Comparison and Analysis of Airborne Radar Detection Distance and Reconnaissance Distance Based on Big Data Background

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Abstract. Airborne radar is the eyes of fighter jets. The sooner a target is detected, the better it will be on the battlefield. With the advent of the era of big data, the author starts from the perspective of affecting the detection of airborne radar and uses data simulation to summarize the influence of radar detection distance. Then, the factor analysis that affects the reconnaissance distance is obtained according to the data simulation; finally, the relationship between the two values is obtained from many data. We must make full use of information technology to solve some complex problems.

Keywords: Airborne radar · radar range · reconnaissance range

1 Introduction

1.1 Research Background

With the improvement of radar technology, its role and function have become more and more abundant, playing an increasingly important role in the military. Therefore, it is necessary to understand the general situation of radar detection range technology and its working principle. Detection range of airborne radar is an important technical index, which has a very important influence on the combat capability of this type of equipment. Reconnaissance capability is also very important, reconnaissance is passive acceptance, good concealment, is also an important tactical index, if we can make a good analysis of these two distances, using existing equipment to detect it in advance without the enemy's knowledge, it is sure to affect the battlefield situation. This paper mainly expounds the relationship between radar detection technology and reconnaissance distance.

1.2 The Main Content

This paper is divided into three parts, the first part analyzes the radar action range, mainly through the radar equation to explain the maximum radar action range and what factors, what are the relations, mainly through simulation to explain the relationship

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between the scattering of different targets and the area of power transmission cooperation between the distance, but also explain the significance of power control. The second part analyzes the radar counter reconnaissance range. In the field of radar countermeasures, the reconnaissance range of radar countermeasures reconnaissance station (hereinafter referred to as the reconnaissance range) is a basic problem, it is a key factor to determine the position of reconnaissance aircraft. To put it simply, reconnaissance range is radar against reconnaissance is the maximum range of the target in any direction. In this sense, the determination of reconnaissance range can be equivalent to the determination of the maximum reconnaissance distance in the specified direction. With the maximum reconnaissance distance can be found in advance of the target, early warning time, will occupy the battlefield advantage. Finally, the relationship between radar action distance and reconnaissance distance is analyzed, and how to use the relationship between the two to preempt the battlefield, before the enemy discovers, before the enemy attacks. Opportunity fleeting, always grasp the battlefield dynamic.

2 Range of Airborne Radar

2.1 Maximum Detection Range of Airborne Radar

In the absence of external factors, the detection range of radar is calculated by radar equation. For airborne pulse Doppler radar, the radar equation commonly used in two forms is:

$$R_{\max}^4 = \frac{P_{av}\sigma_t A_r^2}{4\pi\lambda^2 L_\Sigma S_{\min}} \tag{1}$$

$$R_{\max}^4 = \frac{P_{av}G_t^2\lambda^2\sigma_t}{(4\pi)^3 L_\Sigma S_{\min}} \tag{2}$$

$$S_{\min} = kT_0 B_d F_n (S/N)_{\min} \tag{3}$$

where, P_{av} is the average transmitting power, G_t is the transmitting antenna gain, σ_t t is the target cross-sectional area, R is the distance from the radar to the target. λ is the radar wavelength, A_r is the antenna area, S_{min} is the minimum detectable signal power, L_Σ the total loss of the radar system, B_d is the bandwidth of the Doppler filter, $(S/N)_{\min}$ is the bandwidth of the Doppler filter, and the minimum detectable signal-to-noise ratio of the output of the doppler filter.

Pav is the average transmitting power. The higher the average transmitting power is, the farther the detection range of radar will be. Therefore, when other conditions are constant, increasing the average transmitting power of early warning radar can improve its detection range. We take several typical target RCS and analyze their detection range according to different powers.

Similarly, if other parameters remain unchanged, the detection range of radar will also increase with the increase of antenna gain $\mathrm{G_t}$. $\mathrm{S_{min}}$ is receiver sensitivity reflecting the ability of radar to receive weak signals. The smaller the sensitivity value is, the higher the sensitivity is and the easier it is to detect distant targets. Therefore, the higher the sensitivity of early warning radar is, the stronger is its detection ability.

