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Clutter and Direct Signal Suppression for Fm Passive Radar by Using Normalized Least-Mean Square and Extensive Cancellation Algorithms

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Abstract— The transmitter in passive bistatic radar system classified as non-cooperative transmitter due to is not under the control of designer or user. The suppression of direct signal in the passive bistatic radar is essential to detect the target because the target signal magnitude is weaker than it. The cancelation of direct signal and clutter are necessary to maximize the detection range and improve PBR system performance. In practice there are different methods can be used to remove the clutter and direct signal. This paper shows the effect of clutter and direct signal reflected in passive radar and discuss the target detection in passive radar by implement the Normalized least mean square (NLMS) to suppress the clutter and direct signal and tested the result.

Keywords— Passive Radar, Bistatic Radar, Adaptive filter, NLMS Algorithm.

I. INTRODUCTION

Compressive Passive Bistatic Radar (PBR) is a type of bistatic radar that recently has received international attention for surveillance intentions. The PBR Systems operate by exploit an existing transmitter as an illuminator of opportunity to detect and locate a target. The dispensing with dedicated transmitter provides some attractive features for PBR systems such as low cost, low complexity and reducing an electromagnetic pollution. The RBR systems work in covert operation which make the system invulnerable to strays and low vulnerability to electronic countermeasures [1-6]. There are numerous frequencies of telecommunications transmitters can be used as sources of opportunity such as radio navigation signals (FM, GSM and WiFi... etc.), microwaves and remote sensing applications. However, the waveforms of opportunity sources are not mainly intended for radar operation that make the performance need some processing to acquire optimal result. FM signal is used for PBR due to its efficiency, high bandwidth and noise immunity [1-6]. Ideally, the reflected signal from surveillance receiver should consist of target reflections signal only. The detection ability of Passive Bistatic Radar systems could be limited by the range of the receiver system and the small target reflected signal that can be covered by the unlike transmitted signal received in the same channel [6-7].

The waveform of transmitter of opportunity lead to get Ambiguity Function on the receiver with time varying sidelobe along bistatic range and Doppler. Sometimes the sidelobe occur in the level no much lower than the peak. This undesired contribution due to [4] [8]:

1. The echoes from targets in lower level could be masked by strong target echoes, or interduce false even if a large range Doppler separation available.
2. The fraction of the direct signal coming from the transmitter and received by the side/backlobes of the surveillance antenna that mask target echo signals.
3. Strong clutter and multipath echoes may mask targets with high Doppler frequencies.

Different solutions have been suggested to deal with this issue, which can impact on the results particularly when the direct signal is strong and influenced by multiple reflections on the surface or on separated scatterers [3] [9]. In active radar the above undesired contributions can deal with it by lower the sidelobes via using tapering to the received signal or by remove the strong stationary clutter echoes through applying moving target indication canceller filter. Unluckily no one of these techniques can applied to PBR [4].

Also, it is difficult to avoid a direct signal power coming from the transmitter of opportunity into the sidelobes of the surveillance antenna. The direct signal and multipath/clutter cancellation technique has been designed for this purpose. It is used to remove the unwanted signal to get the required target signal from the signal received by surveillance antenna [4] [8] [9].

A review and discussion of implementation the well know adaptive techniques: Normalized least mean square (NLMS) Algorithm to suppress the clutter and direct signal is presented in this paper to study the effect of adaptive technique in Passive Bistatic Radar processing.

II. SYSTEM MODEL

Compressive The complex envelope of the signal received at the surveillance channel can be written as [4]:

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$$S_{surv} = A_{surv}\, d(t) + \sum_{m=1}^{N_T} a_m\, (t - \tau_{Tm})\, ej2\pi f_{Dm} t + \sum_{i=1}^{N_c} c_i\, d(t - \tau_{c_i})\, n_{surv}(t) \quad (1)$$

(t) is the complex envelope of the direct signal.

- $Asurv$ is the complex amplitude of the direct signal received via the sidelobe/back lobe of the surveillance antenna.

- a $,_{Tm}, and\ f_{Dm}$ are the complex amplitude, the delay (with respect to the direct signal), and the Doppler frequency of the m-th target (m=1…..NT).

