



# X-band Radar Detection Target Tracking Method Based on Internet of Things Sensing Technology

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**Abstract.** If echo data of civil aviation wake scattering can be obtained by Aircraft wake X-band radar detection, which can provide reference data for the stable operation of aircraft. However, the existing target tracking methods have the problem of imperfect target tracking mode, which leads to poor echo strength. A target tracking method of Aircraft wake X-band radar detection based on IOT sensing technology is designed. The structural characteristics of dynamic target are acquired, the target tracking task is formulated, the Aircraft wake X-band radar detection imaging area is set, the distance between the detection imaging area and the target position is calculated, the information fusion technology is used to suppress the same frequency interference clutter, the radio frequency rate of radar in frequency domain and space domain is adjusted, and the sliding window residual is used to obtain the track extrapolation motion track, and the target distance and the target position are measured. According to the spatial position of azimuth angle and pitch angle, the target tracking mode is set based on the Internet of things perception technology, and the data association rules are designed. Experimental results: the average echo intensity of the designed tracking method is 16.777% and 15.461% higher than that of the two existing target tracking methods, respectively, which proves that the target tracking method combined with IOT sensing technology has better practical application effect.

**Keywords:** Internet of things perception technology · Aircraft wake X-band radar · Tracking method · Echo intensity

## 1 Introduction

Aircraft wake is the inevitable product of aircraft lift, its vortex strength is large, lasting for a long time, which has a great impact on the aircraft into which, in serious cases, can lead to aircraft crash. In order to avoid the occurrence of such wake accidents, acoustic, electrical, optical and other detection equipment can be used to detect the aircraft wake, and provide the position, strength and other information of the wake, so as to further enhance flight safety, break through the limitation of safe flight distance standard formulated by the international Civil Aviation Organization (ICAO), and improve transportation efficiency. Due to the advantages of radar in frequency selection

and detection range, more and more attention has been paid to the radar detection technology of aircraft wake.

The traditional detection before tracking technology uses the process of detection before tracking to detect and track targets. After beamforming and pulse compression preprocessing, single frame radar target echo data initially accumulates target energy. Through coherent or non coherent signal processing, the target echo energy is further accumulated, and the detection threshold is set according to the false alarm rate required by the system to detect the echo data, then the parameters of the detected point trace are estimated, and finally the processing results are transmitted to the tracking system to complete the target tracking [1]. In the traditional signal processing flow, the radar echo data is processed by CFAR detection. This operation can reduce the amount of data, but from the perspective of information theory, the amount of information of the target in the data is lost, resulting in the loss of signal-to-noise ratio of the target echo. When CFAR is used to detect weak targets, there is a trade-off between the probability of target detection and the probability of false alarm. In order to ensure a certain detection probability, a lower detection threshold is usually selected. Therefore, in single frame detection, the target may have multiple detection points, resulting in the increase of false alarm number and the uncertainty of observation source. The non target observation with wrong tracking selection can lead to the divergence of tracking filter. Therefore, the correct association of the target observation click with the target track has an important impact on the target tracking accuracy. Target tracking refers to the use of sensors to observe and determine the location, trajectory and characteristics of the target. The target tracking problem faced by modern military is extremely challenging. In the complex environment of modern battlefield, the characteristics of the target such as strong mobility and low RCS make the traditional target tracking method not only affected by the unknown number of targets, but also the low scattering cross section (RCS) The impact of clutter density and other problems, but also increased the low detection probability, data association difficulties and other new problems of interference, the target tracking algorithm put forward higher requirements. Modern radar system requires a tracking algorithm to detect the target track and track it accurately in a complex environment, so as to provide accurate information for the command system and fire control system, so as to effectively interfere with the interested target and reduce the false alarm probability as much as possible while ensuring high detection probability. The final effect of tracking algorithm is the embodiment of radar comprehensive performance. On the one hand, it can improve the performance of tracking algorithm. On the other hand, it should also improve the quality of point trace input as much as possible. The echo intensity of traditional early warning radar to the target has the characteristic of "large near and small far"; The interference of observation noise and clutter is added; In addition, the RCS of high frequency radar cross section is sensitive to the change of target attitude. The radar detection probability is low, and sometimes it can't detect the target effectively for several consecutive cycles [2]. Especially with the development of modern weapon technology, a series of measures, such as electronic jamming, aircraft stealth technology, anti radiation missiles and so on, pose challenges to radar warning, so the combat intelligence support system based on single radar can not meet the needs of the battlefield.