Influence of target radar cross-sectional area on detection performance of airborne radar: The larger the effective cross-sectional area of the target, the longer the warning time of the target, the earlier the target can be found. Therefore, many radar detection indicators should be marked as the detection range of RCS (m^2) targets. In addition, we detect different targets from different angles, and their RCS are different. We should detect the maximum direction of target RCS, and the detection distance is the furthest. Airborne radar uses electromagnetic wave wavelength as wave band, stealth target for x-band electromagnetic wave reflection energy is the least, stealth aircraft RCS is the smallest, airborne radar is almost impossible to detect stealth aircraft. According to the radar equation, the detection range to the fourth power is proportional to the target radar cross-sectional area. According to relevant data, it is estimated that the effective detection range of AN/ APG-77 radar to the target with RCS of 1 m^2 is about 290 km. In order to achieve the same detection performance, for the target with the same distance, the radiated power decreases linearly with the increase of target RCS. We changed different RCS to observe the relationship between the power and the acting distance. We took RCS = 0.01, 0.1, 3 and 30 square meters respectively.

2.2 The Simulation Analysis

P_{av} is the average transmitting power. The higher the average transmitting power is, the farther the detection range of radar will be. Therefore, when other conditions are constant, increasing the average transmitting power of early warning radar can improve its detection range. We can be seen from the chart, with the gradual increase of power, the detection range of radar gradually increases (Table 1 and Fig. 1).

According to the simulation results, the higher the power is, the farther the detection range is, the larger the target cross-sectional area is, and the farther the radar detection range is; With the same transmitting power, the larger the target RCS, the earlier the target can be detected. In the initial search, radar generally uses the maximum energy to detect the target in order to ensure a longer distance. After a target is detected, the radar performs power management (reduction of transmitted power) to avoid continuous high power and to avoid exposure. The radar can detect and track the target normally in a certain distance, but the electronic countermeasure reconnaissance equipment of the target cannot realize the radar communication. Assuming that, $\sigma_1 = 0.01$; $\sigma_2 = 0.1$; $\sigma_3 = 3$; $\sigma_4 = 30$.We can analyze the radar action range according to the simulation results,

Table 1. Typical target RCS value

Typical target value	
Target type	**RCS value (m^2)**
cruise missile	0.01
Stealth fighter	0.1
fighter jet	3
Bombardment Aircraft	30

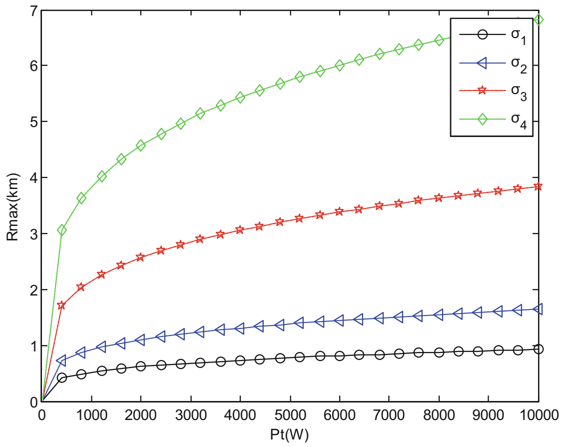


Fig. 1. The relationship between the transmitting power of targets with different effective cross-sectional area and radar range

and can also reduce the transmitting power and increase the detection range through accumulation.

3 Range of Airborne Radar

3.1 The Range at Which Radar Transmits Power

$$P_r = \left(\frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi R_0)^2 L_\Sigma} \right)^{\frac{1}{2}} \tag{4}$$

P_t is the peak transmitting power of radar, Gt is the gain of radar antenna, R_0 is the distance between airborne electronic offensive equipment and radar platform, λ is the working wavelength of radar. G_r is the antenna gain of the reconnaissance plane. Sensitivity P_{rmin} is the minimum signal intensity required by the equipment to determine the signal parameters of the radiation source. L_Σ is the system loss.

