Study on the Influence of Electromagnetic Distribution Environment on Civil Aviation Air Traffic Control Radar Station

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Abstract: In order to improve the optimal training level of civil aviation radar station and improve the flight safety of civil aviation, the impact of electromagnetic distribution environment on air traffic control radar station is analyzed, the electromagnetic environment status is monitored, parameter setting is made, and the radar station is analyzed for peripheral electromagnetic Environmental impact, evaluation and analysis of optimized training results, demonstration of radar electromagnetic environment to ensure that civil aviation aircraft can fly safely under anti-electromagnetic interference, improve air traffic control efficiency.

1. Introduction

At present, many scholars in China have analyzed and studied the electromagnetic environment assessment of civil aviation radar. Air-to-air radar plays an important role in ensuring flight safety of civil aviation. It can display the dynamic information of aircraft in real time, which is an important means for controllers to correctly command flight [1]. The normal operation of the radar is affected by the surrounding electromagnetic environment and site conditions, including the reflection of large obstacles on the radio signal and the interference of the active signal. With the rapid development of the national economy, transportation infrastructure such as High speed railways around the airport is on the rise, but vehicles operating on these transportation facilities will generate electromagnetic waves, which may affect the normal operation of the equipment and cause hidden dangers to flight safety [2-3].

2. Civil Aviation Air Traffic Control Radar Electromagnetic Interference Analysis

The Secondary surveillance radar discovers and identifies the target through ground query and feedback from the receiver's transponder. The signal transmitted by the ground interrogator is called the interrogation (uplink) signal, and the signal transmitted by the airborne transponder is called the response (downstream). signal. The interference effects of the electromagnetic environment are mainly divided into two types: passive interference and active interference. Passive interference means that it does not actively radiate itself, but reflects and changes the radiant energy of the other party; active interference refers to the use of electromagnetic energy generated by itself, and the main action is used for the other party.

2.1 Active interference

Radar interference is a tactical and technical measure that destroys and disrupts radar detection target information. The basic problem of radar detection discussed above is the identification of echo signals in the context of thermal noise generated by the receiving system and external natural phenomena. In fact, noise can also come from other sources. For example, interference pulses from other radars and electrical noise from machines and other electrical equipment. The effect of the interfering signal on the radar equation from the main lobe and side lobes of the radar antenna will be discussed below.

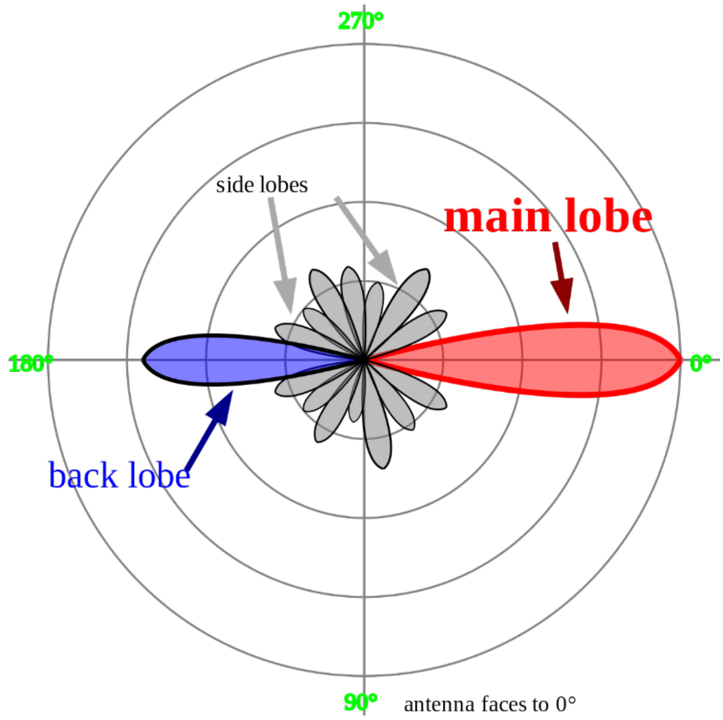

Fig. 1 Path of active electromagnetic interference entering the radar line

2.1.1 Interference signals enter from the main lobe of the radar antenna

The radar distance equation when the interference signal enters from the main lobe of the radar antenna, and the radar receives the target back-scattered signal power as follows.

