Research on TCH and RDH of Glide Path Equipment

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Abstract. There is a certain difference between the RDH obtained from the flight inspection and the TCH calculated from geometry terrain. The problem is always neglected and someone attribute the cause of poor RDH to equipment issues, actually equipment is a problem, but the electromagnetic environment is also a very important factor overlooked by owner. When the electromagnetic environment around glide path antenna is worse, the difference of TCH and RDH is even larger, and even cannot meet the requirements for safe operation. This article study the calculation method of the actual measured RDH, revealing fundamental reason of the difference, and further explaining the importance of protecting the electromagnetic environment of the instrument landing system, providing analysis ideas and solutions for equipment construction and maintenance engineers.

1. Introduction

In recent years, with the increase of airports, there are some cases where the threshold crossing height (TCH) [1-2] cannot support the operational requirements of Instrument Landing System (ILS). TCH is a key parameter during approach and landing stage. The parameter is beyond 15m ~ 18m cannot pass the flight inspection, the consequence is ILS category I approach cannot be approved. That means the pilot can only fly visually during the final approach phase. The effect is bad.

TCH is the height of the glide path above the threshold of the runway. Internationally, Annex 10 "Aeronautical Telecommunications" of ICAO and Order 6750-16E "Siting Criteria for Instrument Landing System" of Federal Aviation Administration (FAA) introduce TCH is calculated by longitudinal slope in front of the glide path reflection plane, glide path angle and setback distance of glide path equipment. Civil Aviation Administration of China cited the methods of ICAO and FAA to calculate TCH.

Actually, the TCH released by AIP is not the calculated value, it is the measured TCH got through flight inspection maybe has more accurate professional name reference datum height (RDH) [1-2]. So in some airports RDH is not equal to the calculated TCH value, some even exceed the standard requirements, and the engineer can just adjust the antenna offset and shift of glide path equipment to optimizing the RDH, but extreme cases often have little effect. The underlying reason is TCH is calculated by geometric formula, but RDH is derived by computing the glide path in flight inspection between points “A” and “B” and by projecting an extension of this glide path through the threshold. Point "A" on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 7500 m from the threshold. Point “B”. A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 1050 m from the threshold, show as Figure 1.
Figure 1. relationship between RDH and points "A" and "B"

2. Calculation of TCH
According to "Electromagnetic environment requirements for aeronautical radio navigation stations" (GB6364-2013) of China, the glide path antenna setback distance can be decided by these parameter include glide path angle, TCH and longitudinal slope in front of the glide path reflection plane.

\[ D = \frac{TCH + Y}{\tan(\theta + \alpha)} \]  

(1)

Glide path antenna setback distance is D, glide path angle is \(\theta\), longitudinal slope in front of the glide path reflection plane is \(\alpha\), the vertical height of the runway threshold above P' is Y, when the sideway slope is less than 1%, it is not necessary to introduce the Y. Glide path antenna siting figure for sloping runway show as Figure 2[3].

Figure 2. Glide path antenna siting figure for sloping runway

One airport is designed \(\alpha\) is 4‰ downslope, glide path angle \(\theta\) is 3°, D is 292, according to formula 1, the calculated TCH is 16.5 m.

3. Calculation of Reference datum height (RDH)
In order to calculate the RDH, the specified portion of the descent path, called ILS Zone 2, is used between ILS Point A (4 NM from threshold) and ILS Point B (3500 feet from threshold). The Best Fit Straight Line (BFSL) [2] must be fitted by measured glide path, RDH is the line extends down to the threshold. The measured glide path and BFSL show as Figure 3 is got by flight inspection.
Figure 3. Best-Fit-Straight-Line and RDH

How to get the BFSL? Every glide path have different DDM value, obviously, the best choice is least square method.

3.1 least square method

The method of least squares assumes that the best-fit curve of a given type is the curve that has the minimal sum of the deviations squared (least square error) from a given set of data. Suppose that the data points are \((x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\) where \(x\) is the independent variable and \(y\) is the dependent variable. The fitting curve \(f(x)\) has the deviation (error) \(d\) from each data point, i.e., \(d_1 = y_1 - f(x_1), d_2 = y_2 - f(x_2) \ldots d_n = y_n - f(x_n)\), show as Figure 4.

![Least squares diagram](image)

Figure 4. Least squares diagram

According to the method of least squares, the best fitting Line has the property show as formula 2, formula 3 and formula 4.

\[
\begin{align*}
    b & = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sum(x_i - \bar{x})^2} \quad (2) \\
    a & = \bar{Y} - b\bar{X} \quad (3) \\
    \bar{Y} & = bX + a \quad (4)
\end{align*}
\]

3.2 parameter of flight inspection

There are many parameters during flight inspection. For glide path antenna, setback distance, sideway distance, glide path elevation, threshold elevation can be got. For aircraft, the flight distance and height of aircraft relative to glide path antenna can be got, show as Figure 5 [4].
Figure 5 location and height of aircraft and glide path antenna