With the improvement of economic level, the upgrading of hardware platform and the development of information fusion technology, multi radar cooperative detection technology provides an effective way to deal with the increasingly complex war environment. Radar detection is not only a new early warning detection theory and method, but also provides advanced and effective equipment and tactical support for radar reconnaissance troops to carry out cluster detection and system operations. Compared with single radar, multi radar has the following advantages:

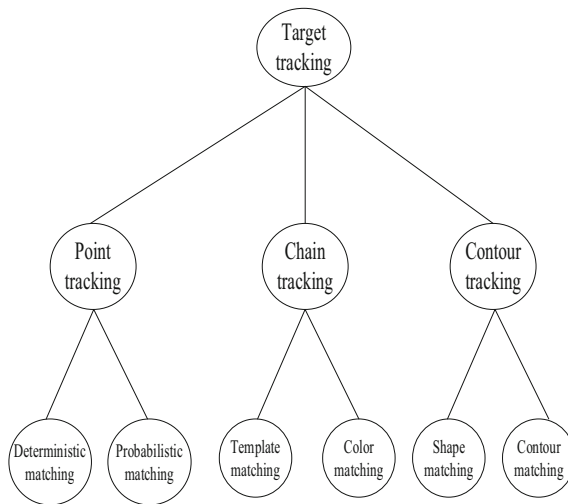
1. Expansion of detection range and target types; The detection range of multiple radars expands with the expansion of the distribution range of each radar. The spatial diversity greatly improves the scintillation of the target echo. The characteristics of multi angle observation target, especially the tracking interruption caused by single radar over the top and the detection blind area caused by electromagnetic environment, are compensated. Because the bands of multiple radars may be different, frequency diversity improves the types of detected targets and greatly improves the defense capability of anti radar technology against enemy electronic jamming.
2. Improve system reliability: multi radar system can maintain each radar of multi radar one by one in non wartime without reducing detection coverage. In wartime, even if a radar breaks down suddenly, multi radar system will retain certain warning ability.
3. Improvement of target tracking accuracy and recognition ability: different radars of multi radar system may achieve multiple coverage of a certain target in a certain area. Multi band coverage of the same target can not only verify the data of multiple radars, but also improve the confidence of the target, Through the configuration between radars, the target detection accuracy of multi radar system can be improved, and even different information can be obtained from each radar to improve the target recognition ability.

## **2 Aircraft Wake X-band Radar Detection Target Tracking Method Based on Internet of Things Sensing Technology**

### **2.1 Acquisition of Dynamic Target Structural Features**

Dynamic target tracking can be defined as estimating the target's trajectory in a scene. However, in the process of tracking, the target may change in occlusion, deformation, scale and illumination. This undoubtedly brings great challenges to the tracking task. To effectively solve the difficulties in the task, the key lies in the following points: first of all, it is to find a reasonable method to mark the target and describe the target with appropriate features [3]. Secondly, find an effective method to track and detect the target, and update the characteristics of the changed target in time. In the tracking method, points can be used to represent the object. Point is used to represent the target, which requires the target to have the key features that can be represented by point, such as the center of mass of the object, the joint point of motion. The targets that can be represented by points generally occupy a small area in the image, such as the moving

targets such as shells and birds in the air, vehicles and pedestrians in the distance. A rectangle and a circle frame are used to delineate the target, which represents the target to be tracked. This method is a common form of target representation in current tracking methods, and it has the characteristics of image, simplicity and so on by using simple geometry [4, 5]. It is mainly suitable for rigid targets, but it is also used for tracking flexible targets, such as pedestrians, animals and so on. However, it puts forward strict requirements for feature selection. In the process of target tracking, the most intuitive image perception of the observer is the contour of the target. Through the contour to find the edge of the target and the background, the area within the contour is the tracked target. The use of contour to mark the target has the characteristics of accurate and intuitive. However, when the edge of the target is not clear enough, the contour information cannot be obtained. In the video tracking task, the application of human tracking is very extensive, because the human body can be regarded as a target connected by joints, which forms a chain region. With this chain connected region, the human body is calculated by calculating the motion model between the parts, and represented by multiple ellipses. For the rigid target or the target with the characteristics of chain region, the target can be represented by skeleton structure. People or animals can usually be represented by the same backbone structure. For tracking tasks, the backbone structure focuses more on reflecting the motion information of each part of the target. For the diversity of tracking tasks, multiple representation methods can also be used to represent the target together. The specific structure is shown in Fig. 1



**Fig. 1.** Target tracking structure

As can be seen from Fig. 1, structural features are obtained through deep neural network training, which are structural features from simple to complex. Deep neural network refers to the structure of animal visual cortex. Taking humans as an example, the information processing of human visual system is hierarchical. From the lower level

to the middle level, the shape features are formed by the combination of edge and corner features, and then to the higher level, even to the whole target. It can be said that the process of visual perception is a process of abstracting from the underlying basic features to the high-level structural features. As the level of abstraction becomes higher and higher, the displayed features have higher-level representation. In the face of the changing targets in the tracking task, the features from the bottom to the high-level can be used to describe [6]. Color features are widely used. In image processing, with the intuitive RGB color space, easy to calculate, widely used to mark the target color. Color histogram is a common color feature, which calculates the proportion of each color in the image color space instead of calculating the position of each color in the image space. For the target without clear edge in space, the description is strong. But for the judgment of color similarity, human subjectivity plays a decisive role, so some people put forward HSV space based on image chroma, saturation and brightness value, which makes it closer to human visual subjective recognition of color through the description of color features [7, 8]. The conclusion that the visual cognitive process of human vision to the target is produced by the movement of the edge can be seen from the experiments of the potential visual mechanism. When the target edge changes, the edge between the object and the background will change dramatically. In the process of setting tracking task, edge detection method can be used to detect the change of edge. Compared with color features, the generation of edge features depends on the moving edge generated by the target and background, not on the subjective understanding of color. So its simplicity and accuracy can be guaranteed.

