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An Electromagnetic Environment Assessment Framework of Instrument Landing System Considering Multiple Classification Obstacles

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Abstract. With the rapid development of civil aviation, the electromagnetic environment of airports is becoming more complicated. The end-around taxiway screen will cause signal interference to the ILS. The electromagnetic interference will be more serious when the obstacle and the reverse localizer are combined. In this paper, the electromagnetic environment assessment model under the comprehensive influence of the end-around taxiway screen and the reverse localizer is firstly established. Secondly, the combined influence of the reverse localizer and the obstacle screen is analyzed by calculating the received strength of field. Then the influence of the obstacle on the radiation characteristics of ILS antenna is simulated by HFSS software. The study results studies on the electromagnetic environment of ILS under the impact of multiple classification obstacles will propose a useful suggestion for airport builder.

Keywords: Electromagnetic environment, HFSS Simulation, ILS, Obstacles

1. Introduction

With the rapid development of civil aviation in our country, the electromagnetic environment of airport becomes more and more complex. The signal interference of the instrument landing system (ILS) caused by the obstacles around the navigation facilities seriously affects the normal display of aircraft instruments and causes the deviation of aircraft landing flight path. It is of great significance to study the electromagnetic environment assessment of the ILS for the airport to ensure flight safety and it’s useful for guiding the flight test of the airport.

Domestic and foreign scholars have carried out a lot of research on the electromagnetic environment assessment of ILS: domestic scholars mostly use MATLAB, ATOLL, FEKO and other software for simulation analysis. Miao Qiang, Wu Dewei et al. [1], Ke Zemu, Shang Xiaofu et al. [2]and Li Zidan [3] all used MATLAB software to simulate the localizer. Shen Xiaoyun, Meng Jian, Jiao Weidong et al. [4] and Wang Ning [5] used FEKO software to analyze antenna radiation field patterns. Zhu Feng, Weng Wenwen et al. [6] used ATOLL software to analyze the influence of multipath interference generated by obstacles at different positions on DDM curve of localizer. Although foreign scholars have different research methods, they all study the influence of a single obstacle. In literature [7], PO method was used to analyze the scattering effect of obstacles on localizer signals, and the reflected signals of obstacles were calculated on the basis of Helmholtz equation. Literature [8][9] used the equivalent current method to study the multipath effect influence of obstacles on the ILS. In literature[10][11], scholar J Honda successively proposed a numerical method based on RTM in the three-dimensional propagation environment for the analysis of the electromagnetic environment of airports caused by multipath interference of obstacles.

The above researches are all about the signal interference analysis of a single obstacle without comprehensive influence of the reverse localizer. Moreover, the software used at present, such as MATLAB and ATOLL, cannot analyze the changes of antenna radiation characteristics, which is not enough to guide the construction of localizer. This paper firstly establishes an electromagnetic environment assessment model under the comprehensive influence of the end-around taxiway screen and the reverse localizer. According to

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the established model, the received field strength changes are calculated to analyze the combined effect of the reverse localizer and obstacles on ILS. Then, HFSS software is used to simulate the influence of the end-around taxiway screen on the antenna radiation characteristics. The HFSS software is a three-dimensional electromagnetic simulation software and can provide comprehensive simulation functions for antenna design, and accurately simulate and calculate various performance of the antenna, including two-dimensional, three-dimensional near field or far field radiation pattern.

The organization of this paper is as follows: In Section 2, it firstly establishes the radiation model for the localizer. Then it analyzes the antenna radiation pattern of SBO Signal and CSB Signal. In Section 3, it establishes an end-around taxiway screen model in HFSS software. In Section 4, the combined influence of the reverse localizer and the obstacle screen is analyzed by calculating the received strength of field. In Section 5, the influence of the obstacle on the radiation characteristics of ILS antenna is simulated by HFSS software, and conclusions are presented in Section 6.

2. Radiation Model for the Localizer

Hongqiao Airport has two close parallel runways, the West runway (18R/36L) and the East runway (18L/36R). End-around taxiways are constructed at both ends of the parallel runway, while an end-around taxiway screen is built on the west runway side to provide a view shield for the pilot. Localizers are installed at both ends of the runway for approach procedures in different directions of the runway. If two localizers transmit signals at the same time when an approaching aircraft passes over the reverse localizer, the ILS will be jointly affected by obstacles and the reverse localizer. The positions of the localizer, the reverse localizer and the end-around taxiway screen are shown in the figure below.

