Bistatic Passive Radar Demonstrator Using COTS

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1. ABSTRACT

A low-cost passive bistatic radar system using digital video broadcasting satellites (DVB-S) as illuminators of opportunity is presented. The system was developed using off-the-shelf components which a global cost of approximately 100 Euros. To increase the target detectability using DVB-S signals in a non-coherent environment a novel methodology, using a reference target and some basic signal processing is presented. The applicability of the passive radar system is demonstrated in a real environment.

Keywords-passive bistatic radar, Digital Video Broadcasting, transmitters of opportunity

2. INTRODUCTION

Passive bistatic radar uses signals echoed from targets that have been illuminated by transmitters of opportunity. These signals can be generated, among other sources, by commercial broadcasts [1, 2, 3]. This kind of system is mainly used in military applications due to its stealth characteristics.

There are many recent publications addressing the problem of passive bistatic radar [4, 5, 6, 7]. However there are very few publications reporting the use of DVB-S as illuminators of opportunity [5]. Due to the huge costs typically involved in implementing such systems, the researchers and the students in most situations only have, at best, access to simulations to validate concepts and to test new algorithms.

To overcome these difficulties, we developed a low-cost passive bistatic radar, using custom off-the-shelf (COTS) components. Due to the low-cost option, two commercial LNB were used with independent local oscillators. This choice has the advantage of, besides low-cost, permitting mobility and spatially distanced channels. However it has the disadvantage of needing to estimate the frequency offset and phase drift between the two LNB. These necessities lead to the development of simple, although efficient, algorithm to overcome such difficulties.

The developed system provides a controlled environment to the experimentation of established signal processing algorithms and to the testing of new ones.

The paper is organized as follows. Section 3 gives some details on the developed system. Section 4 presents experimental results illustrating the usefulness of the developed system. Section 5 presents the concluding remarks.

3. DEVELOPED SYSTEM

Fig. 1 illustrates the considered acquisition geometry. The transmitter of opportunity is a geostationary Digital Video Broadcasting Satellite (DVB-S). A ground based system receives both the direct signal, on the primary antenna, and the signal reflected by a target on the secondary antenna. To detect the target, the received signal on the secondary antenna can be correlated with the signal received on the primary antenna, therefore emulating the matched filter operation.

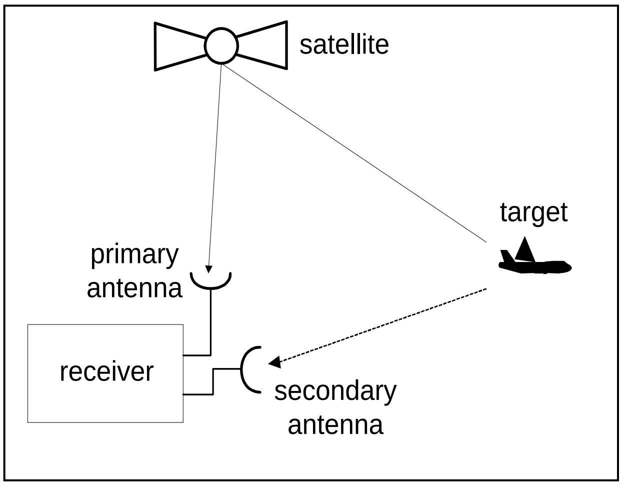

Figure 1. Passive bistatic radar acquisition geometry. The signal emitted from the satellite is reflected on a given target. The receiver antenna processes both the direct and the reflected signal. These two signals exhibit correlation between themselves.

Fig. 2 presents the block diagram of the developed system, which is mainly composed by three functional blocks: Radio-Frequency Unit (RFU), Acquisition and Control Unit (ACU), and Signal Processing Unit (SPU).

The RFU is composed by two reception antennas, two Low Noise Block (LNB) and the Intermediate Frequency (IF) stage. All the components, except the IF stage are off-the-shelf components. This block is responsible for the selection and demodulation to base-band of the signal of interest. The ACU is responsible for sampling and quantization of the baseband signal. It also generates the LNB control signals and sends the resulting samples to the SPU. The SPU is responsible for archiving and processing the samples generated by the SPU.