According to the radar equation, the detection range to the fourth power is proportional to the target radar cross-sectional area. Corresponding to the reconnaissance range 2 power of the reconnaissance plane and the target radar cross-sectional area. Radar action distance is a round-trip detection, reconnaissance distance is directly received, from the formula analysis, if the sensitivity of the reconnaissance plane is enough, in the long reconnaissance distance will find the existence of airborne radar in advance. It is documented that it can be detected at a distance of 800 km by AN/ APG-77 radar with a sensitivity of -70 dBm at full power emission (equivalent radiated power of 120 MW). According to the radar equation, the detection range to the fourth power is proportional to the target radar cross-sectional area. The square of the reconnaissance distance corresponds to the target radar cross section area. Radar action distance is a round-trip detection, reconnaissance distance is directly received, from the formula analysis, if the sensitivity of the reconnaissance plane is enough, in the long reconnaissance distance will find the existence of airborne radar in advance.

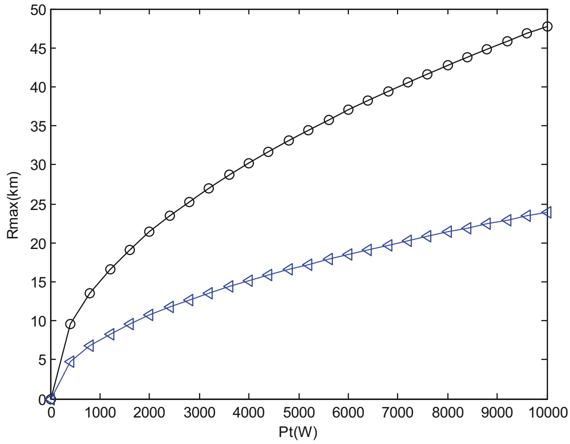


Fig. 2. The transmitting power of targets and radar counter reconnaissance range

3.2 The Simulation Analysis

To obtain a qualitative analysis, we assume the cross-scattered areas of several different reconnaissance aircraft. Let the transmission power varies from 0 to 10,000 watts. It can be seen from the simulation verification results:

(1) When the airborne radar transmits the same power, the effective scattering cross-sectional area of the reconnaissance aircraft is independent of the reconnaissance distance, which is only related to the transmitting power of the aircraft.

(2) As shown in Fig. 2, the triangle marker indicates the detection of the radar secondary flap, and the circular marker detects the radar main wave. Comparing the detection distances of the radar main and secondary lobes, we conclude that using the same reconnaissance device, the main lobe is detected at a longer distance, while the detection distance of the secondary or side lobe is closer.

(3) The direct vision distance is not considered. If the earth curvature is taken into account plus the analysis of direct vision distance.

4 Analysis of Radar Action Range and Radar Counter Reconnaissance Range

The battle over radar detection technology will be a battle between the enemy and me in future wars, The result will have a direct bearing on whether the war is won or lost. Therefore, the next article focuses on the relationship between radar detection technology and radar versus reconnaissance.

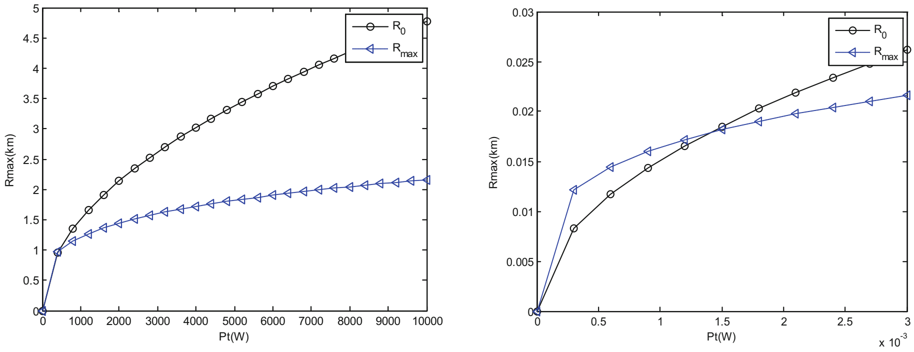
Radar adversarial reconnaissance is passive detection, which completely depends on the electromagnetic wave reflected by the radar of the other side. Reconnaissance range refers to the maximum distance between reconnaissance aircraft and radar under the condition that the signal intensity of the receiving point is enough to ensure the normal operation of the reconnaissance receiver. It indicates how far a reconnaissance aircraft can find radar, and is an important tactical and technical parameter to measure the detection ability of reconnaissance aircraft to radar. The reconnaissance range can be expressed by the reconnaissance equation.

