The Research on Aerial Monitoring Mode of Civil Aviation Radio Interference Based on UAV

Chao Zhou*, Pingfa Jia, Jia Ye and Songru He

Key Laboratory of Flight Techniques and Flight Safety, CAAC, Civil Aviation Flight University of China, Guanghan Sichuan, China

*Corresponding author. Email: 1375102921@qq.com

Abstract. Aiming at the rapid increase of radio interference incidents in the aerial of civil aviation passenger airplane, based on the problem that ground radio monitoring equipment cannot handle, an aerial radio monitoring system based on Unmanned Aerial Vehicles (UAV) with a direction-finding antenna is developed, which aims to find direct radio signals from the aerial Path to locate interference sources. A two-point cross-location actual test was performed on the system prototype. The test results verify the feasibility of the aerial radio monitoring system based on UAV to detect radio interference in civil aviation, which has certain practical guiding significance.

Keywords: civil aviation, civil aviation radio interference, uav, aerial monitoring, test.

1. Introduction
The electromagnetic interference hazards of civil aviation radio frequency are not only erratic and difficult to detect, but also can destroy the communication navigation monitoring equipment in a short time, and can also cause the civil aviation main and standby aircraft to fail at the same time [1]. According to surveys, the number of radio interference reports received by civil aviation in East China in 2012-2017 was 397, 399, 400, 334, 439, and 306. According to statistics in the past 6 years, the number of radio interference in civil aviation has increased. Among them, the proportion of aerial interference has always been high, accounting for 55%, and it is on the rise. Because aerial interference cannot be received on the ground, and the object of interference is the aerial flight attendant, which brings great difficulties to the investigation of interference sources. In actual supervision and investigation, local Office of Radio Management Committee (ORMC) mainly use fixed ground stations, monitoring vehicles, and handheld devices. The investigation efficiency is low and cannot meet the needs of rapid development of civil aviation. On the basis of manned aircraft carrying a monitoring system to the high altitude, the radio interference of civil engineering "industrial, scientific, medical (ISM)" will be monitored and checked. It will be restricted by the airspace environment, and flight routes must be applied in advance. The approval process is complicated and the cycle is long. Civil aviation radio interference has risen to the height of national radio safety, and is an important branch of aviation safety research [2]. Controlling civil aviation radio interference is to maintain the "life frequency" of civil aviation safety, which is of urgency to the lives of myriads of passengers [3].
2. Direction finding and positioning program implementation

2.1. Direction finding and positioning principle

The principle of direction finding and positioning \(^1\) is to obtain the azimuth information of the target signal source at different locations according to the mobile monitoring system. The positions of the two observation points and the target signal source constitute a position triangle, and the position coordinates of target signal source can be detected according to the geometric knowledge of the triangle. As shown in Figure 1, at Q1, the coordinate of the monitoring system at point M is \((x_m, y_m, z_m)\), and the azimuth of the target signal source P is \(\alpha_m\), measured at this time, and the angle of pitch is \(\beta_m\). The monitoring system moves from M to N, at this time the coordinate of monitoring system is \((x_n, y_n, z_n)\), the azimuth angle of the target signal source P at this time is \(\alpha_n\), and the angle of pitch is \(\beta_n\).

In the triangle PMN, if the specific positions of the M and N points are known, and the azimuth and angle of pitch of the observation stations can be obtained at the two points of observation, the triangle formula of the angle of pitch \(\beta_m\) is derived according to the trigonometric function theorem:

\[
\tan \beta_m = \frac{z - z_m}{y - y_m} \cdot \sin \alpha_m \quad (1)
\]

Similarly, the triangle formula for azimuth \(\alpha_m\) is:

\[
\tan \alpha_m = \frac{y - y_m}{x - x_m} \quad (2)
\]

In the same way, the triangle formula from the azimuth angle \(\alpha_n\) is:

\[
\tan \alpha_n = \frac{y - y_n}{x - x_n} \quad (3)
\]

Convert into matrix form is:

\[
\begin{bmatrix}
- \tan \alpha_m & 1 & 0 \\
0 & \tan \beta_m & - \sin \alpha_m \\
- \tan \alpha_n & 1 & 0 
\end{bmatrix}
\begin{bmatrix}
x \\
y \\
z
\end{bmatrix} = \begin{bmatrix}
y_m \cdot x_m \cdot \tan \alpha_m \\
y_m \cdot \tan \beta_m \cdot z_m \cdot \sin \alpha_m \\
y_n \cdot x_n \cdot \tan \alpha_n
\end{bmatrix}
\quad (4)
\]

Suppose \(A=\begin{bmatrix}
- \tan \alpha_m & 1 & 0 \\
0 & \tan \beta_m & - \sin \alpha_m \\
- \tan \alpha_n & 1 & 0 
\end{bmatrix}\), \(X=\begin{bmatrix}
x \\
y \\
z
\end{bmatrix}\), \(B=\begin{bmatrix}
y_m \cdot x_m \cdot \tan \alpha_m \\
y_m \cdot \tan \beta_m \cdot z_m \cdot \sin \alpha_m \\
y_n \cdot x_n \cdot \tan \alpha_n
\end{bmatrix}\)

If \(AX=B\), then \(X=A^{-1}B\), you can determine the location of the target signal source.

2.2. Conversion between the Earth's Rectangular coordinate system and the Earth's Geodetic coordinate system

(1) The Earth's Rectangular coordinate system convert into the Earth's Geodetic coordinate system.