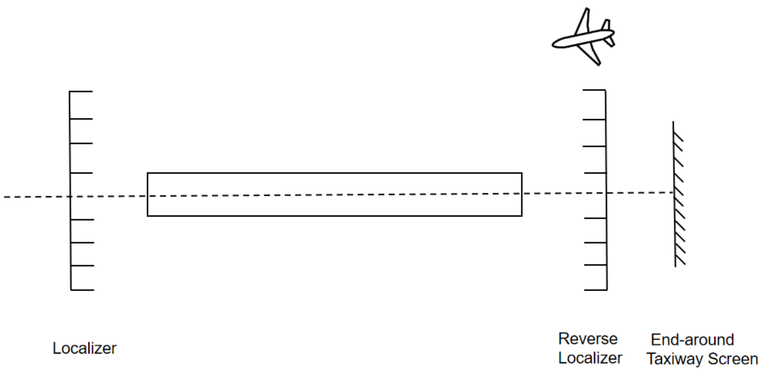


Fig. 1: Comprehensive Influence Model of End-around Taxiway Screen and Reverse Localizer

The localizer adopts a horizontally polarized logarithmic periodic antenna array. Establish an 8-unit mark-II localizer antenna array which is shown in Figure 2.

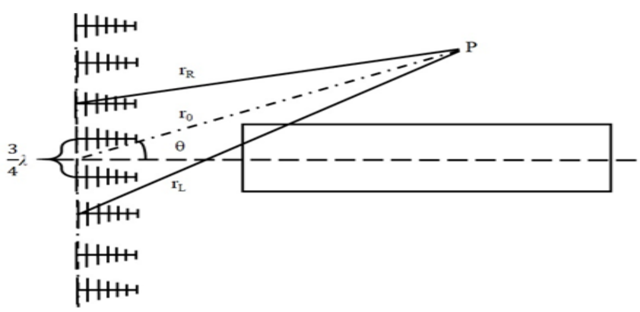


Fig. 2: Mark-II Localizer Antenna Array

The CSB signal feeds the left and right antennas in equal amplitude and same phase, while the SBO signal feeds the left and right antennas in equal amplitude and reverse phase [12]. The directional functions of the CSB signal and SBO signal for an 8-unit logarithmic periodic antenna array are:

$$F_{CSB}(\theta)=\cos(\frac{\pi}{2}\sin\theta)[\cos(\frac{3\pi}{4}\sin\theta)+0.363\cos(\frac{9\pi}{4}\sin\theta)+ \\ 0.143\cos(\frac{15\pi}{4}\sin\theta)-0.055\cos(\frac{21\pi}{4}\sin\theta)] \tag{1}$$

$$F_{SBO}(\theta)=\cos(\frac{\pi}{2}\sin\theta)[\sin(\frac{3\pi}{4}\sin\theta)+0.890\sin(\frac{9\pi}{4}\sin\theta)+ \\ 0.700\sin(\frac{15\pi}{4}\sin\theta)+0.415\sin(\frac{21\pi}{4}\sin\theta)] \tag{2}$$

Simulate the antenna radiation patterns of SBO signal and CSB signal using HFSS software, as shown below.