4.1 The Simulation Analysis Between Radar Range and Reconnaissance Distance at RCS = 0.1

We use R_{max} for radar detection distance and R_0 for reconnaissance distance. When the target cross-sectional area of the reconnaissance aircraft is 0.1 square meters, it is a comparison curve between the radar action distance and the reconnaissance distance of the reconnaissance aircraft.

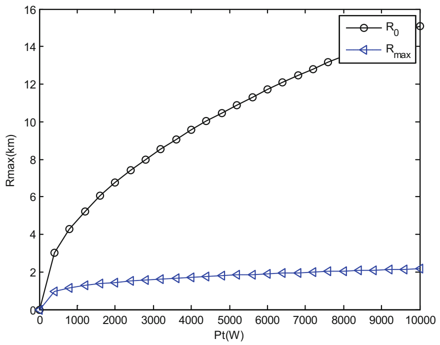
Such a conclusion can be drawn from the simulation results: If we use stealth aircraft as reconnaissance aircraft:

(1) Under the premise of a certain power, the reconnaissance mechanism should be farther than the radar detection distance. The greater the power, the greater the difference between the reconnaissance distance and the radar detection distance.
(2) If the radar transmission power is 1.5 milliwatts, the radar detection distance and the radar reconnaissance distance are 15 m, so the analysis of the two is not practical.
(3) From the perspective of the amplification curve, when the power is small, the radar detection distance is greater than the reconnaissance distance, but because it is a stealth aircraft, the radar detection distance will be raised when the distance between the two is very close, and this analysis is meaningless (Fig. 3).

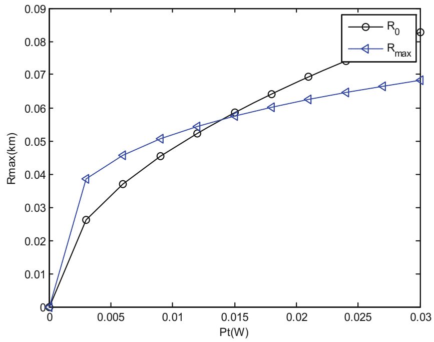


a. Detection distance and reconnaissance distance   b. Quick Detail View Profile

Fig. 3. Comparison curve of radar range and reconnaissance aircraft reconnaissance distance at RCS = 0.1



a. Detection distance and reconnaissance distance



b. Quick Detail View Profile

Fig. 4. Comparison curve of radar range and reconnaissance aircraft reconnaissance distance at RCS = 3

4.2 The Simulation Analysis Between Radar Range and the Reconnaissance Distance at RCS = 3

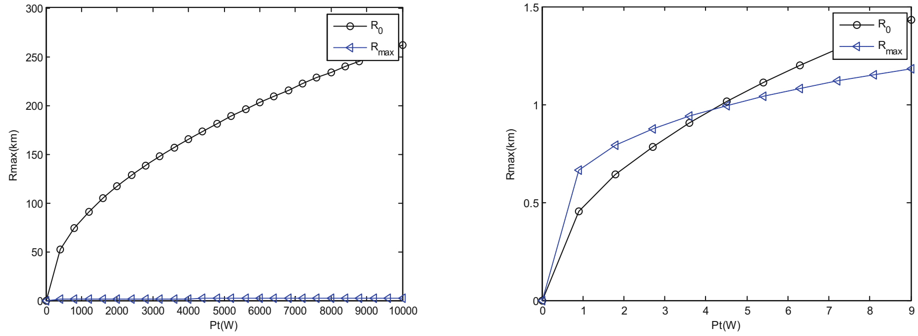
We use R_{max} for radar detection distance and R_0 for reconnaissance distance. When the target cross-sectional area of the reconnaissance aircraft is 3 square meters, it is a comparison curve between the radar action distance and the reconnaissance distance of the reconnaissance aircraft (Fig. 4).