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4 L} \tag{1}$$

Where P_r is the radar receiving the target back-scattered signal power; $P_t G$ is the radar antenna main lobe receiving the interference signal power; R is the target distance.

The expression of the interference power signal when the radar receives the interference signal from the main lobe.

$$\frac{P_r}{P_J} = \frac{P_t G \sigma L_r}{4\pi P_{tJ} G_J R^2 L} \cdot \frac{1}{v_J} \cdot \frac{B_J}{B} = K_J \tag{2}$$

From the relationship between the radar signal detection distance and the power signal to interference ratio S/J, the target can be detected only when the power signal to interference ratio reaches a sufficient value. In the interference environment, when the radar can only detect the power signal-to-interference ratio S/J of the target, the detection distance of the corresponding radar signal is the self-defense distance R_{J0} of the radar. From the above formula, the interference distance of the radar radiation signal when the interference signal enters from the main lobe of the radar antenna can be obtained.

$$R_{J0} = \left[\frac{P_t G \sigma L_r}{4\pi P_{tJ} G_J L K_J} \cdot \frac{1}{v_J} \cdot \frac{B_J}{B} \right]^{\frac{1}{2}} \tag{3}$$

2.1.2 Interference signals enter from the side of the radar antenna

The radar distance equation when the interference signal enters from the side of the radar antenna, the analysis method is the same as above, and the interference distance can be obtained from the radar radiation signal action distance when the radar antenna side flap enters.

$$R_{J0}=\left[\frac{P_t G\sigma L_r}{4\pi P_{tJ}G_J LK_J}\cdot\frac{1}{v_J}\cdot\frac{B_J}{B}\cdot\frac{G}{G_S}\cdot R_J^2\right]^{\frac{1}{4}} \tag{4}$$

2.2 Influence of passive clutter

Clutter is divided into two categories: surface clutter and body clutter. Surface clutter is caused by irregular surfaces, such as rugged terrain; body clutter is caused by spatially distributed scatter such as rain and chaff interfere. The amplitudes of surface clutter and bulk clutter vary with distance, resulting in different distance equations. The object studied here must be the target echo and clutter in the same radar resolution unit [4].

2.2.1 Radiated radiation signal action distance equation under the background of surface distribution clutter

The radar receives the target echo signal power expression.

$$P_r=\frac{P_t G^2\lambda^2\sigma}{(4\pi)^3R^4L} \tag{5}$$

The radar receives the clutter echo signal power expression.

$$P_c=\frac{P_t G^2\lambda^2\sigma_c}{(4\pi)^3R^4L} \tag{6}$$

When the clutter comes from a rough surface, then σ_c is equal to the surface area A_S of the radar illumination; the product of the radar cross-sectional area A_S per unit surface area. The radar antenna beam is fan-shaped, and the formula for A_S is:

$$A_S=\frac{1}{2}c\tau\frac{1}{\cos\theta}R\theta_{\beta 0.5} \tag{7}$$

Where $\theta_{\beta 0.5}$ is the antenna beam pitch half power point width, and $\theta_{\alpha 0.5}$ is the radar antenna beam azimuth half power point width. Because of $\sigma_c=A_S\cdot\sigma_0$, the power-to-noise ratio is:

$$\frac{P_r}{P_c}=\frac{\sigma}{\sigma_c}=\frac{\sigma}{A_S\cdot\sigma_0}=K_J \tag{8}$$

Substituting Equation 7 into Equation 8, the distance equation of the radar radiation signal in the background of surface-distributed clutter can be obtained.