## 2.2 Set up the Aircraft Wake X-band Radar Detection and Imaging Area

Setting the Aircraft wake X-band radar detection imaging area is to match the corresponding points in the front and back video frames, so as to complete the target trajectory tracking. Due to the use of point based features, when the target's rotation, scale and affine change, the point matching will not be affected. However, once the target is occluded and the illumination changes, the target will disappear or appear, will directly affect the imaging area. In continuous video frames, feature points are matched before and after frames, and multiple matching relationships are solved by minimizing the matching cost according to the motion constraints of feature points. So as to find the best match. The principle of optical flow method is to calculate the motion vector of the relative moving object by matching the corresponding points in the front and back frames to form the optical flow field. The Aircraft wake X-band radar can reach  $360^\circ$ . At present, the targets of continuous circular scanning in all directions have been widely installed on ships to avoid collision and ensure the safety of people and goods. The working principle is that the transmitter transmits a series of high-frequency pulses which are repeated in a certain period to the observed direction through the antenna. If there is a target in the propagation path, the target will intercept part of the electromagnetic energy emitted by the radar and radiate the intercepted energy again in the form of electromagnetic wave. Part of the scattered energy will face the direction received by the radar (called target echo). The radar antenna can receive this part of the energy scattered by the target and process it, display the image on the screen. After acquiring radar image data, preprocessing is needed. It includes the determination of

the analysis area for subsequent inversion, data correction, image filtering and coordinate transformation. In signal analysis, if the amount of data used for analysis is too small and the amount of information contained in the signal is insufficient, the real information cannot be restored. However, if too much data is used, the statistical characteristics of the data will be different, which will affect the accuracy of the results. Tracking target can be seen as the superposition of countless sine waves. The acquisition of target information is actually the acquisition of countless sine signals. This paper reasonably selects the amount of data required for each analysis, so that the radar image analysis also has fixed characteristics. In addition, the goal is usually considered as a stationary ergodic stochastic process. By selecting enough data from the samples, the time domain and frequency domain characteristics of the whole system can be analyzed. Therefore, in the actual inversion, several consecutive clutter images are used each time, and the time length is about 1 min. According to the intensity distribution of radar echo image, the distance between the detection imaging area and the target position is calculated. The specific expression formula is as follows (1)

$$Q = \frac{E}{\beta \tan\left(\frac{\delta\pi}{9}\right)} \quad (1)$$

In formula (1),  $E$  is the radar erection height. When the location of the selected area and the radar detection imaging area is 750 m, the number of pixels is 85, and the value range of the center angle is  $60\text{--}70^\circ$ . The polar coordinate expression formula of the imaging region is as follows:

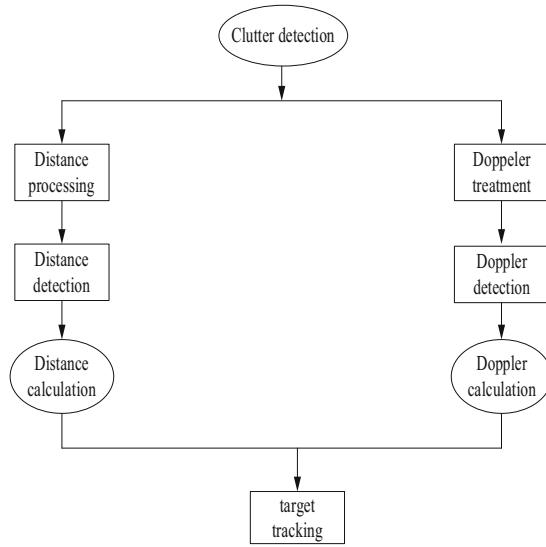
$$\begin{cases} a = l \times \cos\delta \\ b = l \times \sin\delta \end{cases} \quad (2)$$

In formula (2),  $a, b$  represents any two points in the radar imaging area, and  $l$  represents the entire point function value. Radar sea clutter image contains a lot of noise jamming, such as target jamming, rain and snow jamming, CO frequency jamming and so on. The signal needed is weak. Therefore, it is necessary to use median filter to process the image of the region simply and filter out the interference of white noise [9]. When detecting and tracking the imaging area of the target in motion, the constant change of motion attitude and high-speed motion will increase a Doppler frequency to the radar echo. Therefore, it is necessary to compensate for velocity and attitude. Firstly, 32 consecutive images are compensated by angle motion. The first image is taken as the reference, and the other 31 images are rotated accordingly to ensure the same angle to the ground as the first image. Secondly, position correction is performed on 32 consecutive images in the same way [10, 11]. Frequency aliasing is a phenomenon in the process of signal acquisition. With the advent of the digital signal era, the use of computer processing signal data has been recognized by the majority of technical workers. However, because the computer can only process digital signals, it is necessary to sample analog signals and convert them into digital signals. Sampling theorem is the basis of understanding frequency aliasing. The basic meaning of the

sampling theorem is: when the signal is sampled discretely, the sampling frequency should be greater than twice of the highest frequency of the signal, so that the sampled digital signal can completely retain the information in the original signal. The radar antenna transmits electromagnetic wave and receives its echo every 100 rotations. The energy distribution of each line is recorded in the image data. The radar scans its area in 3600 directions, so that the radar image contains a lot of information, which does not meet the needs of the algorithm. Therefore, the data in the above rectangular box is still used for wave inversion. After determining the center angle and starting position of the selected rectangle, the nearest point interpolation is used to obtain the imaging area of radar detection.