The conversion formula of the Earth's Rectangular coordinate system to the Earth's Geodetic coordinate system is shown in formula (5):

\[
\begin{align*}
L &= \arctan \left( \frac{\frac{2}{\pi} \frac{z}{\sqrt{x^2+y^2}}}{\sqrt{\frac{2}{\pi} \frac{z}{\sqrt{x^2+y^2}} (\frac{\pi}{\sqrt{N+H}})^{-1}}} \right) \\
B &= \arctan \left( \frac{\frac{2}{\pi} \frac{z}{\sqrt{x^2+y^2}}}{\sqrt{\frac{2}{\pi} \frac{z}{\sqrt{x^2+y^2}} (\frac{\pi}{\sqrt{N+H}})^{-1}}} \right) \\
H &= \sqrt{\frac{x^2+y^2}{\cos B}} N
\end{align*}
\quad (5)
\]

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In formula (5): x, y, and z are the three-axis coordinates of the Earth's Rectangular coordinate system; L, B, and H are the longitude, latitude, and height of the earth: \( e^2 = (a^2 - b^2)/a^2 \), a is the long radius length of the earth ellipsoid (6378137m), b is the short radius length of the earth ellipsoid (6356752m), e is a constant indicating the first eccentricity of the earth; N is the radius of curvature of the earth's prime vertical, \( N = a/\sqrt{1-e^2\sin^2(B)} \).

(2) The Earth's Geodetic coordinate system convert into the Earth's Rectangular coordinate system.

The formula for transforming the Earth's Geodetic coordinate system into the Earth's Rectangular coordinate system is shown in formula (6):

\[
\begin{align*}
  x &= (N+H)\cos(B)\cos(L) \\
  y &= (N+H)\cos(B)\sin(L) \\
  z &= [N(1-e^2)+H]\sin(B)
\end{align*}
\]

In formula (6), L, B, and H are the longitude, latitude, and height of the earth; x, y, and z are the three-axis coordinates of the Earth's Rectangular coordinate system; N is the radius of curvature of the earth's prime vertical; e is a constant indicating Earth's first eccentricity.

2.3. Direction finding and positioning system program

The direction finding and positioning system program is written in the MATLAB GUI environment according to the direction finding and positioning algorithm model. The position information of the target signal source output by the direction finding and positioning system simulation program can be directly used in the electronic map to determine its specific location and provide some theoretical support for aerial radio monitoring.

3. Overall design scheme of aerial radio monitoring system

Based on the overall requirements of aerial monitoring civil aviation radio interference, a scheme for carrying radio interference monitoring equipment by UAV was designed. The aerial radio monitoring system mainly includes UAV platforms, UAV airborne monitoring systems, ground terminals, and image transmission modules. The overall plan is shown in Figure 4. As a UAV platform, the DJI S1000 carries a P9030 comprehensive tester, a laptop, a RunCam Swift 2 camera, and an AOMWAY image transmission module as the aerial hardware part of the aerial radio monitoring system. Among them, the P9030 comprehensive tester includes a portable receiver, direction finding antenna, and self-contained-complete frequency spectrum monitoring software. The fixed direction-finding antenna is in the same direction as the nose. The position information of the direction-finding antenna is determined by the UAV position information, that is, the incoming wave location information of the radio signal. Location information. The ground part contains the Futaba remote control of the UAV, the image transmission and receiving module of the Eagle Eye Vision series all-in-one machine, and the laptop computer with the ground station software installed. The aerial radio monitoring system is shown in Figure 2.

Figure 1. Schematic diagram of cross-position.
Figure 2. Physical picture of the aerial radio monitoring system.
Figure 3. Test scenario diagram.
4. Two-point cross-location test of aerial radio monitoring system

Use the WBTER radio (8W, about 442MHz) as the simulated interference source in the two-point cross-location positioning test, place it at point P, and select the UAV platform height that is basically higher than the height of the obstacles around the test site. The height of test is 15m), so that the target radio signal close to the line-of-sight (LOS). Points A1 and A2 were selected as the monitoring sites for the aerial intersection test of the aerial radio monitoring system. The aerial radio monitoring system flew to points A1 and A2 to monitor the simulated interference sources. The aerial test scenario is shown in Figure 3. During the test, the GPS information of the aerial radio monitoring system at points A1 and A2 is recorded in real time. The aerial radio monitoring system performs five tests on the simulated interference sources.

The coordinates calculated by entering the direction finding and positioning program is (104.3037, 30.9492, 420.0194), as shown in Figure 4, and the actual position coordinates of the P point of the simulated interference source is (104.30321, 30.94984, 421.992). The location and the actual location of the simulated interference source are displayed in the electronic map as shown in Figure 5.

![Figure 4. Simulation results of direction-finding positioning program.](image)

![Figure 5. Position of the target signal source by cross-and location(red)and actual location of the target signal source (blue).](image)

Test results show that the simulation program can be used to detect the geodetic coordinates of the target interference source when really monitoring radio interference. And the two-point cross-location solution found that the distance between the simulated interference source and the actual simulated interference source was about 85m, and the error in the X, Y, and Z directions was (53.99, -22.21, 61.83) m. The source of the error was mainly due to the accuracy of the direction-finding angle of the target signal source's incoming wave location is not high when the aerial radio monitoring system monitors the target radio signal. However, this method can basically achieve direction finding and positioning, and has certain application value in real life.

5. Summary

In this paper, Designed and built an aerial radio monitoring system, and conducted two-point cross-location testing on the system, verifying the feasibility of the aerial radio monitoring system to detect radio interference from civil aviation, which has certain practical guidance significance. However, the aerial radio monitoring system designed in this paper to detect the radio interference of civil engineering is still in the preliminary stage. The location information of aerial radio monitoring system and spectrum monitoring information of radio signals are integrated in the same software, which will further enhance the aerial radio monitoring system in the investigation of civil aviation radio interference.

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