2.2.2 Radar radiation signal action distance in the background of body distribution clutter

If the clutter is generated by a spatially distributed caterer (such as rain or chaff interferes), the calculation of the distance is the same except for $\sigma_c=\eta V_S$. It is generated instead of the ground scattered η as the body-distributed clutter scattering system, that is, the cross-sectional area of the unit-volume clutter radar; V_S is the volume of simultaneous illumination, that is, the echo signals of the scattering points in V_S fall in the same Within a distance unit, it can be calculated as:

$$\sigma_c=\frac{1}{8}c\tau\pi R^2\theta_{\beta 0.5}\theta_{\alpha 0.5}\eta \tag{9}$$

Then the power signal to noise ratio is:

$$\frac{P_r}{P_c}=\frac{\sigma}{\sigma_c}=\frac{\sigma}{V_S\cdot\sigma_0}=K_J \tag{10}$$

Substituting Equation 10 into Equation 9, the distance equation of the radar in the background of bulk distribution clutter can be obtained:

$$R_{J0} = \left(\frac{\sigma}{\frac{1}{8}\pi c \tau \theta_{\beta 0.5} \theta_{\alpha 0.5} K_J \eta} \right)^{\frac{1}{2}} \tag{11}$$

3. Analysis and evaluation

According to an airport construction plan, the horizontal distance from the nearest radar station in the district air traffic control is 100m, the distance from the radar antenna is 105.2m, and the height difference between the radar antenna and the High speed railway is 32.7m. The relative position is shown in Figure 2.

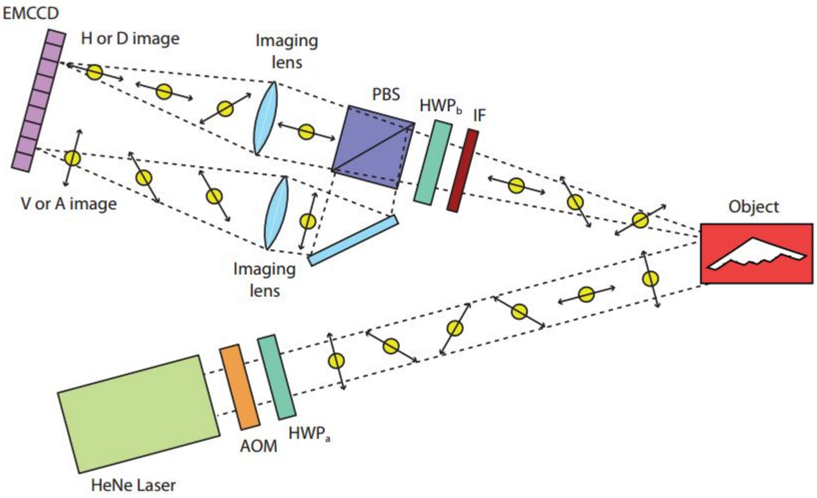

Fig. 2 Schematic diagram of the relative position of the air traffic secondary radar

3.1 Data collection

Tools required for data acquisition include receivers and antennas. Types of antennas include loop antennas, bicoastal antennas, large logarithmic period antennas, and small logarithmic period antennas. The types of receivers include vacuum air traffic control, chambers, etc. [5]. The selection of test tool types is important and has a large impact on the accuracy of the measured data. According to the measured frequency band and accuracy requirements, the test project team selected HL223 type large logarithmic period antenna, the test frequency range is 0.3~2 GHz, and the German R&S company meeting the requirements of CISPR16-1-1 and meeting the civil EMC standard. ESCI receiver. At the test point, using the ESCI receiver and the large logarithmic period antenna, in the frequency range of 1 080~1 100 MHz, the point frequency is used to test the active interference field strength generated by the High speed railway at each frequency point, and the ESCI receiver frequency is used. In the test, the resolution bandwidth is selected strictly in accordance with the relevant provisions of GB/T 24338.2--2011 [6]. Since the monitoring radar receiver operates at 1 090 MHz, the 120 kHz bandwidth is selected. The test data is shown in Table 1.

Since the test sites are selected as high-speed auxiliary roads, interchange interchanges and high-speed airports, and the test types include horizontal average, horizontal peak, vertical average and vertical peak, it can be seen that the selected test sites are representative and the test types are comprehensive. Therefore, the interference field strength derived from the test data is also relatively scientific.

