Research on the Influence and Control of Obstacles Around the DVOR

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Abstract. This paper studies the influence and control of obstacles around the DVOR and propose the control methods by combining the standards and theories. First of all, according the relevant technical standards of GB6364-2013 and MH/T4003.1-2014 to control the height of obstacles, then perform modeling and simulation and analyze whether obstacles will affect the signal coverage of DVOR. In order to prevent attenuation, this paper strictly controls the height of obstacles based on the theory of signal propagation, the Fresnel Zone principle and Diffraction theory. The results show that technical standards are the minimum operating requirements when used. When we set the height of obstacles only reply on the technical standards, the signal will not fully meet the signal coverage of requirements. It is necessary to analyze and control the obstacles deeply according to actual condition.

1. Introduction

DVOR is a navigation device that usually works in conjunction with an onboard receiver, which provide the aircraft with comprehensive guidance information and guide the aircraft to fly, enter, depart, and approach along a predetermined route (line) [1] [2]. With the rapid development of the city in recent years, the obstacles around the DVOR are increasing in height above vertical elevation. This seriously affects the signal quality of the navigation station and threatens aviation safety. Therefore, it is urgent to analyze the impact of obstacles and propose the reasonable and effective control methods. The paper analysis how the obstacles with different vertical elevation angle affect the signals on the basis of standards, and propose the control method based on the theory of space signal propagation.

The current control methods for the obstacles around the DVOR currently rely on the provisions of GB6364-2013[3] and MH / T4003.1-2014 [4] for vertical elevation angles. Taking the centre of the DVOR antenna as the reference point and the plane of the antenna counterpoise as the reference plane:(1) There should be no obstacles beyond the height of the reference plane within a radius of 100 m;(2) There should be no obstacles such as roads, buildings, dams, hills, etc. that exceed the height of the reference surface within a radius of 200 m;(3) The vertical elevation angle of obstacles with a radius of 100 m to 200 m with respect to the reference plane shall not exceed 1.5 °, and the horizontal angle shall not exceed 7 °;(4) The vertical elevation angle of obstacles with a radius of 200 m to 300 m with respect to the reference plane shall not exceed 1.5 °, and the horizontal angle shall not exceed 10 °;(5) There should be no railway beyond the height of the reference plane within a radius of 300 m; the vertical elevation angle of obstacles outside the radius of 300 m with respect to the reference plane should not exceed 2.5 °.
The lowest signal field strength in the VOR signal coverage area is $90 \text{ \mu V/m} (-107 \text{dBW/m}^2 \text{ or } -78 \text{dBV/m})$ [5] [6]. If the site is not adequately protected, the signal strength may not be satisfactory.

2. Simulating

Take for example, the obstacle located the south of DVOR, the distance of the nearest point of the obstacle and DVOR is 577 meters, the counterpoise of DVOR is 15.7 meters, the height of obstacle is 54 meters, the horizontal angle is $30^\circ (164^\circ \sim 194^\circ)$. The relative position is shown in the Figure 1.

![Figure 1. The relative position](image)

Assuming the ground is horizontal, after calculation the vertical elevation angle of the obstacle relative to the DVOR is $3.8^\circ$, which does not meet the standard requirements. The comparison of simulation results of signal coverage is shown in the Figure 2.

![Figure 2. The comparison result of $0^\circ$ and $3.8^\circ$](image)

In this position ($164^\circ \sim 194^\circ$), the signal coverage reduced 18km. According to GB6364-2013 and MH/T4003.1-2014, the vertical elevation angle of obstacles outside the radius of 300 m with respect to the reference plane should not exceed $2.5^\circ$. The height of the obstacle was need to reduce to meet the requirements of the standard. We reduce the obstacle height to 40m, and the vertical elevation angle is $2.41^\circ$. The signal coverage results are shown in the Figure 3.
In Figure 3(a), when the vertical elevation angle=0°, the maximum signal coverage distance in the obstacle azimuth is 39km. In Figure 3(b), when the vertical elevation angle=2.41°, the maximum signal coverage distance in the obstacle azimuth is 33km. Compare these two pictures, although the height of obstacle has been reduced according to standards, the max distance of the coverage is 33km, which is also small than 39km. So the signal coverage of the DVOR in the direction of the obstacle is still greatly affected.