### **2.3 Inhibition of Clutter by Information Fusion Technology**

Target location is one of the main functions of radar. As an active detection sensor, the radar transmits electromagnetic waves to the monitored field through the transmitting antenna, and then receives all backscattered echoes from the objects in the field through its receiving antenna. By processing the echo, the feature information of the interested target is extracted, and then the state information of the target, such as presence, position, motion state, friend or foe attribute, is obtained. The position information of the target can be obtained from the observation results of the arrival time, the angle of arrival, the time difference of arrival and the received signal strength of the echo [12–14]. For the traditional location method based on direct wave information, each radar station can only obtain a single characteristic information of the target location, whether it is a monostatic radar with the same receiving and transmitting antennas or a bistatic radar with separate receiving and transmitting antennas. Because the distance between the same frequency jamming radar and the experimental radar is too close, and the jamming clutter is a very strong signal, the echo formed by the same frequency jamming noise in the radar image is very saturated. In general, it is more difficult to eliminate the same frequency synchronous jamming than the asynchronous jamming. In general, the elimination method is to use some suppression methods to suppress the same frequency synchronous interference after it is converted into asynchronous interference. In the experiment, the same frequency interference in the radar image collected is basically asynchronous interference, so the subsequent detection and suppression methods are all asynchronous interference. In order to suppress the co channel interference, the active interference suppression method can be used. First of all, the signals transmitted by radars can be distinguished or unique by certain methods, which is also the most fundamental method to suppress co channel interference. Firstly, the same frequency interference clutter is detected, and the distribution range is determined before centralized processing. The detection process is shown in Fig. 2



**Fig. 2.** Same-frequency interference detection process

As can be seen from Fig. 2, in the process of target tracking, it is necessary to reduce or even avoid the same frequency interference energy received by the radar receiver. It can adjust the transmitting frequency of radar in frequency domain, spatial domain or time domain, interleave the working time of the same type of radar, or extend the distance between the formed ships, so as to minimize or avoid the same frequency interference received by radar receiver. The echo characteristics of the monitored target are different from those of the same frequency interference to achieve the purpose of suppressing the radar receiver receiving the same frequency interference [15, 16]. Firstly, the number of repeat frequency points can be increased, then the same frequency synchronous jamming can be converted into asynchronous jamming by certain methods, and finally the corresponding signal processing methods can be used to reduce the influence of the same frequency jamming. Adjust the radar receiving frequency. The common processing methods are: median filter, mean filter, adaptive filter, geometric filter based on morphology, filter based on wavelet transform and so on. These methods have good results, but the first several classical methods will change the target information in the radar image; The latter two methods are slightly better in preserving image information. The most widely used wavelet transform is to remove the Gaussian noise in the image, and its effect is very good. For bistatic radar, the distance traveled by the signal between the radar and the target is not equal. Therefore, if the bistatic radar obtains a certain arrival time, the point trace of the possible position of the target meeting the arrival time forms an elliptical contour with the transmitter and receiver as the focus, and the sum of the distance between the target and the transmitter and the receiver as the focus [17]. According to the difference of pulse repetition period and transmitting frequency, the same frequency jamming of radar can be divided into

synchronous jamming and asynchronous jamming. If the repetition frequency and pulse width of the pulse transmitted by one of the radars are known, and the repetition frequency and pulse width of the pulse transmitted by the other radar are also known, the relationship between them is expressed as follows:

$$\Delta d = \frac{1}{k_1} - \frac{1}{k_2} \quad (3)$$

In formula (3),  $k_1, k_2$  represents the pulse frequency transmitted by two radars. At the same time, the more the radars are turned on, the more the concentric circles are. The width of the same frequency synchronous jamming is generally larger than the corresponding distance of the radar pulse width, and the concentric circles will move outward (inward) slowly. In addition, due to the slight difference in the period of each radar, the radius of the jamming loop on the radar screen changes with time: the display of one radar changes from small to large, and changes circularly; The other part may change from large to small. If more than two radars work at the same time, the pattern of image jamming will be more complex. The image of the same frequency asynchronous jamming on the radar screen is fan shaped and divergent dotted line, and the concrete manifestation of the same frequency asynchronous jamming on the radar screen is not unique [18, 19]. With the difference of interference pulse width and working repetition frequency, the dots of the scattering fan shape are different in length. Usually, when the display works in a large range, the interference source is close to each other, and the antenna direction is right, the interference becomes serious. Due to the random range and azimuth of the interference, especially when the interference density is high, it has a certain impact on the tracking stability.