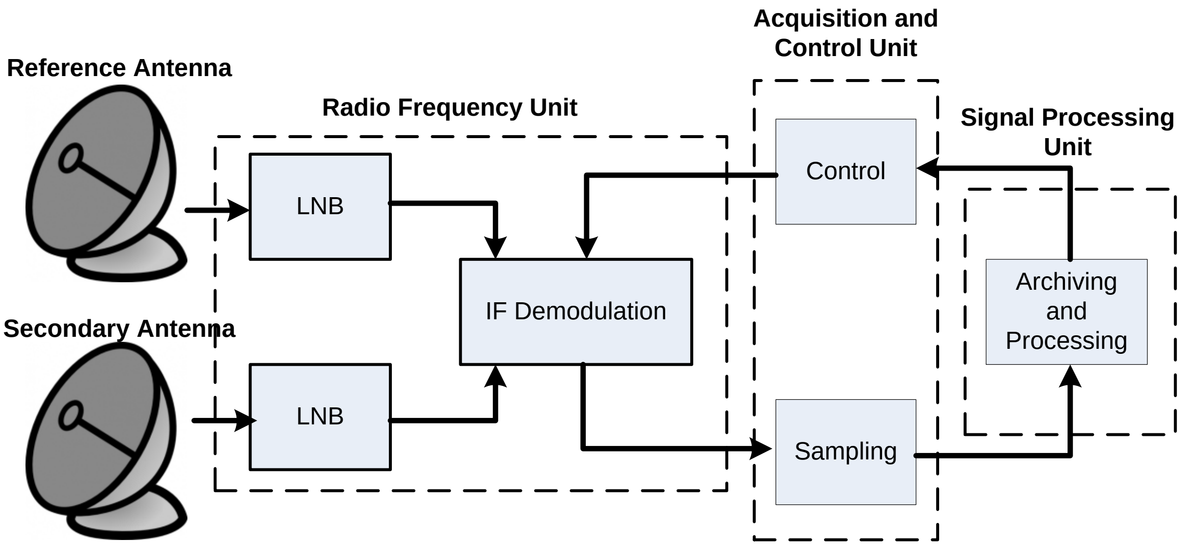

Figure 2. Block diagram of the implemented bistatic passive radar.

With the goal of minimizing the overall cost of the system, the demodulation of the RF signal to IF is done by two commercial LNB (model LNC54U), one for the direct signal and the other for the scattered signal. Both primary and secondary receiving antennas are common two small commercial satellite dishes.

The SPU is a generic signal processing unit which is, in the present situation, a Windows laptop using MATLAB for the signal processing. The implemented MATLAB algorithms are able to perform the pulse compression, coarse software correction of the phase drift, emulation of matched filtering operation, noise estimation with adaptive filtering techniques, based on the Least Mean Squares (LMS) algorithm and target detection and range position estimation.

Increasing target detectability

The SCR is, in each measurement, very low since the system uses DVB-S signals. Under these circumstances the classical solution consists in coherently adding several measurements of the same area [5]. However, since in this system, due to the low cost requirements, each LNB has its own independent local oscillator, this solution cannot be used. Therefore, the detection capability is seriously impaired.

To overcome this situation, a very simple methodology was employed to increase the target detectability. Instead of coherently summing several direct measurements, an alternative solution is used, which consists in adding coherently several signals of the same area, after pulse compression.

The demodulation stage in the IF block outputs real samples with only two possible phase values of 0 and 180 degrees. In order to correct the phase under such adverse conditions, the system uses a reference target which is present for all measurements. This way, since the reference target position is known, the signal phase, after pulse compression for each measurement, can be corrected and the signals summed coherently.

