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Glide Path Flight Inspection Geometric Reference Point and Recommendations for International Standards

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ABSTRACT

The internationally recognized standards for flight inspection (ICAO Annex 10 and Doc 8071) do not specify a geometric reference point for flight inspection of image-type glide path facilities.

The lack of a standard has required member states and service providers to establish their own policy and procedures. This has resulted in inconsistencies among states and between results reported by various service providers.

In recognition of the desire for common international aviation standards, this paper provides a statement of the problem, gives an historical perspective, presents theoretical and real data relevant to the issue, and offers recommendations.

It is hoped that this paper will serve as a catalyst for promoting debate among interested parties such that a consensus can be reached that will encourage ICAO to publish a clear and well-defined standard for use by all member states.

STATEMENT OF THE PROBLEM

While ICAO reference documents provide a multitude of recommended standards and tolerances for various glide path flight inspection parameters, many of which that are determined by angular measurements, they do not define a point in three-dimensional space to which the measured angles should be referenced.

Without a well-defined geometric reference point, the standards and tolerances are not truly "standards" at all. Ultimately there is no calibration traceability without a standard for the glide path reference point.

Use of an improper geometric reference point in effect produces the same types of errors as a mis-calibrated flight inspection receiver or inaccuracies in the aircraft position reference system.

Indicated flight inspection results for glide paths will vary significantly depending on what geometric point is used as the measurement reference, regardless of the type of equipment used. Moving the reference point can cause the glide path performance to appear to be better or worse than the actual signal provided to the aircraft on approach.

It is important to note that these effects have the greatest magnitude near the runway threshold, precisely where glide path performance is most critical for ILS Category II and III approaches.

In the absence of an ICAO recommended standard, member states have been left to establish their own policy and procedures. This has resulted in inconsistencies between states. Communications with representatives of several civil aviation authorities and flight inspection service providers have indicated that significant variations exist between the policies and standards of various states, and in some cases variations exist even within a single organization.

The lack of a standard also presents a special problem for states that do not have their own flight inspection capability, and which must contract for inspections from other service providers. There have been a number of cases in which differing results were reported by different service providers for the same facility, with the variations ultimately traced to the use of different glide path reference points.

The observations noted above make clear the need for a standard.

SCOPE

The scope of this paper is limited to image-type glide path equipment. For the purposes of this paper, an image-type is defined as any glide path for which the performance is intentionally dependent upon the interaction of the antenna system with the surrounding ground. Stated another way, it is a glide path whose antenna patterns are dependent on the terrain.

The term "image-type" comes from electromagnetic theory in which antenna performance is calculated from a theoretical model for a perfectly reflected wave from an infinite ground plane. The model considers that the reflected signal is instead radiated from a mirror "image" antenna located below the ground plane.

Image-type glide path equipment is by far the most common throughout the world. Image-type systems have been, and are currently produced, by numerous manufacturers. These image-type systems include the Null-Reference, Sideband-Reference, and Capture-Effect (or M-Array) configurations.

Non-image glide path systems such as end-fire, waveguide, or similar types are not considered

BACKGROUND

The position for the geometric reference point for ILS Localizer flight inspection is so trivial that is has never been a source for debate. The center of the antenna array is used, and although there is some room for argument over where the exact phase center is for certain antennas, such as the Log-Periodic Dipole type, the distances from the Localizer antennas to the flight inspection aircraft on approach render the matter insignificant.

For Glide Path, one might think that for the simplest case the position of the geometric reference point (or simply "reference point") would be obvious. However, the position of the reference point has been a source of debate even for the simplest cases.

The simplest case in fact leads to the primary issue to be considered when selecting what the international standard should be for a glide path reference point.

WHAT IS A PERFECT GLIDE PATH?

Is a "perfect" glide path a straight line, or a hyperbola?

In practice an optimally-adjusted, image-type glide path system does not provide a straight line path, but rather provides a hyperbolic on-path indication.

For historical reference, it should be noted that from the time ILS was first being developed in the 1940's, and in fact well into the 1960's, much effort was expended to develop a "straight line" glide path. This work was eventually abandoned, since it was found that in practice aircraft could approach and land perfectly well using a hyperbolic-shaped approach path.

CONIC SURFACE

For an omni-directional, image-type, glide path antenna system located on an ideal ground plane, the loci of on-path indications would consist of a half-plane conic, with a vertex located at the base of the antenna mast.

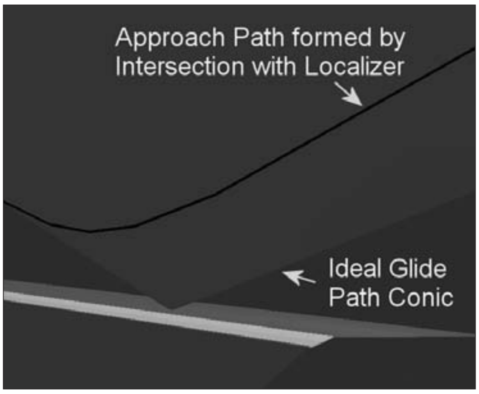
During a perfectly flown ILS approach the aircraft is on the centerline of the localizer; therefore, the actual approach path is defined by the intersection of the glide path conic with a vertical plane through the runway centerline.

