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Experimental Analysis on the Multipath Interference Error of Obstacles Effect

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Abstract

This paper focuses on the multipath interference by an obstruction or rough terrain is studied. The detriment of Glide path information to an aircraft that is approaching the airport with a precision ILS (Instrument Landing System) landing is due to the wrong siting. Terrain irregularity or roughness is the worst and most common glide slope siting deficiency. The degrading effect of rough terrain results from the random dispersion and/or phase shift of ground plane signal. In order to study the possibility of glide path signal interference, the new site that is under construction a big apartment complex and 3km distance away from glide path antenna is selected as a representative model in domestic airport. In the study, computerized simulation technic is employed to predict the probable reflected energy caused by the multipath conditions from antenna, obstructions and siting criteria. This study suggests the solution of a similar case through this analysis method.

Keywords: *Air Navigation Aids System, ILS System*

1. Introduction

1.1 The ILS provides guidance information to pilots of properly equipped aircraft to assist them in landing safely under conditions of reduced ceilings and lowered visibility. The use of an ILS materially aids the service to airports under all weather conditions.

1.2 Localizer Function is a Course Guidance. The localizer course guidance information is provided by the modulation of the transmitted signal with audio signals of 90 Hz and 150 Hz. The antenna radiation pattern is designed so that the 150 Hz signal is predominant to the right side of the approach, and the 90 Hz signal is predominant to the left of the approach. The localizer course itself is a theoretically straight, but in reality it is formed by the locus of the points where equal levels of 90 and 150 Hz signals are received and detected by the aircraft. The localizer course is usually adjusted to coincide with the runway centerline and centerline extended.

1.3 Glide path Function is a vertical descending Guidance. Proper operation of the glide path is primarily a function of the quality of the vertical radiation lobe structure. The system is designed so the radiation pattern has a predominance of 150 Hz signal below the glide path and conversely, a greater level of 90 Hz signal above glide path. The glide path itself is the locus of the points where equal levels of 90 and 150 Hz signals exist. The elevation angle of the glide path is a function of the antennas' heights above ground in the image systems.

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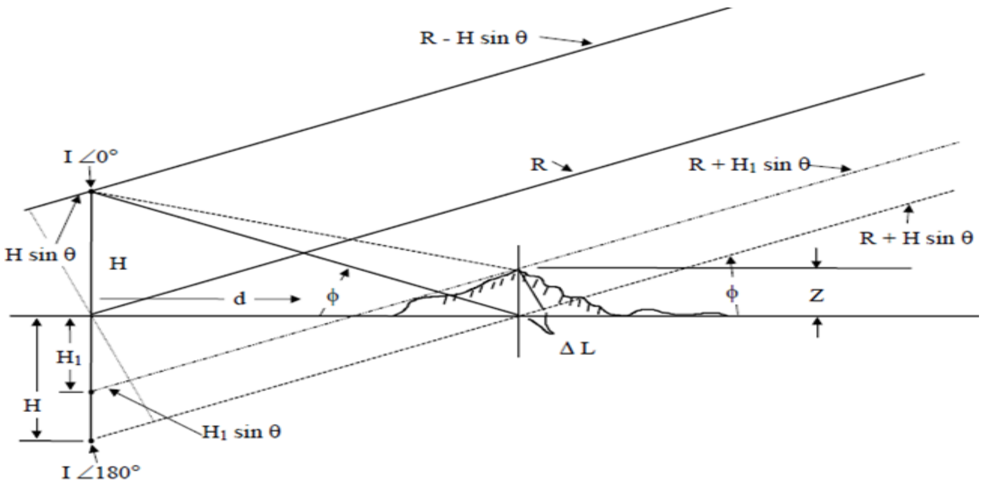


Figure 1. Glide Path Image Antenna

1.4 Basic Theory of Image Antenna; the glide slope guidance signal depends on the terrain conditions due to the inherent image antenna concept: radiation from an antenna located above a reflecting surface. The reflected signal appears to emanate from an "image" antenna along the same vertical plane as the real antenna and at a distance below the reflecting surface equal to the distance of the real antenna above the surface (see Figure 1).

