact, depends on both the target RCS and the integration gain. The integration gain of a false target is usually lower than that of the true one since the false target echo will be delayed with respect to true target one. However, since the delay-time is typically much smaller than the Coherent Processing Interval (CPI), the integration losses are expected to be not so high. Therefore, false targets are expected to have similar or even higher intensity than the true target in the RD map.

Conversely, the false targets delay-time and Doppler coordinates are difficult to be controlled since the receiver location is not a priori known. Then, several false targets can be generated in order to reduce the probability of detection and identification of the true target.

III. SIMULATION RESULTS

A. Simulated case study description

The simulated geometry is represented in Fig. 4. The target is a ship which moves along y axis with constant velocity. The target is a point-like target as depicted in Fig. 3.

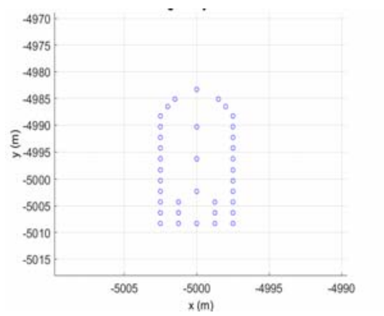

Fig. 3. Point-like target model.

The target is equipped with the jammer in Fig. 1, therefore it emits multiple echoes in every direction. It is supposed here that both the receivers start the acquisition at the same time instant.

A certain number of false targets have been emulated at different delay-time and Doppler and with different RCSs. As already said, in a real scenario the delay-time and Doppler frequency cannot be controlled by the jammer since the geometry is not a priori known. Conversely, since the bistatic RCS of the target is a priori known, the jammer can emulate targets with much higher RCS that will appear in the RD map with higher energy than the true one independently on the receiver location.

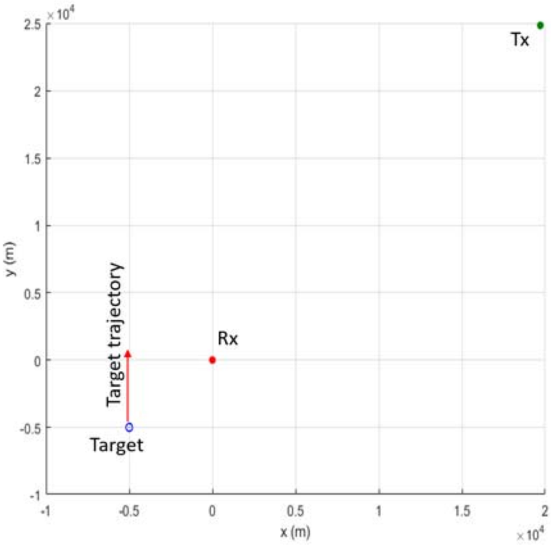

Fig. 4. Geometry of the simulated scenario.

The transmitted signal is a simulated DVB-T signal composed of three adjacent frequency channels centered at $f_0 = 698MHz$. The receiver bandwidth is $B = 8MHz$ and therefore it is able to receive only one of the three DVB-T frequency channels which compose the transmitted signal. In a real scenario to effectively deceive a receiver, the jammer should be able to generate false targets at different frequency bands and possibly by considering different illuminator of opportunities since it cannot a priori known what kind of IO (and therefore of signal) a receiver is going to use.

The processing chain at the receiver is depicted in Fig. 5.

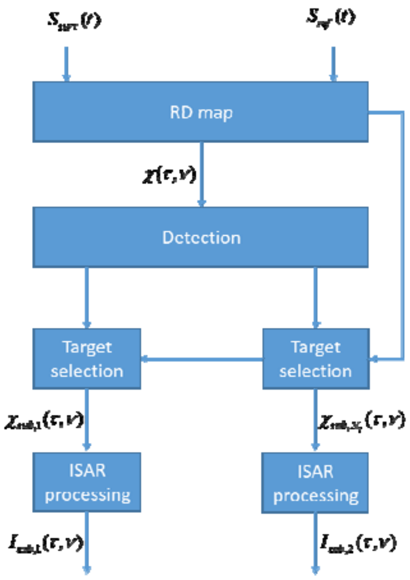

Fig. 5. Processing chain at the receiver

After the RD map computation, targets are detected. Passive ISAR processing is then applied to each detected target separately. Then, the detected targets are cropped from the RD map. The target sub-image selection aims at isolating the echo of that target from the received signal since the ISAR processing can be applied to a target at a time. Further details about this processing chain can be found in [5], [6], [7], [8] and [9].

B. Results

Fig. 6 shows the Range-Doppler map obtained at the receiver. The surveillance area is observed by the receiver for 6 seconds and the RD maps in Fig. 6 and Fig. 10 have been obtained by processing 0.5 s of the received data. The RD map in Fig. 6 contains 6 false targets that are located at different range and Doppler coordinates with respect to the true target. Fig. 7 represents a zoom of Fig. 6 where the red circled target represents the true one.