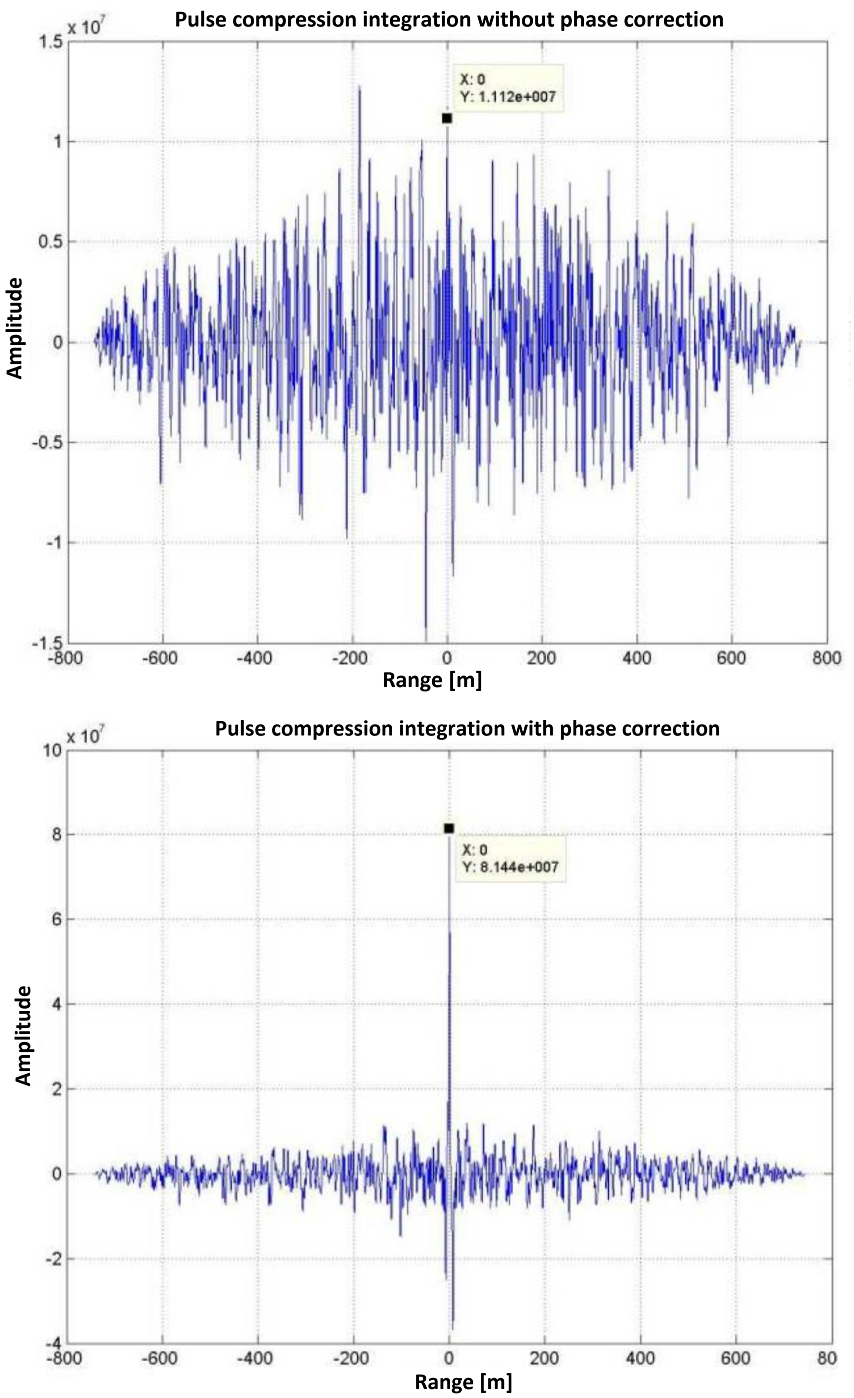

Figure 3. Target detectability improvement by coherently adding pulse compressed signals of the target area. Figure 3 shows the enhancement due to the use of such a simple methodology.

The target detection is implemented in two alternative ways: a Neyman-Person detector or a linear classifier which uses the variance and the peak amplitude, after pulse compression, as features.

4. RESULTS

This section illustrates the usefulness of the developed system for target detection using DVB-S signals. Fig. 3 shows the secondary antenna positioned in order to demonstrate the system ability to detect a metallic object at a distance of 12 meters.