Tab.1 Measurement data of electromagnetic interference generated by expressway

Test point	Test type	Interference field strength	Derivation of field strength
Test point 1 (10m)	Horizontal average	38.97	18.53
	Horizontal peak	45.97	25.53
	Vertical average	39.97	19.53
	Vertical peak	33.97	13.53
Test point 2 (10m)	Horizontal average	37.97	17.53
	Horizontal peak	38.97	18.53
	Vertical average	40.97	20.53
	Vertical peak	39.97	19.53
Test point 3 (5m)	Horizontal average	40.97	20.53
	Horizontal peak	39.97	19.53
	Vertical average	47.97	21.51
	Vertical peak	51.97	25.51

3.2 Simulation experiment

In order to further evaluate the impact of the proposed expressway on the secondary radar, the project team verified it through simulation tests. In the process of simulation verification, a certain high speed is selected to simulate the proposed expressway, and the air traffic monitoring equipment similar to the airborne secondary radar receiving principle (the receiving frequency is the same as the air traffic secondary radar, both 1 090 MHz) is adopted. (ADS-B) to simulate a secondary radar. By collecting the received data of the ADS-B receiver, as shown in Fig. 3, according to the quality of the received data, this is compared and analyzed to verify the influence of the High speed railway on the receiving performance of the air traffic control secondary surveillance radar[7]. The simulation verification test used ADS-B for a one-hour data record, and the longest distance to the target was 300.25km. Based on the analysis of the collected ADS-B data, it can be seen that the flight path of the aircraft is continuous and the data quality is almost the same. Therefore, through the ADS-B simulation verification analysis test, it can be seen that the expressway will not affect the ADS-B (secondary radar-like) receiving signal and will not cause active interference.

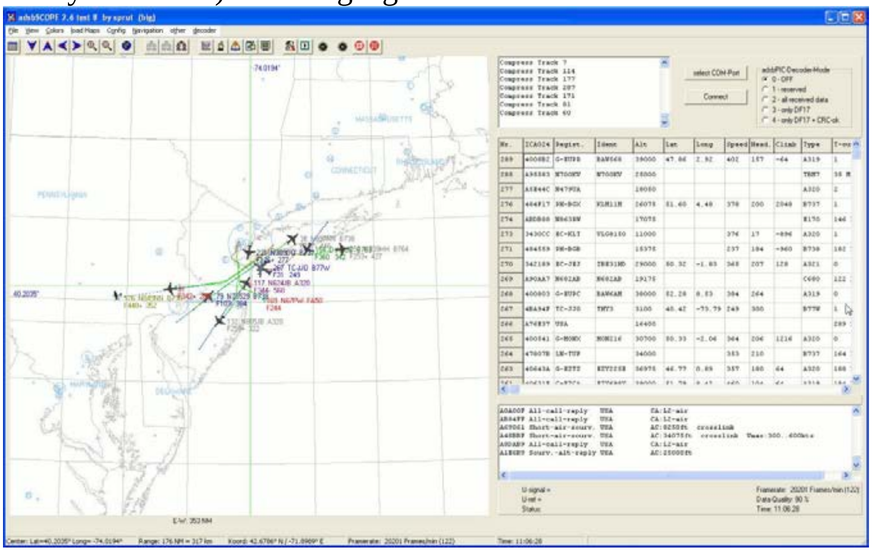

Fig. 3 ADS-B output data map

4. Conclusion

China's civil aviation industry is in a period of great development, and all localities are planning and building new airports, especially general aviation airports. The construction of airport infrastructure, especially air traffic control equipment, is susceptible to interference from various obstacles and other equipment. In order to ensure the normal operation of the airport air traffic control equipment, it should conduct a safety assessment of the electromagnetic environment. Based on the secondary radar site safety assessment of electromagnetic environment, this paper uses active interference and passive interference analysis methods to analyze and verify the field strength of the interference object, which is suitable for the current airport electromagnetic environment safety assessment. Taking the situation of the proposed secondary High speed railway of air traffic control at an airport as an example, through testing, analysis and verification, it can be seen that the peak field strength and average field strength generated by the proposed expressway will not affect the proposed airport.

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