#### 2.4 Obtain the Orbital Extrapolated Motion Trajectory with the Sliding Window Residue

In the process of target tracking, the design of tracking filter is a very important problem. Using sliding window residuals to obtain trajectory extrapolation requires tracking filter, which can obtain more accurate measurement results by jointly processing the current and past measurement data. At the same time, the filter predicts the position of the target at the next moment, and the radar controls the tracking gate and antenna (beam) pointing according to the prediction results. It can be seen that tracking filtering is the basis of continuous measurement [20]. Least square filtering is a very robust method because it does not make any assumptions about the distribution of data. This characteristic makes it widely used in tracking filtering. The improved form of least square filtering: sliding window residual least square filtering. The main idea is to eliminate the main nonlinear term in the observation data by orbit extrapolation, and use a simple polynomial model to smooth the residual. Through the sliding window method, high-precision final results can be obtained without changing the data rate. In this process, it is assumed that the earth is a uniform sphere, but in fact, due to the influence of rotation, the earth is an ellipsoid, and its equatorial radius is 21 km more than the polar radius. As a result, the gravitational field of the earth does not point to the center of the earth. The calculation formula of orbit extrapolation is as follows:

$$w(f + v) = z(v) + f \times \frac{s_1 + s_2 + s_3 + s_4}{4} \quad (4)$$

In formula (4),  $w$  represents the time of the orbit extrapolation,  $f$  represents the semi-long axis of the track,  $v$  is the eccentricity of the track,  $z$  is the inclination of the track, and  $s$  is the included angle of the earth center. Similar to the state vector of the target, the orbital root number also describes the motion of the space object completely. The position and velocity of the target at any time can be obtained by knowing the number of orbital roots of the target; On the contrary, the number of orbital roots can be obtained by knowing the position and speed of the target at a certain time. At present, some foreign scholars publish the root number information of all the catalogued targets in the form of TLE file every day [21, 22]. The title data consider the factors of various perturbations including the earth's non spherical, solar and lunar gravity, atmospheric resistance, and eliminate the periodic influence by specific means, so it is an average root number. When using the title information to extrapolate the orbit, the same method must be used to reconstruct the periodic disturbance term to obtain the accurate position and speed of the target. In engineering application, TLE data is usually used in combination with a gp4 model to extrapolate the track to achieve the best prediction accuracy. Radar can obtain its position in space by measuring the distance, azimuth and pitch angle of the target. Radar measurement always has errors, including physical error and measurement error. Generally, the physical error can be compensated by calibration in advance, so that the main source of measurement error is random noise. Filtering is a method to reduce the influence of random noise [23]. By filtering the measurement with random noise superimposed, the relative more accurate measurement can be obtained. The simplest linear model is polynomial model, but the radar observation equation is highly nonlinear. The mismatch between the filter model and the actual situation seriously affects the accuracy of the filter, and even introduces additional physical errors. Although the higher order polynomial can be used to approximate the nonlinear real situation, higher-order model means more computation. The results of the second order fitting and the third order fitting are not different from those of the third order fitting. The maximum error (absolute value) of fitting is about 2 m, considering the distance of the target is about 600 km, so the fitting error of this degree can be ignored. For azimuth, the second order fitting effect is very poor, and its maximum error (absolute value) reaches about  $10^\circ$ , while the third order fitting has obvious improvement, but its maximum error (absolute value) is about  $2^\circ$ . Similar to the distance, the fitting results of pitch angle are also ideal. The difference between the second and third order is not big, and the maximum error (absolute value) is about  $0.2^\circ$ . It is predicted that the maximum azimuth error of the third order polynomial least square filter is about  $2^\circ$ , which will directly lead to the loss of the target. Since the reference orbit is not far from the real orbit of the target, it can be considered that the nonlinear term contained in the reference orbit is consistent with the non-linear in the observation data. By subtracting the measured data and reference orbit, the main nonlinear terms in the observed data are eliminated. The residual data will mainly include the residual error of the orbit and the random error of the measurement. Compared with the original observation data set, the residual error has been greatly reduced, so it is possible to use low order polynomial fitting to reduce the influence of

random error. Some catalogued targets can get the information of orbital elements in advance, so it is inferred that the extrapolated orbit can be used as reference orbit. However, space target is a non cooperative target, especially for ballistic missile, it can not obtain the previous information in advance. So the more feasible method is to estimate the state of the target in real time in the process of filtering, and the orbit derived from the extrapolation is used as the reference orbit.