The signals from the real and image antenna combine in space; therefore, the three types of glide slopes are often referred to as "image" systems. The glide path information (null reference system) is formed by the vector sum of four different signals: the direct and reflected signals from the carrier antenna and the direct and reflected signals from the sideband antenna. The instrument Landing System is the primary airport approach and landing aid in use throughout the world today. The detrimental effect of hangars and other structures on ILS signals has been a serious problem of long standing. With the introduction of the new generation of jumbo jet aircraft and the resulting hangar construction associated with their operation, the multipath interference problem will rapidly get worse. This paper presents an approach to determining the potential effects of an airport's environment on the performance of the Glide path facility. Several methods have been considered for analyzing the reflections. An exact solution of the wave equation for an actual problem is usually so difficult as to be impractical. The Glide path facility multipath problem has been treated by other investigators [1, 2], but little has appeared for general publication. Recently, Redlich and Gorman [3] published a paper on reflections from hangars based on re-radiation from induced currents. Because the terrain reflects the ground signal in a specular manner from the smooth terrain for small distances will not usually have an adverse effect on the glide slope signal.

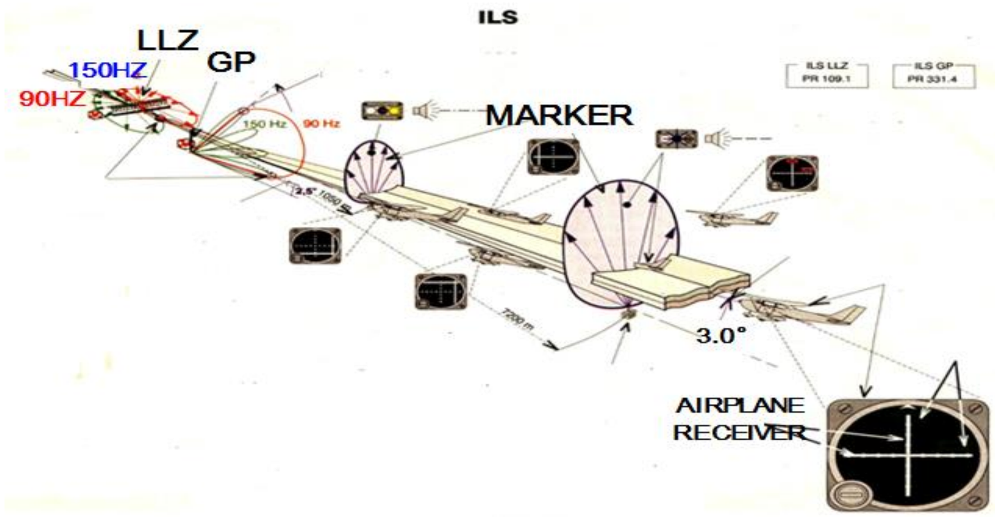


Figure 2. ILS Functional Block Diagram

1.5 The smooth terrain terminates when it encounters extensive roughness of a large magnitude such as a hill or valley. The reflected signal contribution must be continuous for the terrain to be considered smooth; therefore, the smooth surface terminates at the point where roughness is encountered even though a smooth reflecting surface exists beyond the roughness. The ideal siting environment is a perfectly smooth, level ground surface both laterally and longitudinally, and an infinite ground plane extent. To the extent practical, grading contours should be straight, parallel, and equally spaced, within grading lateral slope limits, to provide a consistent ground plane through the approach.

1.6 An initial step in siting a glide slope is to determine where the facility should be located in relation to the runway and other movement areas. Obstacle clearance with respect to adjacent taxiways or adjacent runway operations may impact approach minimums or airport capacity. The glide slope should be located on the side of the runway free from such interference. If terrain or other factors preclude locating the facility away from these areas, it may be necessary to restrict the flow of ground traffic to prevent glide slope interference. The analysis in their paper used a different approach and was done independently. Also, this paper deals with general reflecting surfaces of buildings complex. In this paper, the approach is based on the solution of the computer simulation.

2. Instrument Landing System

The aircraft glide path receiver responds to the difference in detected levels of the 90Hz and 150Hz signals. The received glide path signal is processed in a simple heterodyne amplitude modulation receiver similar to the schematic diagram shown in figure 3.

The signal received in this case will include the radiation from the desired and undesired glide path. Since both the desired and undesired signal are within the same frequency band, the receiver will process the signals received as a two frequency capture effect glide path. AM detector, typically diode detector, are directly proportional to the level of the 90 and 150Hz. This detected audio is then applied to 90 and 150Hz filters to separate the frequencies.