For safety reasons the glide path antennas are of course placed well to the side of the runway. However, it should be clear that if the glide path antenna were placed on the runway centerline, the approach path would be a straight line.

When the glide path is installed to the side of the runway the on-path conic intersection with the localizer-defined vertical plane creates a hyperbolic path.

Runways are crowned to provide for runoff of rainwater. The terrain to each side of the runway is also graded to slope away from the runway in order to provide drainage.

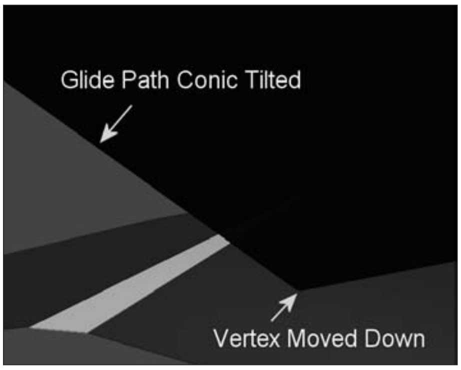
The "ideal" conic glide path surface and the corresponding approach path are shown in the figure below:



The previous figure does not show the effects of the lateral terrain slope. The lateral slope changes the geometry of the ideal conic and its intersection with the localizer.

LATERAL TERRAIN SLOPE EFFECTS

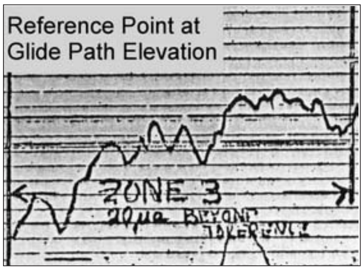
There are two significant effects on the glide path when the terrain slopes downward laterally:
1) The glide path conic is tilted with the sloping terrain
2) The vertex of the glide path conic is moved vertically down
These effects are shown in the figure below:

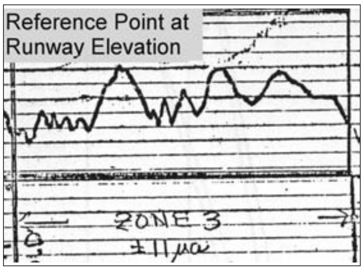


These two effects work in opposing directions. The tilting of the conic increases the height of the approach path, but the vertical moving down of the vertex decreases the height of the approach path.
It has been shown that for lateral terrain slopes of up to 5%, these two opposing effects essentially cancel[1,2].

AN HISTORICAL LESSON

The only documented standard identified by the author that specifies a glide path position reference is FAA O AP 8200.1, which provides a procedure for positioning a theodolite for glide path flight inspections.
While theodolites are rarely used for flight inspection today, the reference point considerations are still relevant.
The two effects of laterally sloping terrain were identified during commissioning of a Category II glide path installed in Atlanta, Georgia, USA, in 1968[2].
The site in Atlanta had a lateral terrain slope of 0.6 degree. With the reference point positioned at the base of the glide path antenna (in accordance with the then current version of 8200.11a) a large flare was indicated on the flight inspection recording. This was not being observed by pilots flying the approach, who considered that the glide path was "near-perfect".
It was determined that the reference point was incorrect, and that the reference point should be moved to the elevation of the runway abeam the glide path.
With the reference point at the elevation of the runway abeam the glide path, the actual performance was indicated.
The results of two measurements with the different reference point positions are provided in the figures below. These recordings were made on 5 December, 1968, using a pen-style chart recorder and a radio-telemetering theodolite.





OTHER CONSIDERATIONS

Indicated flight inspection results for glide paths will vary significantly depending on what geometric point is used as the measurement reference, regardless of the type of equipment used. Moving the reference point can cause the glide path performance to appear to be better or worse than the actual signal provided to the aircraft on approach. It is important to note that these effects have the greatest magnitude near the runway threshold, precisely where glide path performance is most critical for ILS Category II and III approaches.

RECOMMENDATIONS

The procedure currently provided in FAA O AP 8200.1 for theodolite placement places the reference point horizontally at the position of the glide path antenna, and vertically at the elevation of the runway abeam the antenna.
Use of this reference point has been shown to provide minimum errors for typical glide path sites with uniform lateral terrain slopes.
This position for the glide path reference point corresponds most closely with the actual signals transmitted by an ideally-adjusted image-type glide path facility.
The author recommends that ICAO should adopt an equivalent standard for glide path reference point, and include also updated information to consider modern aircraft position reference systems. It is further recommended that the standard be included in the next printing of Doc 8071.
Whether the reference point recommended above is adopted or not, the author firmly believes that the need to adopt a standard is very apparent, and considers that even a different standard certainly is better than no standard at all.
It is sincerely hoped that this paper will serve as a catalyst for promoting debate among interested parties such that a consensus can be reached that will encourage ICAO to publish a clear and well-defined standard for use by the member states.

REFERENCES

1. "Effects of Irregular Path-Forming Terrain on Glide Slope Reference Datum Heights", Larry Brady & R.H. McFarland, May 1985, Technical Memorandum G-8, Avionics Engineering Center, Ohio University.
2. "Radio Theodolite Placement Criteria for Glide Path Measurement", January 1969, Ohio University.