Such a conclusion can be drawn from the simulation results: If we use fighter jet as reconnaissance aircraft:

(1) As the RCS increases, the reconnaissance distance is farer than the radar detection distance. The greater the power, the greater the difference between the reconnaissance distance and the radar detection distance, and the beep RCS hour gap increases.
(2) If the radar transmission power is 0.015 watts, the radar detection distance and the radar reconnaissance distance are 60 m, so the analysis of the two is not practical.
(3) From the perspective of the amplification curve, when the power is small, the radar detection distance is greater than the reconnaissance distance, but because it is a bomber, when the two are very close to each other, this analysis is also meaningless, but with the increase of power, the radar detection distance is not as fast as the reconnaissance distance is improved, so if there is reconnaissance equipment on the fighter, the combat opportunity will find the target first.

4.3 The Simulation Analysis Between Radar Range and Reconnaissance Distance at RCS = 30

We use R_{max} for radar detection distance and R_0 for reconnaissance distance. When the target cross-sectional area of the reconnaissance aircraft is 3 square meters, it is a comparison curve between the radar action distance and the reconnaissance distance of the reconnaissance aircraft.



a. Detection distance and reconnaissance distance b. Quick Detail View Profile

Fig. 5. Comparison curve of radar range and reconnaissance aircraft reconnaissance distance at RCS = 30

Such a conclusion can be drawn from the simulation results: If we use Bombardment Aircraft t as reconnaissance aircraft:

(1) The reconnaissance distance has an absolute advantage, when the power is small, the radar detection distance is greater than the reconnaissance distance, if the detection radar adopts power control, then the reconnaissance distance is very close, and we cannot detect the target.
(2) The premise of our analysis is that the radar gain value input is very small, only 4dB, if other parameters are changed, the simulation results will change, we just get a relative qualitative relationship based on the simulation.
(3) If we are the reconnaissance party, we have to choose the bomber to be farther away from the carrier aircraft according to the analysis, and if we are the probe party, we have to use power control to make the detection distance greater than the reconnaissance distance. In this way, it can occupy a favorable position (Fig. 5).

5 Conclusion

The era of big data has arrived. We use mass data to analyze the factors affecting the maximum range of radar and the range of radar against reconnaissance, analyze and summarize the relationship between the two and draw a conclusion. First of all, we use massive data to analyze many factors affecting the radar range, and through the simulation results, it is concluded that the larger the RCS, the farther the radar range; When the RCS is fixed, the greater the transmitting power, the farther the radar detection range. Secondly, the factors affecting the detection distance are also analyzed by using massive data. The main and side lobes are simulated by using massive data, and the detection distance of the main lobe is relatively far. It is also found that the greater the radar transmitting power, the farther the reconnaissance distance. The reconnaissance distance has nothing to do with the RCS of the reconnaissance plane. Finally, through data analysis and comparison, it is found that when the reconnaissance aircraft RCS is small, the radar detection distance is larger than the reconnaissance distance, but this is an ideal state, no two aircraft are so close. When bombers and other aircraft carry reconnaissance equipment, the reconnaissance distance is much larger than the radar detection distance, so the long-range reconnaissance distance has an advantage, and the short-range radar detection is dominant. In our analysis, the substitution values of some data parameters are small, and other parameter factors are simplified, just to draw qualitative conclusions for your reference, and the follow-up work will be further improved.

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