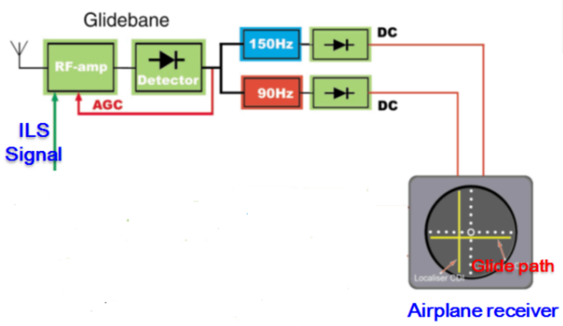


Figure 3. Schematic Diagram of a Typical Glide Path Receiver

A balance adjustment is typically used to compensate for gain errors in the audio filters. The individual 90 and 150Hz signals are rectified by a full-wave bridge rectifier, giving a positive voltage that is directly proportional to the sum of depth of modulation (SDM), flag current. The signal applied to the CDI is directly proportional, as seen below, to the difference in depth of modulation (DDM) between the two modulating frequencies [4-6]. When single frequency arrays are used the separate sideband components are greater than the carrier sidebands. Where this condition occurs, space modulation is greater than transmitter modulation thus resulting in the measured total modulation exceeding 40 percent. Certain glide path receivers use algorithms, which expect the received total modulation to be 40 percent throughout the coverage area and use this value to normalize the calculated cross pointer deflection indicator CDI. This normalization process reduces the CDI reading.

Glide Slope CDI = 150 PA / 0.175 DDM

The aircraft glide path receiver responds to the difference in detected levels of the 90Hz and 150Hz signals. When the aircraft is on the glide path, the glide path cross-pointer receives equal levels of 90Hz and 150Hz signals and remains at mid-scale; the cross-pointer deflects downward when the aircraft is above path and upward when below path indicating “fly-down and fly-up”. The vertical angle corresponding to full scale deflection for the cross pointer is defined as the glide path sector width. The difference in depth of modulation (DDM) is computed from the audio tones at the output of the respective audio filters.

If the actions of these filters are denoted by and the output of the ILS receiver can then be represented as

$$V_{90}(\mathrm{t}) = H_{90}[V_{AF(t)}],\ V_{150}(\mathrm{t}) = H_{150}[V_{AF(t)}] \qquad (1)$$

Several factors that affect the received signal, which must be incorporated in the detected audio signal, V,(t), are the receiving aircraft’s motion, multipath, and other spurious effects that occur in the reception of dual frequency signals. All these factors are considered in the development of this model for the audio signal detection. The analysis of signal processing presented here follows the development by Chin, et al, [l] which followed a procedure suggested in part by Manney [2]. The total IF output signal for reception from a two- frequency system may be written as

$$A_1(t) = \sum_p (C_p + S_p)\, e^{j\emptyset p} \qquad (2)$$

consists of the carrier amplitude and the modulating signal from the first carrier,

$$(t) = \sum_p (C' + S_p')\, e^{j\emptyset p} \qquad (3)$$

consists of the carrier amplitude and the modulating signal from the second carrier. The C, C,' and S, S' represent the carrier-plus-sideband and the sideband- only components of the two frequencies, respectively. The subscript p, denotes the specific propagation path for the received field, which includes path attenuation due to multipath.