According to formula 2, $x_i$ is distance between of landing point to aircraft, $y_i$ is flight height of aircraft. Because glide path antenna is sited on side of runway, actually $X$ in formula 2, 3 and 4 can be replaced by $X_{oi}$ that could be calculated from formula 3:

$$X_{oi} = \sqrt{x_i^2 + O^2}$$ \hspace{1cm} (5)

$$y_i = \tan \theta \times X_{oi}$$ \hspace{1cm} (6)

$$\bar{X} = \frac{\sum x_{oi}}{n}$$ \hspace{1cm} (7)

$$\bar{Y} = \frac{\sum y_i}{n}$$ \hspace{1cm} (8)

$$x_i = X_{oi} - \bar{X}$$ \hspace{1cm} (9)

3.3 RDH Calculation

One airport the glide path antenna site is ideal, down slope in front of glide path antenna is 4‰, lateral slope from runway to glide path antenna is less than 1%. Setback distance is 293 m from threshold, lateral distance is 120 m from runway centre line and glide path angle is 3°. The calculated TCH is 16.5 m according to formula 1, but the measured RDH by flight inspection and simulation is 16.79 m, shown as Figure 6.

Figure 6 RDH by simulation

In actual flight inspection, the distance and height of aircraft, location of glide path antenna is definite, so all parameter can be got ease show as Table 1.
Table 1. parameter for calculation RDH(ft)

| Sample | $\theta_m$(°) | X     | X₀    | Y     | x    |
|--------|---------------|-------|-------|-------|------|
| Pt "A" | 3.00048       | 24600 | 24603 | 1290  | 10496|
| 1      | 3.00048       | 23616 | 23619 | 1238  | 9512 |
| 2      | 3.00048       | 22632 | 22635 | 1186  | 8528 |
| 3      | 3.00048       | 21648 | 21652 | 1135  | 7544 |
| 4      | 3.00048       | 20500 | 20504 | 1075  | 6396 |
| 5      | 3.00048       | 19516 | 19520 | 1023  | 5412 |
| 6      | 3.00048       | 18532 | 18536 | 972   | 4428 |
| 7      | 3.00048       | 17548 | 17552 | 920   | 3444 |
| 8      | 3.00048       | 16564 | 16569 | 868   | 2460 |
| 9      | 3.00048       | 15580 | 15585 | 817   | 1476 |
| 10     | 3.00048       | 14596 | 14601 | 765   | 492  |
| 11     | 3.00048       | 13612 | 13618 | 714   | -492 |
| 12     | 3.00048       | 12628 | 12634 | 662   | -1476|
| 13     | 3.00048       | 11644 | 11651 | 611   | -2460|
| 14     | 3.00048       | 10660 | 10667 | 559   | -3444|
| 15     | 3.00048       | 9512  | 9520  | 499   | -4592|
| 16     | 3.00048       | 8528  | 8537  | 447   | -5576|
| 17     | 3.00096       | 7544  | 7554  | 396   | -6560|
| 18     | 3.00096       | 6560  | 6572  | 345   | -7544|
| 19     | 3.00096       | 5576  | 5590  | 293   | -8528|
| 20     | 3.00144       | 4592  | 4609  | 242   | -9512|
| Pt "B" | 3.00144       | 3608  | 3629  | 190   | -10496|

The slope of the BFSL is 0.0524 according to formula 3, corresponding to 2.998° glide path angle ($\theta_b$). The correspondingly RDH is 16.79 m that very close to flight inspection and simulation value.

4. RDH and site environment

Throughout the calculation process, the RDH is related to the aircraft flight height, the aircraft flight height is related to the glide path structure, which is closely related to the site environment [2, 5]. So, electronic magnetic environment around glide path antenna is very important, same longitudinal and transverse slopes for same glide path antenna. A cabin is 260 meters in front of the glide path antenna, 22 meters to the side, length is 4 meters and height is 4 meters, the flight inspection and simulation RDH is 16.82 m which is big different, show as Figure 7.

![Figure 7. Simulated RDH for cabin in front of glide antenna](image)

5. Conclusion

The RDH verified by actual flight inspection has always been inconsistent with the TCH calculated by geometry terrain, and even the measured RDH does not meet the requirements for airport safe operation.
The main reason is because the electromagnetic environmental protection area around the glide antenna is not done well. At present, there are too many airports built at high speed in China, the protection area in front of glide antenna are not handled well. At commissioned flight inspection, all parameter (including RDH) are good, as the time goes, rainwater washed away and the protection area in front of settlement severely, which resulted in the deterioration of the glide structure, which affected the RDH. As a result, the equipment engineer cannot meet the equipment operation requirements no matter how to debug equipment.

During constructed the airport, especially in the construction and levelling of the site in front of glide antenna, the site should be designed and constructed in strictly accordance with the requirements of "Electromagnetic environment requirements for aeronautical radio navigation stations"(GB6364-2013) and "Specification for aeronautical communication navigation and surveillance station siting criteria—Part 1:Navigation" (MH / T4003.1-2014) to compact and secured to ensure the equipment continued safe operation.

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