Simulation and Research of DME Signal Coverage

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Abstract. In civil aviation land-based navigation equipment, the DME(Distance Measuring Equipment) system is a widely used short-range navigation equipment. Through the research on the antenna of the DME equipment, the antenna signal of the DME equipment is modeled and simulated, and the electromagnetic signal three-dimensional pattern of the DME equipment and the corresponding pattern of the E plane are obtained. On the basis of mastering the antenna signal radiation characteristics of each navigation device, the DME coverage area is simulated and analyzed.

1. Introduction
The DME ranging system is an important part of the civil aviation radio navigation system. It can be used as route navigation equipment, as well as airport navigation equipment. The terminal area DME/VOR is usually combined in the same location and is mainly used for aircraft. The slant distance information and azimuth angle information of the beacon station are used for precise positioning and navigation of the aircraft [1-2]. Even with the rapid development of navigation technology today, DME still plays a very important role in navigation technology. The beacon antenna used by the DME ground station equipment in the civil aviation wireless electric navigation technology is a double cone antenna. This study will carry out theoretical modeling of the double cone antenna and study the signal coverage of the DME ground station beacon antenna.

In civil aviation land-based navigation equipment, the DME system is a widely used short-range navigation equipment. It can be used as a route navigation device, and can also be used in combination with other short-range navigation devices such as a VHF omnidirectional beacon to provide navigation in the terminal area.

2. DME antenna modeling and simulation
Usually the beacon antenna used in the ground DME beacon station is an antenna array composed of 1-11 vertically arranged asymmetric biconical antennas, so a single biconical antenna is first analyzed [3-5].

Biconical antenna is a typical broadband antenna, which can be divided into infinite length and wired length according to its cone height. Figure 1 shows the wireless long biconical antenna. It can be regarded as formed by one rotation of the angle between a metal wire and the z-axis, and the distance d between the vertices is infinitely small. A periodically changing radio frequency signal is added between the two cone angles, and current is generated from the cone surface and electromagnetic waves are radiated outward.
The general model of a finite-length biconical antenna is shown in Figure 2. When the two cones are equal in length and finite, the upper and lower half cone angles are respectively and, at that time, it was an asymmetrical biconical antenna, and then it was a symmetrical biconical antenna. The asymmetric biconical antenna is mainly used as the research object.

In this study, a 10-unit asymmetric biconical antenna is used as an example to simulate a DME beacon antenna. Figure 3 shows the asymmetric biconical collinear antenna array model.
When the voltage excitation of each antenna element of the biconical collinear array is the same, the impedance of the entire array antenna is the sum of the impedance of a single antenna element in parallel, that is:

\[ Z_N = \frac{1}{Z_1 + Z_2 + \cdots + Z_n} \]  

(1)

The following table shows the parameters of the 10-unit DME beacon antenna:

| parameter name                   | Parameter value |
|----------------------------------|-----------------|
| Vibrator phase shift \( \varphi \) | \( \varphi_1-\varphi_{10} = 0^\circ, 10^\circ, 20^\circ, 30^\circ, 40^\circ, 50^\circ, 60^\circ, 70^\circ, 80^\circ, 150^\circ \) |
| Upper and lower cone length \( l \) | 60mm            |
| Each vibrator interval           | 13mm            |
| Upper cone angle \( \theta_1 \)  | 30°             |
| Upper cone angle \( \theta_2 \)  | 60°             |
| Frequency \( f \)               | 962~1213MHz     |
| Impedance of each vibrator \( z \) | 0.2Ω            |

According to the direction function and DME beacon antenna parameters, a MATLAB program is written to obtain the radiation characteristics of the DME ground station beacon antenna. The E-plane pattern is shown in Fig. 4, and the three-dimensional pattern is shown in Fig. 5.
Based on the analysis of the above results, the H surface is omnidirectional, the maximum gain of the E surface points to 4° and the maximum gain is about 10.88dB, which meets the requirements of DME in civil aviation land-based navigation equipment.

