Design of an Adaptive Sidelobe Cancellation Algorithm for Radar

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Abstract: In complex electromagnetic interference environments, adaptive sidelobe cancellation is an effective measure to suppress radar active jamming. It adopts spatial filtering technology, which can effectively suppress sidelobe interference[1]. In this paper, the basic theory of adaptive sidelobe cancellation system is introduced, and two commonly used algorithms are briefly introduced. In practical application, the cancellation effect decreases due to many factors. In order to improve the performance of adaptive sidelobe cancellation, this paper proposes a method of adaptive acquisition of interference sampling data, and uses this method to simulate and analyze the collected jamming data. Now the device function is becoming more and more powerful, and the system hardware platform has also developed rapidly. Compared with the traditional method, this new interference data sampling method has certain advantages and is of practical significance. At the same time, the problems that should be paid attention to in engineering implementation are put forward.

1. Introduction
As a kind of military equipment, radar plays an irreplaceable role in modern warfare. In radar system, jamming has the most destructive effect on radar detection performance. With the continuous emergence of advanced electronic jamming measures and equipment, modern radar is faced with increasingly complex electromagnetic environment. All kinds of jamming have serious influence and threat on radar performance. An effective anti-jamming method is a condition for the radar to work normally, and an accurate interference analysis method is a prerequisite for effective anti-jamming. In the working environment of military radar, there may be various interferences, most of which enter into the receiving channel from the antenna side lobe. Generally, radar can not eliminate the sidelobe active interference only by the low side lobe of the antenna beam, so effective measures must be taken to suppress the side lobe interference[2].

Adaptive sidelobe cancellation technology is one of the effective measures to suppress radar active interference. Combining a certain type of radar, this paper proposes an adaptive sidelobe cancellation segmentation processing method, which can improve the anti-jamming performance of the radar.

2. Principle of sidelobe cancellation
The main lobe width of the radar antenna is narrow, and the gain is high, and it has extremely strong directivity, while the side lobe of the antenna is very wide, so the active interference signal generally enters from the side lobe of the receiving antenna[3]. When the intensity of the interference signal is strong, the intensity of the interference signal entering from the side lobe may be greater than the interference signal entering from the main lobe, and the interference signal may overwhelm the target.
signal, causing the radar to fail to find the target.

Sidelobe cancellation is to use the interference signal received by the auxiliary antenna to suppress the directional interference coming in through the antenna sidelobe direction. The basic idea is to send the interference signals received by the antenna main lobe and side lobes to the adaptive processor at the same time, and calculate the optimal weight through a certain adaptive algorithm to minimize the total output power, so as to achieve interference cancellation purpose.

Adaptive antenna sidelobe cancellation is a kind of spatial filtering technology\[4\]. Similar to time domain filtering, the pattern of spatial filtering is equivalent to the frequency response of time domain filtering, and the direction selection of spatial filtering is equivalent to the frequency selection of time domain filtering. The block diagram of side lobe cancellation is shown in Figure 1.

\[
\begin{align*}
\text{V}_0 &= X - \sum_{n=1}^{N} W_n^* Y_n \\
&= X - W^H Y
\end{align*}
\]  

(3)

Where "*" represents conjugation, "H" represents conjugate transposition, and "T" represents transposition.

In order to minimize the total output power, the minimum mean square criterion is usually used, and the mean square value is calculated according to Equation (4), the optimal weight vector to minimize \( \xi \) can be obtained as follows Equation (5).
\[ \xi = \mathbb{E}[|V_0|^2] \]  
\[ W_{\text{opt}} = R_{YY}^{-1}R_{YX}. \]  

A typical adaptive sidelobe cancellation system consists of a main channel and several auxiliary channels. The main channel signal is weighted by the main antenna and synthesized to determine the target direction. The auxiliary channel signal is fed by each auxiliary antenna separately. The auxiliary antenna is usually an omni-directional antenna with low gain, whose gain is equivalent to the sidelobe level of the main antenna. When the desired signal and interference arrive at the main and auxiliary antennas at the same time, the expected signal component in the auxiliary channel is far less than that in the main channel, while the interference amplitude is roughly the same. If the auxiliary channel is weighted in real time to compensate for the fixed phase difference caused by the wave path difference between the main channel and the auxiliary channel, and then subtracting with the output of the main channel, the interference can be eliminated adaptively.

Generally speaking, the performance of interference cancellation is determined by the structure and algorithm of the cancellation system[5]. The structure of sidelobe cancellation system is mainly closed-loop and open-loop.

### 2.1. Open loop adaptive sidelobe cancellation

The commonly used open-loop adaptive sidelobe cancellation weight algorithm is the direct matrix inversion method, namely DMI method. The minimum mean square error (MMSE) criterion is used to calculate the optimal weight. The weight of the auxiliary channel can make the output power of the main and auxiliary channels after weighting be the minimum. The structure of the open-loop side lobe cancellation system is shown in Figure 2.