- c_i and τ_i are the complex amplitude and the delay (with respect to the direct signal) of the i-th stationary scatterers (i=1...,N_c), respectively.

- $n_{sur}(t)$ is the thermal noise contribution at the surveillance channel.

We can represent the strong reflections by chose small and independent number of scatterers to shows the discrete scatterers, the continuous scattering can be represented as the reflection by a large number of scatterers.

The desired direct signal to be collected from receiving channel to apply the matched filtering. It possible to neglect that the targets and clutter echoes which received via sidelobes due to the required direct signal will received by the main lobe of the receiver antenna.

The complex envelope of the signal at the reference channel can written as:

$$S_{ref}(t) = A_{ref}\, d(t) + n_{ref}(t) \qquad (2)$$

where A_{ref} is the amplitude of the direct signal (complex) and $n_{ref}(t)$ is the noise collection. The idea of performing the adaptive cancellation filter is by summing up a number of suitably delayed and weighted replicas of the transmitted signal, the undesired interference signal is gained by an estimation. Then this estimation signal subtracted from the received signal to remove the interference contribution. To apply this approach, we have to know the transmitted signal and its properties. In this paper, a radio signal Frequency Modulation (FM) is used as a source of opportunity to assess the performance of the cancellation techniques in our system. To evaluate the performance of the cancellation techniques in our system We choose to our experiment a USRP 2499R as a receiver which has up to 160 MHz of baseband bandwidth. We assume for this case study, the direct signal included stationary scatterers (clutter) and moving scatterers (targets echoes), the number of stationary scatterers Ns = 4 in the range delays between 0.08 msec and 0.32 mesc. The moving scatterers has detailed in the table listed below:

Table 1: Targets echoes parameters

Target Number	1	2	3	4	5	6	7
Delays (msec)	0.045	0.069	0.22	0.37	0.485	0.745	0.821
Doppler freq (Hz)	20	-100	60	100	-70	-150	150

When the cancelation technique not applied (Doppler zero and delay zero), a strong peak signal received from surveillance antenna (in comparing with direct signal). The moving scatterers and stationary scatterers are covered by the side lobes in 2D matched filter output as shows in figure (1) An effective cancelation for PBR can be gained by applying the Adaptive Algorithms for direct signal and clutter cancelation.

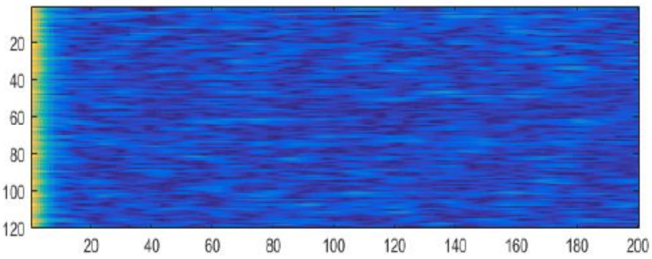

Figure 1: 2D matched filter output after direct signal and zero-Doppler

III. SYSTEM ADAPTIVE ALGORITHMS TECHNIQUES FOR DIRECT SIGNAL AND CLUTTER CANCELLATION

There are different types of adaptive filters and algorithms can be applied to remove the direct signal and clutter, in our case study the Normalized Least-Mean Square Algorithm (NLMS) were applied for our experiments.

3.1. Normalized Least-Mean Square Algorithm (NLMS)

The NLMS is modification of Least Mean Square algorithm which widely used and originated by Widrow and Hoff in 1960 [10]. The LMS uses a transversal filter to produce the output of the filter and to update simultaneously the adaptive tap weights (figure 2). The objective of the LMS algorithm is to minimize the least mean square of the output of the filter. A substantial feature of the LMS algorithm is its simplicity. It does not need measurements of the relevant correlation functions, also it does not require matrix inversion. In fact, the simplicity of the LMS algorithms that made it the standard against which other adaptive filtering algorithms are evaluated. The LMS algorithm consists of two key processes:

1. Filtering procedures, which involves (a) computing the output of a transversal filter by generated by a set of tap inputs, and (b) generating an estimation error by comparing the filter output to a desired response.
2. An adaptive process which adjusts the tap weights of the filter automatically in conformity with estimation error to update the set of filter taps.