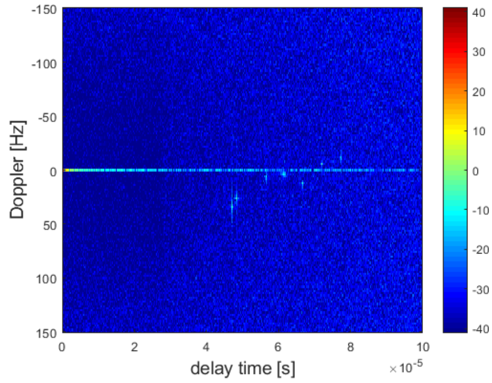

Fig. 6. Range-Doppler map obtained by emulating 6 false targets with both range and Doppler different from the true target.

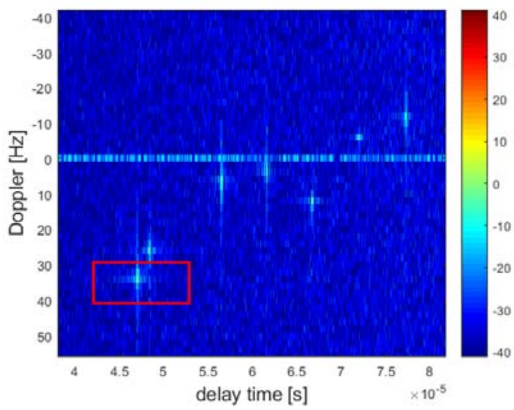

Fig. 7. Zoom of Fig. 6

To verify whether the jammer is robust against radar imaging, the passive ISAR image of the true target is compared with the passive ISAR images of the false targets.

Fig. 8 shows both the true target image before (left) and after (right) the ISAR processing. These two images are displayed in order to show that the passive ISAR processing is able to generate a better focused e.m. image of the target. Fig. 9

shows the ISAR images of two different false targets, specifically the closest (left) and the farthest (right) to the true one.

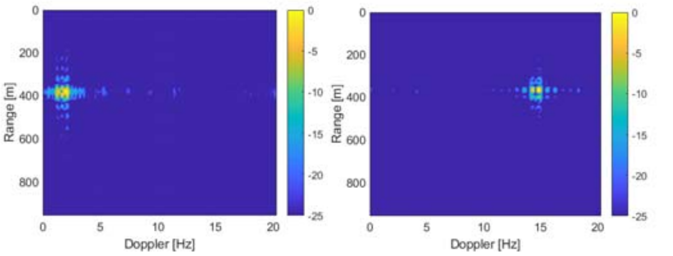

Fig. 8. RD image (left) and ISAR image (right) of the true target.

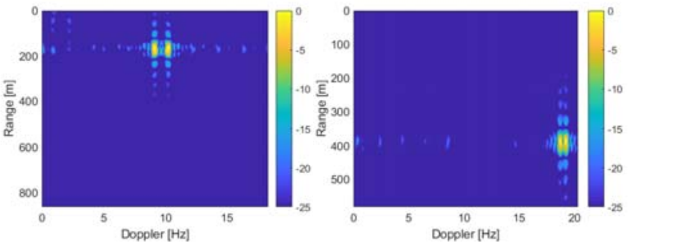

Fig. 9. ISAR images of two false targets, specifically the closest (left) and the farthest (right) with respect to the true one.

As it can be noted the Passive ISAR image of the false targets resemble that of the true one. This also demonstrates that the Passive ISAR processing can be applied to all of the detected target independently from the fact that they are true or false targets.

A second scenario has been emulated in which the false targets have the same range coordinate of the true one but different Doppler coordinate. Fig. 10 shows the range Doppler map in this case. As it can be noted, under this condition the true target cannot be isolated from the others and passive ISAR fails in this case, thus giving an image which does not correspond to the true target one.

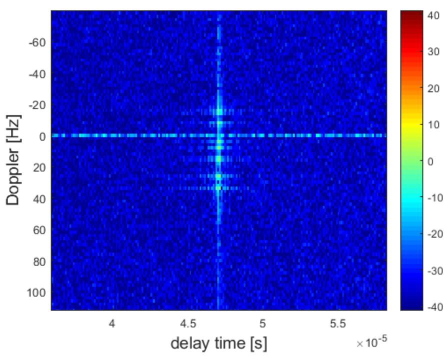

Fig. 10. Range-Doppler map obtained by emulating 6 false target with same range of the true target but different Doppler values.

IV. Conclusions

OFDM based passive radar are notoriously robust to jammers, either because the receiver cannot be intercepted and because of the random nature of OFDM signal.

Nevertheless, this paper aimed at investigating the possibility to deceive a passive radar which exploits OFDM based IOs.

The proposed idea consists on a deception jammer installed onto the target itself which is able to intercept the incoming signal and omnidirectionally transmit false target echoes to prevent the receiver from detecting, imaging and recognizing the true target.

The target-on-board jammer should be able to receive the incoming signal, sample it at the Nyquist rate and then modulate it by introducing amplitude and phase terms which may reproduce false targets. False targets may deceive the receiver in several ways, by preventing its detection, localization and recognition.

A number of simulations have been performed which demonstrate the concept and provide evidence that the proposed scheme can effectively deceive a receiver by preventing it from true target detection (first case study in which several false targets are at different range and Doppler coordinates) and recognition (second case study in which the false targets partially overlap or are close to the true one).

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