![Open-loop adaptive sidelobe cancellation diagram](image)

Figure 2. principle block diagram of open-loop adaptive sidelobe cancellation.

### 2.2. Closed loop adaptive lobe cancellation

Based on the steepest descent method, the closed-loop adaptive sidelobe cancellation algorithm is a typical adaptive filtering algorithm. It takes the minimum mean square error (MMSE) as the criterion, and continuously feeds back the calculation error to the weight estimation module to ensure the convergence iteration and obtain the optimal weight. The structure of the closed-loop adaptive sidelobe cancellation algorithm is shown in Figure 3.
Figure 3. block diagram of closed loop adaptive sidelobe cancellation.

The closed-loop method achieves the best interference cancellation effect by gradually changing the weighting coefficient. The advantage of this method is simple, but the convergence speed is slow. LMS feedback technology is a common feedback method.

3. Design of adaptive sidelobe cancellation algorithm

3.1. Effective selection of SLC interference sample points

When sidelobe cancellation is used in existing radars, the cancellation coefficient is calculated by using the jamming sample data of radar resting area, and is used for the interference cancellation processing in the whole detection range. This method is suitable for the situation that the jamming signal is continuous in time. However, for the case of irregular intermittent interference released by non partners, the sampling data of interference signal may not be obtained in the rest area, and the calculated cancellation coefficient will not achieve the optimal cancellation effect.

In order to solve the problem of only extracting the sampling data of interference signal in the rest area, this paper proposes a method of adaptive acquisition of interference sampling data, which is suitable for the situation that the interference signal is continuous or discontinuous in time, and calculates the optimal cancellation coefficient to achieve the optimal side lobe cancellation effect and improve the detection performance.

The adaptive interference sampling method is to segment the data and take samples in order. The sampling length is 32, 64, 128, 256 and other lengths. The segment length can be customized. This method requires more computing time resources, but the interference will be traversed one by one, SLC cancellation effect is good.

The method of sequential sampling of distance segments avoids the situation that interference samples cannot be obtained. The extracted jamming samples really contain jamming features, which makes the calculated cancellation coefficient more accurate, and the sidelobe cancellation has better interference suppression ability, which improves the anti-jamming performance and detection performance of radar, and reduces the false alarm caused by interference.

The adaptive interference sampling method divides the echo data of the main and auxiliary antennas within the detection range into n segments, and the sampling length of each segment is 32, 64, 128, 256, etc. A schematic diagram of the segmented sampling method is shown in Figure 4.
After sampling the data of each main and auxiliary channel in segments, calculate each segment of data in turn, obtain the optimal weight, and obtain the cancellation result of each segment of data respectively, and then perform the cancellation result data of each segment Join together to get the final result of cancellation.

The segmented sampling data is used to calculate the cancellation coefficient, which avoids the situation that the sampling data cannot be extracted. It can be applied to the situation that the jamming signal is continuous or discontinuous in time. It can better suppress the influence of jamming and improve the anti-jamming of radar.

3.2. Real time calculation of multidimensional matrix
If the number of sample points is too large or the scale of matrix is too large, it will take a lot of time to calculate the cancellation weight coefficient. In the case of limited computing resources and processing time, it is difficult to guarantee the real-time performance.

In order to solve the problem that the number of sample points is too large or the scale of matrix is too large, it takes a lot of time to calculate the cancellation weight coefficient.

4. Comparative analysis of MATLAB simulation
A radar is jammed by jammer, the received signal is stored, and the jamming data is simulated and analyzed.

Method 1: obtain the results of interference sample data before and after the rest period and side lobe cancellation, as shown in Figure 5.
Figure 5. Comparison of sampling side lobes before and after elimination of resting period.

Method 2: the interference sample data is obtained by sections, and the results before and after side lobe cancellation are shown in Figure 6.

Figure 6. Comparison of segmented sampling before and after side lobe cancellation.
It can be concluded that the anti-interference effect of segmented sampling is better than that of rest sampling.

5. Conclusion
The method of adaptive acquisition of jamming sampling data proposed in this paper is suitable for the situation that the jamming signal is continuous in time. Compared with the traditional side lobe cancellation anti-jamming measures, it can improve the anti-jamming performance of radar. However, when the number of sample points is too large or the scale of matrix is too large, the calculation time is more time-consuming and the hardware requirements are higher.

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References
[1] Zhang Junping, Song Wanjie, Zhang Zijing, Hu Min. (2008) Performance Analysis and Simulation of Adaptive Sidelobe Canceller. Radar Science and Technology. Vol.6 No.6: 486-491.
[2] Chu Hongwei. (2009) Simulation and Implementation of an Analog Digital Hybrid Sidelobe Cancellation System. Xidian University, Xi'an.
[3] Chen Boxiao. (2012) analysis and design of modern radar system. Xidian University Press, Xi'an.
[4] Sun LianBo. (2002) research and implementation of digital open line sidelobe adaptive cancellation technology. Xidian University, Xi'an.
[5] Zheng Fei. (2014) Research on and Implementation of ASLC System. Xidian University, Xi'an.