3. Attenuation analysis
Taking 170° azimuth as an example, the signal field intensity profile when the vertical elevation angles are 0° and 2.41° shown in Figure 4.

If the field strength is low than -78dBV/m, the aircraft couldn’t receive the DVOR signal from the transmitter on the ground. In Figure 4(a), the blue curve is the cross-sectional view of the signal strength on a 170° azimuth when the vertical elevation angle=0°, the maximum signal coverage distance is 21.1NM. In Figure 4(b), the blue curve is the cross-sectional view of the signal strength on a 170° azimuth when the vertical elevation angle=2.41°, the maximum signal coverage distance is 17.8NM.

3.1. The Fresnel ellipsoid
According to the The Fresnel zone [7] [8] principle of telecast transmission, the energy from the wave source T to the receiving point R is basically transmitted by some Fresnel zones with T and R as the
In order to obtain the free space transmission better, it is necessary to protect the Fresnel zone from being blocked, show in the Figure 5.

![Figure 5. The Fresnel Zone](image)

When the height of transmitter point is 15.7m, the height of receiver point is 900m, the radius of the 1-th Fresnel zones at point M(obstacle) is given by:

\[
F_1 = \sqrt{\frac{300d_1d_2}{f \cdot d}} = 38.6m
\]  \hspace{1cm} (1)

The radius of the 0-th Fresnel zones at point M(obstacle) is given by:

\[
F_0 = 0.577F_1 = 22.3m
\]  \hspace{1cm} (2)

If the obstacle penetrates the 0-th Fresnel zones, the signal strength of free space propagation will be unguaranteed, which greatly affected the signal. Otherwise, the signal strength transmitted in free space is not affected. After calculation, the height of obstacle needs to be reduced to 18.25m.

3.2. Diffraction Theory

Calculate Fresnel parameters \(v\) and diffraction loss according to diffraction theory. When the height of transmitter point is 15.7m, the height of receiver point is 900m, the vertical elevation angle of obstacle is 2.41°, the propagation clearance \(H_c\) can be calculated, show in Figure 6.

![Figure 6. The model of \(H_c\)](image)

After calculation, \(H_c = 0.16 m < 0\) (the earth chord height in this same position is 0.68m), and the Fresnel parameter \(v = 0.0057\). The curve of diffraction loss as a function of Fresnel parameters [9] is shown in Figure 7. From the curve, if \(v = 0\), the diffraction loss is 6dB. And if the Fresnel parameter \(v < -0.8\), the diffraction loss is close to 0.
As long as the propagation clearance $v$ is smaller than -0.8, which will not affect the propagation of free space signals. After calculation, the height of obstacle needs to be reduced to 18.25m, this requirement is very strict.

3.3. Control method
Comparing the point A in Figure 4 (a) and point C in Figure 4 (b), in the same position from the transmitting antenna 21.1NM, the field strength is $-78$dBV/m when the vertical elevation angle=0°, and the field strength is $-82$dBV/m when the vertical elevation angle=2.41°. The attenuation of the obstacle which vertical elevation angle is 2.41°reached 4dB in the same place. Can we continue to reduce the height of the obstacle and reduce the loss by 4dB to improve the signal coverage instead of reduce the height of obstacle to 18.25m.

After calculation, the height of the obstacle need to be reduced to 27m,and the Fresnel parameter $v$=-0.47. The diffraction loss is 2dB and the vertical elevation angle of obstacle is 1.12°. The simulation results of signal coverage after obstacles are controlled is shown in the Figure 8.

It can be seen from the simulation results that when reduce the height to reduce the loss by 4dB, the coverage distance is the same as when there is no obstacle.

4. Conclusion
The control method of obstacles around the DVOR not only depends on the current existing technical standard specifications, but also combines the actual position of the obstacle and the height of the transmitting and receiving antennas for analysis. If the vertical elevation angle around the DVOR is only controlled according to the standard, the presence of large buildings will cause the signal coverage to be unsatisfactory. But if we control according to Fresnel zone or diffraction theory, the height of obstacles
around DVOR will be controlled very strict, which is not possible for most navigation stations. For some obstacles that may affect the critical azimuth signals, they need to be controlled by analysis.

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