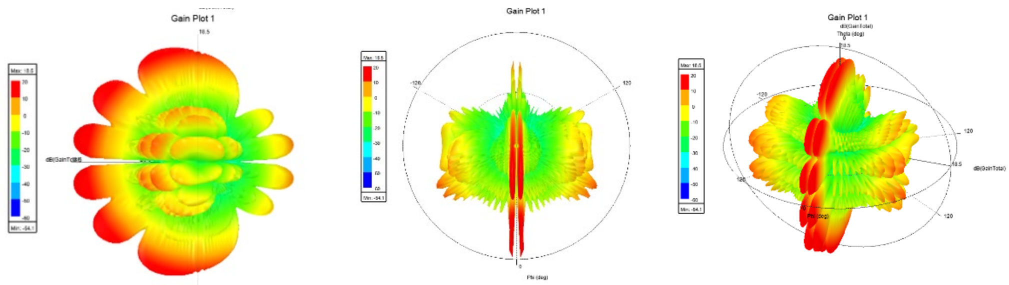


Fig. 3: Antenna Radiation Pattern of SBO Signal

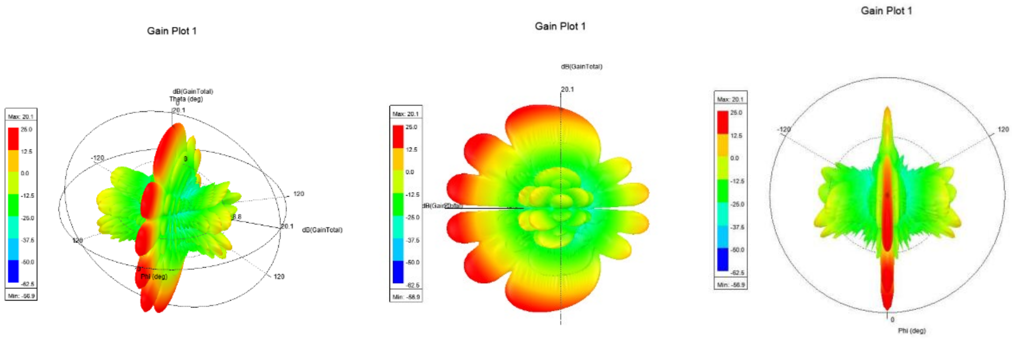


Fig. 4: Antenna Radiation Pattern of CSB Signal

3. Impact on End-around Taxiway Screen

The end-around taxiway screen of Hongqiao Airport is composed of aluminum alloy panels, metal support rods, foldable brackets, and connectors [13]. The length is 240m, the height is 5.8m, and it is located about 4000m in front of the localizer antenna array, 388m away from the runway entrance. The end-around taxiway screen is vertically installed on the extension line of the runway centerline and perpendicular to the extension line of the runway centerline. Establish an end-around taxiway screen model in HFSS software as shown in the following figure.

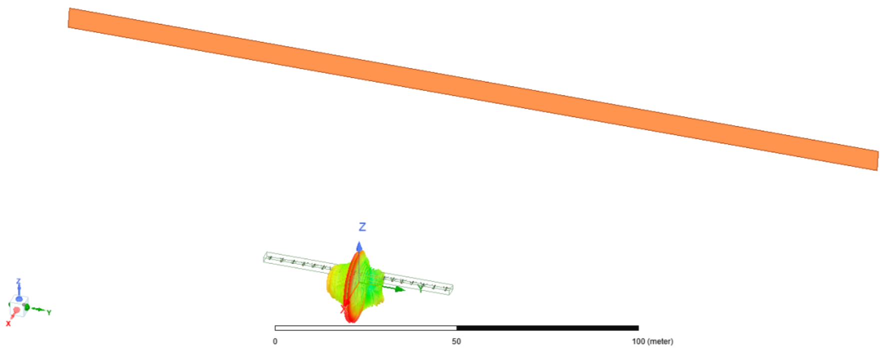


Fig. 5: End-around Taxiway Screen Model (Custom View)

4. Impact on Reverse Localizer

Based on the power and other information of the localizer at Hongqiao Airport, calculate and analyze the localizer signal interference of the aircraft at different altitude positions above the reverse localizer, and comprehensively consider the influence of the end-around taxiway screen for comparative analysis. Set the power of the antenna arrays of the two localizers to 20W, calculate the field strength of each antenna array received at different heights above the reverse localizer, and vector overlay to obtain the total received field strength. The received field strength in SBO mode and CSB mode is shown in the tables below:

Table 1: Received Field Strength in SBO Mode

End-around Taxiway Screen	Height (meters)	the Field Strength of the Far-side Antenna Array (dBV/m)	the Field Strength of the Near-side Antenna Array (dBV/m)	Total Received Field Strength (dBV/m)
No	30	-41.34936132	-23.55348882	-23.55348411
Yes	30	-41.13394082	-22.95821182	-22.95820788
No	40	-41.14809982	-21.38076132	-21.38075944
Yes	40	-41.20483032	-21.05085732	-21.05085575
No	50	-41.15590032	-23.14302332	-23.14301907
Yes	50	-39.89516432	-22.82847582	-22.82846918

Table 2: Received Field Strength in CSB Mode

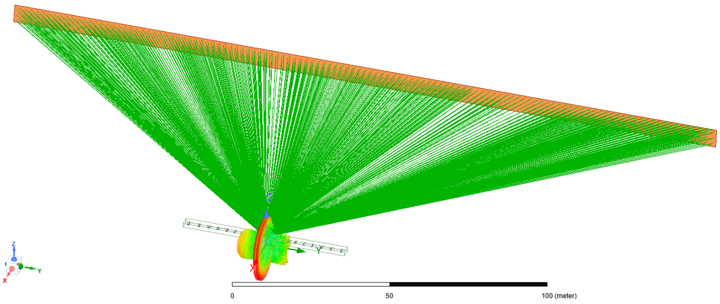
End-around Taxiway Screen	Height (meters)	the Field Strength of the Far-side Antenna Array (dBV/m)	the Field Strength of the Near-side Antenna Array (dBV/m)	Total Received Field Strength (dBV/m)
No	30	-26.20443982	-2.756736825	-2.756736481
Yes	30	-25.99540482	-2.836460825	-2.836460432
No	40	-24.97236382	-3.437327325	-3.437326494
Yes	40	-24.83994632	-3.260517825	-3.260517011
No	50	-24.01544132	-3.943352825	-3.943351191
Yes	50	-23.72702232	-4.094908825	-4.094906821

The distance from the far-side antenna array to the receiving point is relatively long, and the radiation power of the SBO is relatively small compared to the near-side antenna array. The beam power of the SBO is about 35dB lower, which is only about 1/3000 of the radiation power of the near-side antenna; The beam power of CSB is approximately 40dB to 45dB lower, which is about 1/10000 to 1/30000 of the radiation power of the near-side antenna, so the total received field strength remains basically unchanged. Meanwhile, as can be seen from the table, the end-around taxiway screen has only a slight impact on the numerical value of the received field strength, and the actual change is very small and can be ignored.