We can write the basic equations of LMS filter for signals as following:

Filter output equation: $y(n) = w^H(n)\, u(n)$ (3)

Estimation error equation: $e(n) = d(n) - y(n)$ (4)

Tap weight adjustment equation: $w(n+1) = w(n) + \mu\, u(n)\, e^*(n)$ (5)

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where $w(n)$ is the set of filter taps at time n,μ is the adaptation constant, $e^*(n)$ is the complex conjugate of the error and $u(n)$ is the input data.

When the input data (n) is large, the LMS algorithm experiences called gradient noise amplification problem. To alleviates this issue, we may normalize the coefficient update equation $(n+1)$ with respect to the squared Euclidean norm of the input data (n) [10]. With minimize the squared Euclidean norm the tap weight vector $(n+1)$ will change to:

$$\delta\hat{w}(n+1) = \hat{w}(n+1) - \hat{w} \qquad (6)$$

$$= \frac{\hat{\mu}}{\|u(n)\|^2}\, u(n)\, e^*(n) \qquad (7)$$

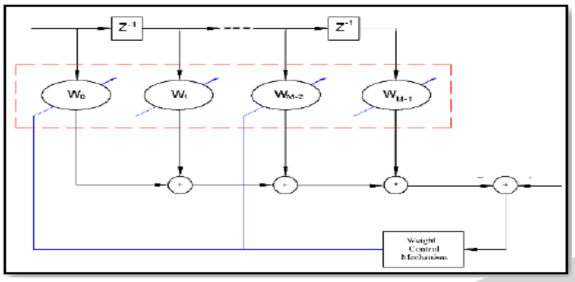

Figure 2: Sketch of a transversal filter structure

The NLMS algorithm can be summarized as following:

- Parameters:

• M = number of taps.

• $\hat{\mu}$ = adaptation constant.

• $0<\hat{\mu}<2$.

• a = positive constant.

- Initialization: If prior knowledge on the tap weight vector, $\hat{w}(n)$, is available, use it to select an appropriate value for $\hat{w}(0)$. Otherwise, set $\hat{w}(0) = 0$.

- Given Data:

• (n): M-by-1 tap input vector at time n.

• (n) : desired response at time n.

- Data to be computed:

• $(n+1)$ = estimate of tap-weight vector at time $n + 1$

- Computation: $n = 0; 1; 2;$

• $(n)=d(n)-\hat{w}H(n)\, u(n)$ (8)

• $\hat{w}(n+1)= \hat{w}(n)+ \hat{\mu}a+\|u(n)\|2\, u(n)\, e*(n)$ (9)

IV. RESULTS AND DISCUSSION

Figures (3 & 4) shows the receiving FM signal (101 MHz) via both channels reference channel and surveillance channel in absence of the NLMS algorithm. We can notice the little difference between them due to the noise and the other reflections.

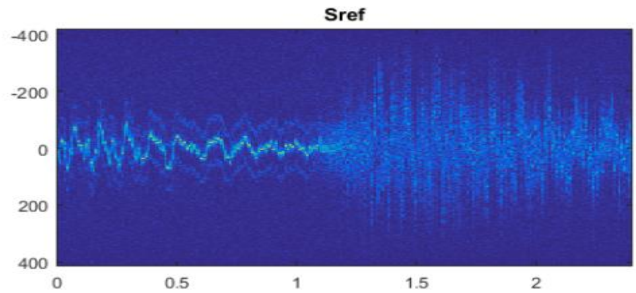

Figure 3: The received signal by reference channel.

Figures (5) shows the output of the 2D matched filter of the full signal before performing the filtering cancellation. The stationary targets (clutter spikes) are slightly apparent in zero Doppler and both targets (stationary and moving) are visible but still very weak. Figure (6) shows the output of the 2D matched filter when the direct signal is cancelled by NLMS algorithm. As shown, we can see a better result appears at zero Doppler for stationary targets (clutter echoes) and also moving targets are slightly better and some of them can be identified.