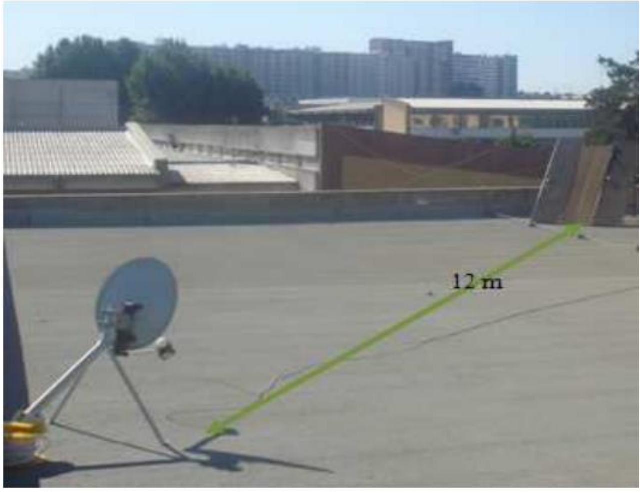

Figure 4. Secondary antenna positioned to detect a metallic target at 12m range.

Fig. 5 shows the signal received by the secondary channel (the reflected signal). As expected it has a noisy behavior.

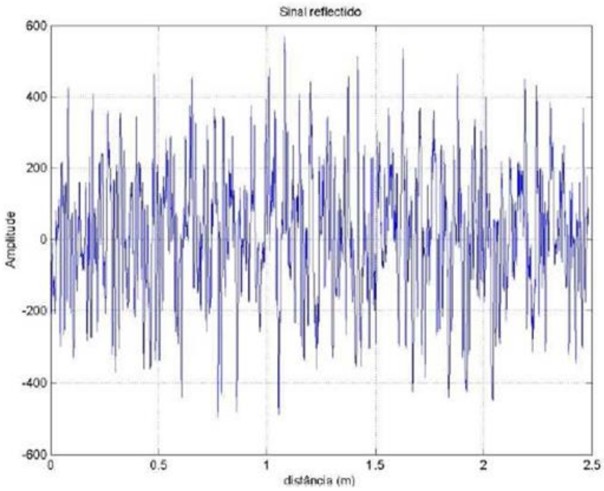

Figure 5. Signal received in the secondary antenna

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Fig. 6 shows the processed signal, exhibiting a peak at the target position. The peak is detected at 24m since this distance corresponds to the round trip computation.

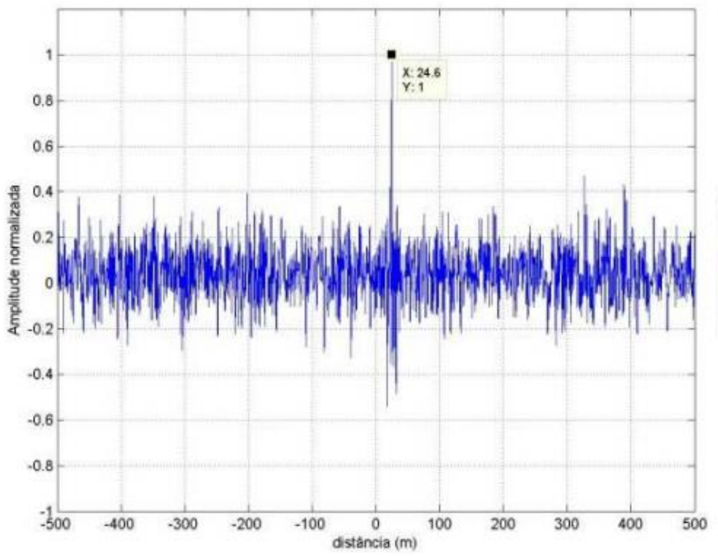

Figure 6. Processed signal: the signal after pulse compression shows a clear peak at range position 24 meters (round trip).

4. CONCLUSIONS

The paper describes a low-cost passive bistatic radar system which uses digital video broadcast satellites as illuminators of opportunity. The resulting platform provides students and researchers with a realistic environment for development and testing of existing and new algorithms.

Due to the use of the low cost commercial LNB to perform demodulation of the RF signals, there is a frequency and phase drift which was mitigated using a reference target and basic signal processing techniques.

Although functional, the system is only able to detect targets with a range distance up to 50 meters, due to the use of low power DVB-S signals and the employment of very low cost components.

5. REFERENCES

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