## 2.5 Setting Target Tracking Mode Based on Internet of Things Perception Technology

Based on the perception technology of Internet of things, target tracking mode is set. The perception layer is a more complex part of the trust mechanism in the Internet of things, mainly because of the heterogeneity and openness of these two factors: the first factor is due to the lack of a unified standard, now the implementation of information collection and transmission is mainly implemented by the industry using different hardware, resulting in many different application models. At the same time, different terminals have different processing capabilities, which makes them diversified, so they can not rely on a single trust mechanism. Sensor nodes can be deployed either through the interaction of sensor nodes or through the access of sensor nodes. At the same time, the interaction of data is also very strong, and even can interact across institutions. The fuzzy boundaries are divided into clear boundaries, so that the perception data can find its trust level, find its corresponding reputation organization, and authorize it to obtain the corresponding trust value, so as to make the complex perception data orderly. In fact, the perception layer is not a physical layer. By definition, the perception layer is defined as a hierarchical mechanism, so that each layer has its own different trust needs. When the perception data flows gradually in each layer and meets the trust needs of each layer, the perception data is safe and effective, This also ensures the availability of sensing data, rather than a pile of redundant and useless garbage data. Things are connected, it is not limited to the computer network, but a number of heterogeneous networks connected with each other, its data has been the previous power exponent times There is a problem: how to separate their own useful data from the mass data, how to determine the legitimacy of these data, people need to design the corresponding association rules. In order to avoid the congestion of Internet of things nodes, the fairness of network nodes is measured.

$$h = \frac{\left(\frac{r_1}{p_i}\right)^2}{D\left(\frac{r_2}{p_i}\right)^2} \quad (5)$$

In formula (5),  $r$  is the total number of network nodes,  $D$  is the number of packets,  $p$  is the average packet rate, and  $i$  is the energy consumption coefficient of data transmission. Considering the attenuation of data, the perceptual data is endowed with certain vitality. Due to the real-time nature of the data on the Internet of things, not all

data is immutable. On the contrary, data can be updated immediately. After a period of time, in the time definition of the Internet, the time taken to change is very short. These perceptual data will take on other forms after changes. Through the relevant algorithm to determine whether it is near the limit of life, if there is, then discard the data, think it is useless. It mainly determines whether the reputation value of perceptual data is rapidly declining, or malicious data. If the perceptual data is considered useless or even threatening, it will be rejected and discarded. In the implementation of specific operation protocol, it is above the multiplication gate and the addition gate. Analog operation, pseudo-random operation and polynomial operation are common problems. From a more high-end point of view, it belongs to the field of computing related to geometric computing, statistical analysis, data mining, special operations, such as linear algebra operations, privacy preserving data query and pattern recognition, etc.; From a more high-end point of view, it can be some specific agreements, such as electronic like, electronic purchase auction and so on. In the complex environment, the echo signal returned from the target reaches the radar antenna through different paths, which reduces the accuracy of target positioning and even causes the problem of false target. Generally speaking, for the point target with large elevation angle, the multipath component enters from the radar antenna sidelobe, and the monopulse radar can locate the target with high accuracy. However, for low elevation point target, due to the multipath signal entering the sum and difference main beam, there will be large positioning error, and even lead to positioning failure. At this time, if the traditional matched filtering method is used to locate, due to the interference of multipath signal, the radar will mistakenly detect multiple false targets, so it is unable to accurately detect the real position of the target. Under the condition that the geometric characteristic parameters of buildings and roads in the detection area are clear, the multipath propagation can be predicted. After geometric transformation, the detection results of mirror position points can be converted into the results of real observation position, so the multipath echo also has available information. The calculation formula of echo signal received by receiving antenna is as follows:

$$g = \sum_{b=1}^3 \Gamma_b^2 c (m - \tau_b) \quad (6)$$

In formula (6),  $b$  is the arrival time of the echo,  $\Gamma_b$  is the echo amplitude,  $c$  is the data noise,  $m$  is the echo path, and  $\tau_b$  is the echo velocity. From the perspective of inverse ray tracing, it can also be considered that multipath propagation introduces the virtual mirror observation base station. If the multipath information can be used effectively, then the target location can be achieved only by a single radar station. Combined with the technical characteristics of IOT sensing technology in practical application, the design of Aircraft wake X-band radar detection target tracking method is realized.

### 3 Experimental Study

Through prior knowledge and association rules, target tracking in low SNR scenes can be achieved. However, this algorithm considers all candidate echoes in the correlation gate comprehensively, and the tracking error is larger in clutter dense scenes than in ideal detection conditions using only the correct observation of Kalman filter. In order to verify the radar echo strength of the designed target tracking algorithm in different SNR scenes, two existing tracking methods are selected and compared with the designed tracking method. In this paper, the effectiveness of the proposed method is verified by the X-band radar detection experimental data of a certain type of civil aircraft wake.

#### 3.1 Setting Experimental Parameters

According to the needs of experimental test, the experimental parameters are set as shown in Table 1.