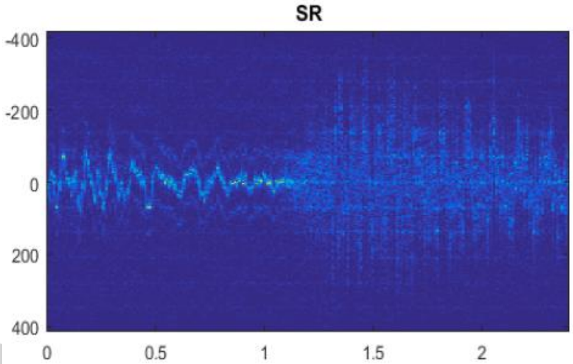

Figure 4: The received signal by surveillance channel.

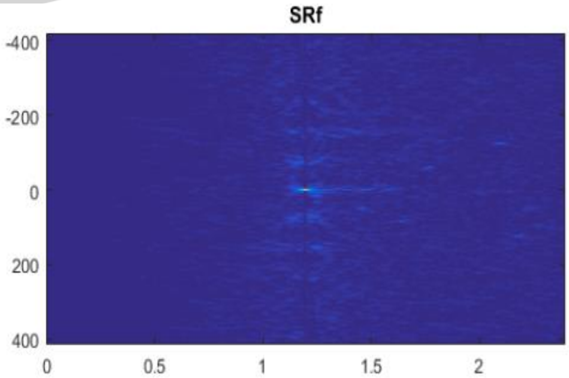

Figure 5: 2D matched filter output before cancellation it shows some targets but there are very weak.

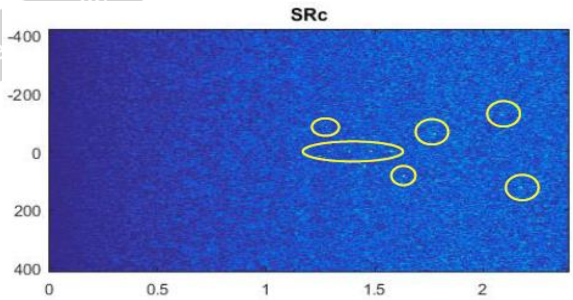

Figure 6: The 2D Delay-Doppler maps after applying cancelation filter by NLMS.

Figure (7 & 8) show the output of the 2D matched filter after removing the direct signal and noise for stationary and moving targets respectively. It seems easy to recognize and determine the targets and they can be identified.

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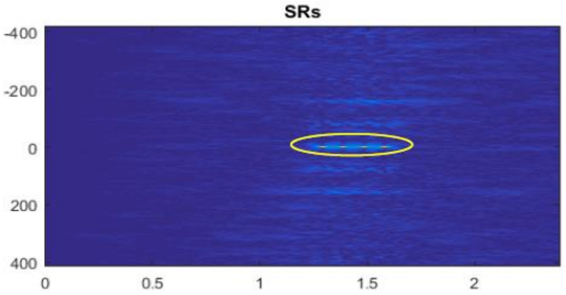

Figure 7: The 2D Delay-Doppler maps for stationary Targets.

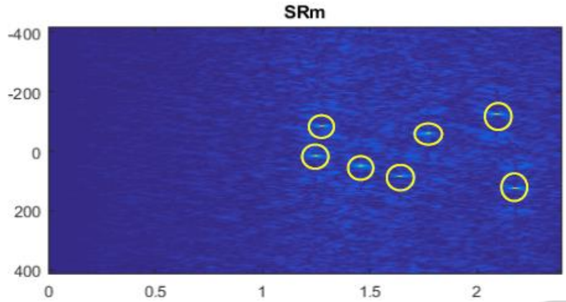

Figure 8: The 2D Delay-Doppler maps for Moving Targets.

V. CONCLUSIONS

One of the significant challenges in the Passive Bistatic Radar system (PBR) is the cancellation of the undesired direct signal and clutters returns in the surveillance channels and the development of a cross-correlation algorithm. We described and performed analyses for NLMS algorithm. The result showed us that the NLMS algorithm is acceptable for clutter and direct signal cancelation also useful for targets detection. this effect yields a partial cancellation of the target echoes whose delays are included in the cancelled area.

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