Analysis to the Technique of Track-before-detect
Anti Radar Main-lobe Interference

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Abstract. With the development of jamming technology, it has become a very urgent need to deal with radar main lobe interference. This paper focuses on the principle of several signal accumulation methods of Track-before-detect technique. The signal-to-noise ratio in radar main-lobe interference background is usually negative, and which makes it difficult for the technique to take effect. Therefore, we must establish the concept of comprehensive confrontation.

Introduction
With the continuous development of information war situation, the importance of countermeasure technology to radar electronic interference has been highlighted, and the development of various types of interference also makes radar very hard to detect target. For the radar, the interference mode is nothing but the main lobe interference and side lobe interference, and the interference type includes suppressed interference or deceptive interference. But for application and research to the interference of radar main lobe, they are started later and also because of interference in the main lobe, which makes it difficult for the radar to access data process and is developed slower. In recent years, with the improvement of radar system and many kinds of hardware and software performance, a variety of anti-jamming algorithm research has also made some progress. In this paper, we will discuss the technique of track-before-detect to suppress the main lobe interference and how to enhance the radar detection performance.

It is found that the difficulty of the main lobe jamming exists in the aspect that the interference is at the same angle with the target (and are both at the main beam), and the angle coordinates of interference and target are close to or even coincide with each other. Meanwhile, processing suppress to main lobe interference in the airspace will weaken the target power and reduce the detection performance of radar system to the target.

The Technique of Track-before-detect
In recent years, Track-before-detect has received extensive attention from radar researchers. This technology breaks through the classical radar tracking and detecting process, and uses non-coherent or coherent accumulation techniques of long-time to increase the observation time of signals. From the analysis we know that it can increase the SNR and improve the target discovery ability of radar system. This technique is usually applied to the weak target detection in noise. Aiming at the target in main lobe jamming, the method can improve the ratio of signal to interference by the long-time accumulation technique, and also the detecting ability of radar system in main lobe jamming.
Radar Detection Performance Improvement Based on Radar Signal Long-term Accumulation Technique to Radar Signal

In 1999, the academician BAO Zheng discussed a long time accumulation method for radar signal \(^{[1]}\), and also summarized the principles and commonly used algorithms to the long-time and non-coherent or coherent accumulation of radar systems.

**Analysis to the Algorithm of Long-time and Non-coherent Accumulation**

Being an accumulation method of processing to the modulated echo signal, non-coherent accumulation usually stores every echo signal after distance cycle detection in the distance-time matrix, shown in figure1, and then implements accumulation detection to the echo according to certain rules.

Hough transform is a frequently used algorithm in the long-time and non-coherent accumulation detection technology. It can map the graphs matching a feature to a point in another 2D plane. The graph shown in Figure 1 can be transformed by Linear Hough Transform to achieve higher non-coherent accumulation gain, and estimate its slope, intercept and other parameters. The typical process of achieving signal detection by Hough Transform is shown in Figure 2.

![Figure 1. Distance-time Distribution After Detection\(^{[1]}\).](image)

![Figure 2. Radar Signal TBD Processing Flow Based on Hough Transform.](image)
**Long-time and Coherent Integration Algorithm**

Non-stationary characteristics of the signal should be considered before processing long-time and coherent accumulation to radar echo. The methods of short-time Fourier transform (STFT) and Wigner-Ville have short-term accumulation effect on non-stationary signals, which can be applied to the local coherent accumulation of target echo signals to improve the signal-to-interference ratio (SNR).

The analysis shows that STFT can effectively accumulate the linear phase signal, while the Wigner-Ville distribution can effectively accumulate the quadratic phase signal by means of the short-time cross-correlation function $S(t + \frac{1}{2})S^*(t - \frac{1}{2})$. However, due to the reason that Wigner-Ville distribution can not be completely filtered cross-term interference in radar signal detection, signal accumulation circuit shown in figure 3 is usually used to accomplish coherent accumulation of the secondary phase signal.

![Figure 3. Coherent accumulation with acceleration compensation](image)

When the system is working, the quadratic phase signal generated by the target maneuver is compensated by the acceleration compensation unit, and the compensated signal then enters the Fourier transform filter bank to realize the coherent detection of the target with different velocity.

In the last ten years, the domestic and foreign scholars have made further research on the target coherent accumulation based on the signal transformation theory, and put forward a variety of signal coherent accumulation algorithms.

In 2007, Perry et al. in MITRE Corporation studied the method of distance migration compensation in long-time coherent accumulation process, and proposed a coherent accumulation method based on Keystone Formatting. The used Keystone Transform can be expressed as the following formula.

$$t_k = \left(\frac{f_c}{f + f_c}\right)^\tau$$  \hspace{1cm} (1)

In 2011, PANG Cunsuo and TAO ran of Beijing Institute of Technology studied on high-speed target detection method, and proposed a long-term signal accumulation method based on STFrFT transform. Using this method, the long-time coherent accumulation of high-speed moving target is realized. The transformation can be expressed as follows.
In 2014, Chen Xiaolong of Naval Aeronautical and Astronautical University studied the long-time and coherent accumulation technique of pulse compression radar, and proposed a signal detection method based on RFRFT (Radon-Fractional Fourier Transform) technology\(^4\). With this transformation, the coherent accumulation to target with radial uniform motion or radial uniform acceleration motion is accomplished. And this transformation can be represented by the following equation.

\[
STFrFT_{x_0,m}(t, u) = \int_{-\infty}^{\infty} x(\tau)g(t - \tau)K_p(\tau, u)d\tau
\]

Here, \(K_p(t, u)\) is the kernel function of FRFT.

**Summary**

The analysis shows that the track-before-detect technique is suitable for the SNR of about 3~5dB. In the background of the main-lobe interference, the SNR is usually negative, which makes the technique difficult to apply. Conventional interference countermeasures against radar signals are based on the separation of signals and disturbances in spatial domain, frequency domain or time domain, and in different domains. Due to the special position of the main lobe interference, and combined with other deceptive means, it is hard to use only one anti-jamming measure to confrontation in any field. This situation requires us to form a comprehensive concept of confrontation, which means combining different methods of different areas to find the differences of signals and interferences, so as to identify and screen them. Currently, the problem of confrontation to radar main lobe interference is still very serious, and the related research urgently needs further development.

**References**