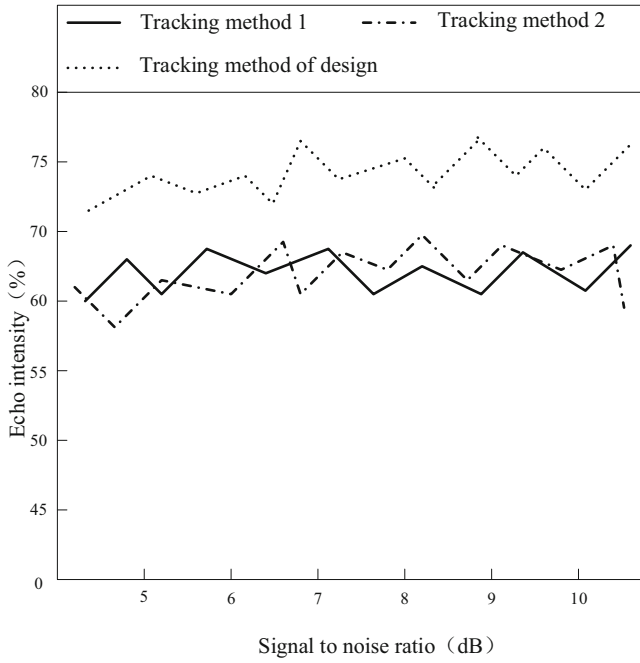
**Table 1.** Tracking method smoothing parameters

Serial number	Name	Parameter
001	Carrier frequency	3.5 GHz
002	Bandwidth	4 MHz
003	Pulse repetition rate	1.92 kHz
004	Number of coherent integration pulses	34
005	Half power beamwidth	8°
006	Observation interval	12 s
007	Detection probability	0.88
008	Clutter density	$10^{-6}$
009	Correlation gate threshold	18.2
010	Gate probability	0.9964
011	Fixed interval length	10 frames

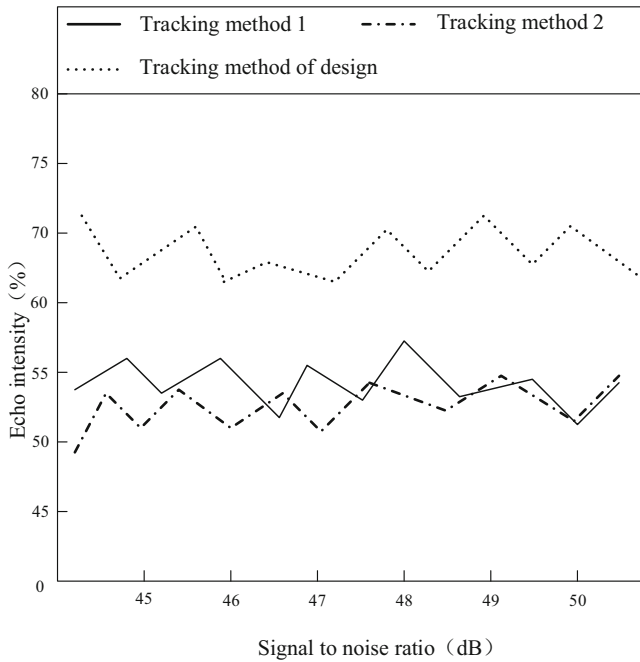
Under the above experimental parameters, the echo intensity of the three target tracking methods is tested, and the experimental results are obtained.

#### 3.2 Experimental Results

Suppose that the X-band radar peak power of the civil aircraft wake is  $10^6$  W, the transmission gain is 40 dB, the wavelength is 0.056 m, the pulse accumulation number is 16, the radar cross section is  $3 \text{ m}^2$ , and the receiver's direct frequency bandwidth is  $1.6 \times 10^6$  Hz. The minimum output signal-to-noise ratio of the receiver is 2, and the noise temperature of the radar receiver is 290 K. Under different SNR conditions, the echo strength of three tracking methods is tested, and the experimental results are shown in Fig. 3