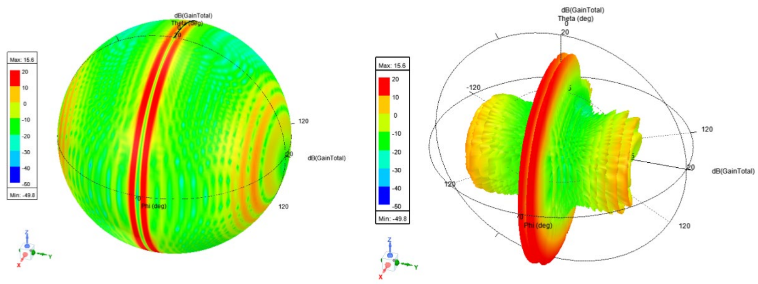
5. Simulations and Results

5.1. Analysis of Radiation Characteristics of SBO Array

Using HFSS software to simulate and analyze the radiation characteristics of the SBO signal considering the impact of the end-around taxiway screen at Hongqiao Airport. Due to the fact that the working wavelength of ILS is an electrically large problem, this article comprehensively uses finite element analysis (FEA) and ray bouncing method (SBR) for impact analysis. The high-precision FEA method is used for simulation analysis of the array, which can accurately estimate the far-field radiation distribution of the array; And the SBR method is used to analyze the interaction relationship between the array and the rear obstacle.



(a) Interaction Between End-around Taxiway Screen and Antennas (Custom View)



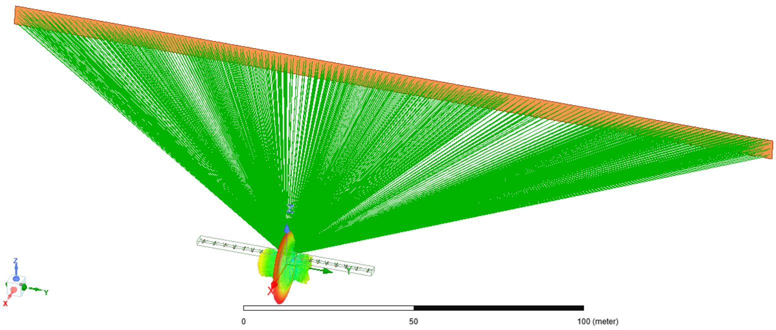
(b) The Antenna Radiation Characteristics Considering the End-around Taxiway Screen (custom view)

Fig. 6: The Radiation Pattern of the Localizer Antenna and the Interaction with End-around Taxiway Screen

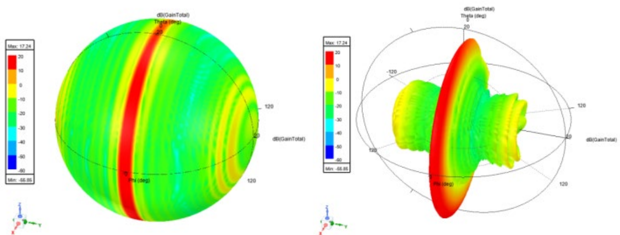
By comparison, it can be seen that the presence of the end-around taxiway screen has a certain impact on the radiation performance of the array. Relatively speaking, the normal radiation characteristics of the array change more dramatically.

5.2. Analysis of Radiation Characteristics of CSB Array

Using the same method to analyze the radiation characteristics of the CSB signal considering the impact of the end-around taxiway screen, the results are shown in the following figure.



(a) Interaction Between End-around Taxiway Screen and Antennas (Custom View)



(b) The Antenna Radiation Characteristics Considering the End-around Taxiway Screen (custom view)

Fig. 7: The Radiation Pattern of the Localizer Antenna and the Interaction with End-around Taxiway Screen

By comparison, it can be seen that the presence of the end-around taxiway screen has a certain impact on the radiation performance of the array. Relatively speaking, the normal radiation characteristics of the array change more dramatically.

6. Conclusions

This paper established an influence model, and the combined effects of the reverse localizer and obstacles on ILS are analyzed by calculating the changes in the received field strength. Then HFSS software is used to simulate the impact of the end-around taxiway screen on antenna radiation characteristics at Hongqiao Airport.

Compared with previous obstacle electromagnetic evaluations, this article takes the influence of reverse localizer into account, making the analysis more comprehensive. The results of this article have certain guiding significance for the electromagnetic environment assessment of newly constructed obstacles in airports, and can be applied to Shanghai Hongqiao Airport in the future.

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