3. DME signal coverage simulation analysis
Take the ILS/DME instrument approach to Runway 32 of Mianyang Nanjiao Airport as an example. The rangefinder is combined with the gliding platform, which is mainly used in the middle and final approach stage of the precision approach procedure of Runway 32. The aircraft for this segment provide reliable ranging information. To simulate the electromagnetic signal coverage of its DME rangefinder, analyze whether it meets the operational requirements of flight procedures, first we need to analyze the height and distance information of the intermediate and final approach stages of the precision approach to Runway 32, and then calculate the signal coverage of the corresponding altitude and compare it with the route of the corresponding altitude to determine whether the signal coverage can meet the operational requirements of the route [6-9].

In "Annex X of the International Convention", it is recommended that the DME signal covers the farthest receiver sensitivity, so this study uses the reference value to determine the DME signal coverage. The DME station is located on the west side of the airport runway, 287.5m inside the south end, about 124.8m horizontally from the center of the runway. The geodetic coordinates (WGS-84 coordinate system) are: latitude 31° 25'22" north latitude, 104° 44'41" east longitude, antenna The elevation is 5 meters. The main flight altitudes for the intermediate and final approach stages of the instrument approach procedure of Runway 32 are 1400m and 950m, as shown in Figure 6 below.
According to the route description of the flight procedure of Runway 32, the intermediate approach anchor point IF, with an altitude of 1400m, cuts into the course and follows the 324° magnetic track to the final approach anchor point FAF. The signal coverage calculation method is used to simulate the 1400m height layer by MATLAB, and the calculation results are shown in Figure 7 below. The unit of the radial direction is kilometers, and the blue curve is the maximum radiation distance of the DME antenna signal at the height of 1400 meters. The red curve is the calculation of the coverage distance of the DME antenna signal at the same height layer by the method of literature. It can be seen that the calculation results of the two methods are roughly similar, but the calculation results of this study show that the coverage distance is more accurate. Mainly because the calculation method of this study not only considers the terrain shading situation, but also considers the radiation characteristics of the antenna of the ground navigation station equipment itself. In practical applications, the antenna performance of the navigation equipment is the most direct factor that can affect the signal transmission; secondly, the navigation ground station The signal transmission of communication with the aircraft is not only spread in a single environment, but also considers the influence of obstacles such as terrain, landforms, buildings, trees, hills and other obstacles on the propagation path to the signal attenuation. This study also uses the Longley-Rice model to simulate The attenuation loss of channel transmission does not affect the coverage distance. Therefore, it can be seen from the calculation results that the coverage distance calculated by the method of this study is smaller, but more accurate.

![Figure 7](image1.png)

Figure 7  The maximum radiation distance of DME antenna at 1400m level

Similarly, the calculation result of the signal radiation distance of the 950m altitude layer is shown in Figure 8 below.

![Figure 8](image2.png)

Figure 8  The maximum coverage distance of the DME antenna at a height of 950m
Figure 9 above shows the signal coverage of the rangefinder antenna at a height of 950 meters. The red line is the trajectory of the intermediate approach segment. The intermediate approach segment is flying at an altitude of 1400 meters to no less than 950 meters. From the above figure, it can be inferred that the signal coverage of the 950-meter segment fully meets the flight of the intermediate approach segment.

4. Conclusion
The main research purpose of this paper is to establish a mathematical model of electromagnetic signal corresponding to the antenna of the device by analyzing and researching the antenna type of the DME equipment of the rangefinder and the radiation characteristics of the antenna signal, and then combining the antenna specific parameters of the actual situation of each navigation station according to the relevant antenna theory, Using the MATLAB simulation platform to simulate the antennas of different navigation equipment. Finally, taking Mianyang Nanjiao Airport as an example, the signal coverage of the navigation ground station under the specified altitude is calculated, and the signal coverage of the navigation station ground station is visualized on the map. The research of this article visually presents the electromagnetic signal coverage of navigation equipment, and provides effective technical support for the location, erection and evaluation of navigation station performance in the future.

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