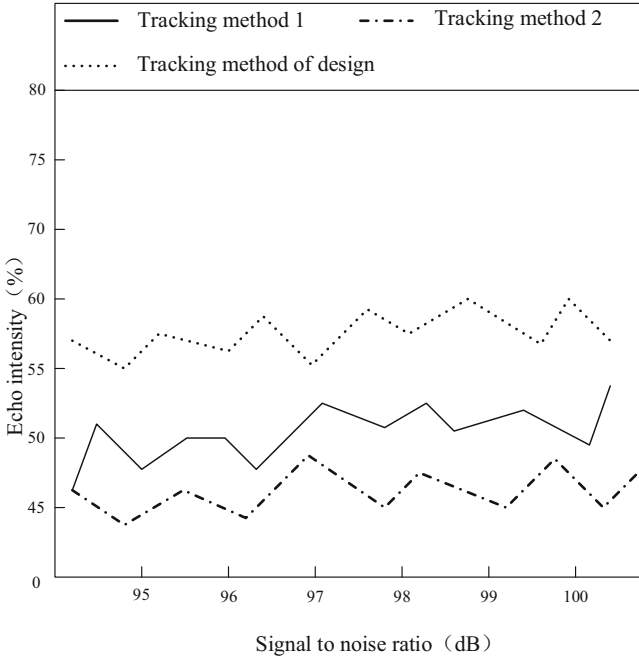


(a) 10 dB SNR

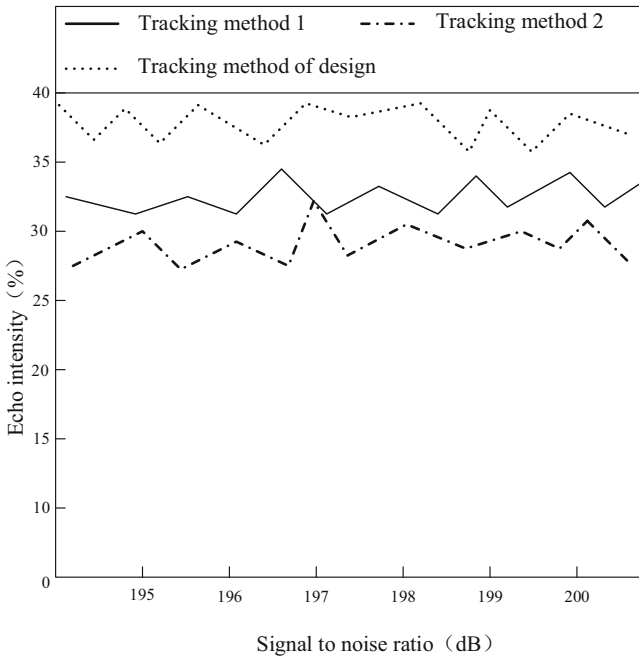


(b) 50 dB SNR

**Fig. 3.** Experimental results of echo intensity

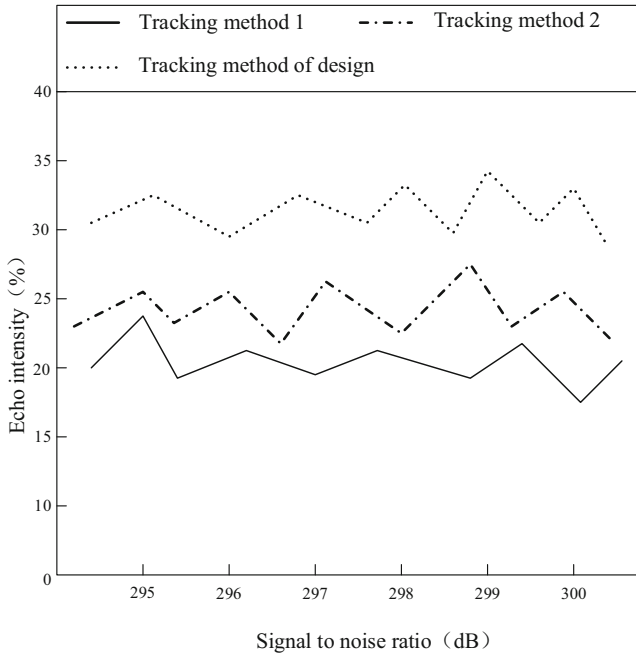


(c)100 dB SNR

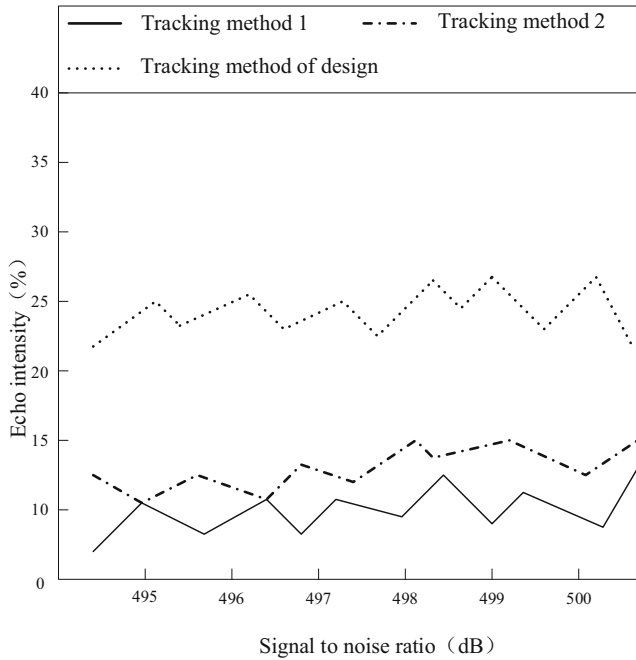


(d)200 dB SNR

Fig. 3. (continued)



(e) 300 dB SNR



(f) 500 dB SNR

**Fig. 3.** (continued)

It can be seen from Fig. 3 that under different SNR conditions, the average echo intensity of the designed tracking method and the two existing target tracking methods are 56.464%, 39.887% and 41.203% respectively, which proves that the designed target tracking method is more practical.

## 4 Conclusion

Wake radar detection technology is generally used to enhance the flight safety of civil aviation aircraft and improve transportation efficiency. In the field of military applications, because the electromagnetic scattering characteristics of aircraft wake are closely related to aircraft wingspan, takeoff weight and flight speed, the wake radar detection technology is expected to be applied to aircraft target detection, recognition and other fields. Therefore, this paper proposes an X-band radar detection target tracking method based on IOT sensing technology, and carries out experimental research. The target tracking method designed in this paper is proved to have better performance than the existing tracking methods by experimental test, which enriches the academic literature on target tracking. At the same time, it broadens the application field of IOT perception technology to a certain extent, and lays a theoretical and practical foundation for academic research. Due to the limited research conditions, the research on the application of IOT sensing technology in other fields is not thorough enough, and will continue to improve in the future.

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