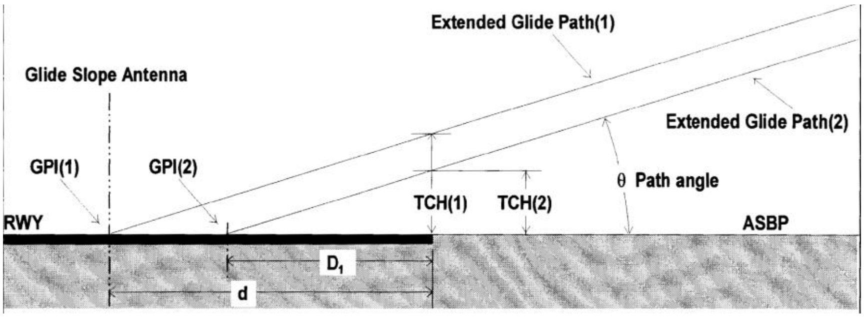


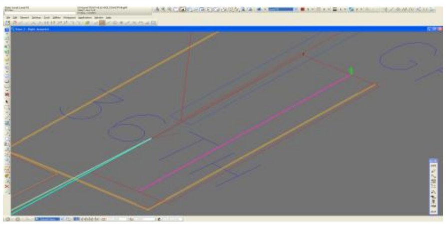
Figure 4. Glide Path Site Pedestal Case

Some sites will be found to be graded such that the ground stops down from the runway thus putting the runway effectively on a pedestal (see Figure 4). This requires consideration of the height of the pedestal. The height of the pedestal requires the phase center to be moved back away from the threshold by an amount equal to the height of the pedestal divided by the tangent of the glide path angle (Θ). Given the design TCH obtained from FAA Order 8260.3, the next step is to assess the topography of the prospective site. Both the lateral slope and longitudinal slopes are very important. If there are no slopes, which is seldom the case because of the need for drainage, the glide path site is located as shown in Figure 4.

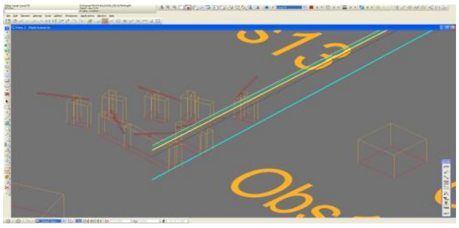
The optimum site, glide path system, and operational parameters for each establishment or relocation must be determined by a thorough engineering analysis of the particular siting conditions in accordance with the principles described in this paper. Where severe site conditions are encountered, a site test may be conducted to measure the deviations from the ideal path and off path clearances and to determine the exact facility site. Where establishment of a satisfactory glide path requires deviation from the siting criteria or operational parameters.

It is desirable that the glide path be a smooth line approaching a theoretical hyperbolic curve. In the area above and below the path sector width, the differences in the detected 90Hz and 150Hz signals must be sufficient to maintain the cross pointer in a fully deflected position. The latter is of particular importance in the below-path areas. The capability of the glide path to meet the operational requirements depends to a great extent on the terrain conditions between the antenna system and receiving aircraft and the absence of objects that may reflect undesirable energy into the glide path region.

3. Experiment Model



(A) Original Basic Circumstance Geometry



(B) Schematic Representation of the Obstacles

Figure 5. Circumstance Geometry

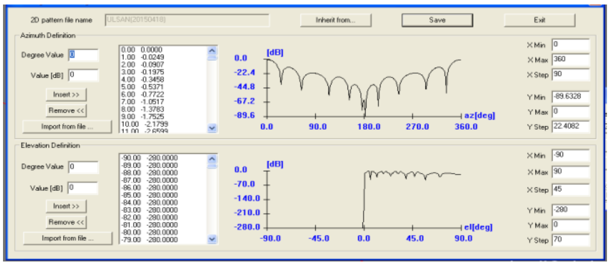


Figure 6. Computer Simulation Data

In this study, in order to accurately predict the effect of the reflection, we built a computer simulation model which takes into account the multi-layered real size buildings. The original basic real circumstance is shown in Figure 5(a). Figure 5(b) shows schematic representation of the obstacles such as building and Figure 6 shows the computer simulation data of the Glide path equipment.

The simulation results correlate with the flight check results at 2NM and less. Beyond 2NM the simulation is showing less error than flight check results. With more time the simulation may be able to show additional error. But this error is not due to the apartments or cranes, which is the primary subject of this report.

In the experiment, a slope reversal for the Glide path occurs near the 1500ft continuous slope maximum and should be further analyzed. However, the reversal does not exceed 25 micro-amps and therefore should be compliant. Note the Glide path tower is too close to the runway and the perimeter fence is too close to the Glide path, per siting criteria and maximum height allowance. This circumstance should be confirmed with more accurate measured elevation data at the Glide path tower and the runway centerline abeam the Glide path tower location. It appears that the antenna heights may need to be lower than set in the field. There is some difficulty in the simulation to achieve exactly 3.0 degree and to correlate this between approach and level run simulations. However, flight check results have varied from 3.0 to 3.02+ degrees and the simulation does the same. Terrain irregularities have the effect of changing the path length and the relative phase of the ground reflected signal. The amount of terrain roughness that can be tolerated is determined by the effect of the resulting phase shift on the aircraft cross pointer indicator. Tolerance for path deviations is$\pm$25μA.

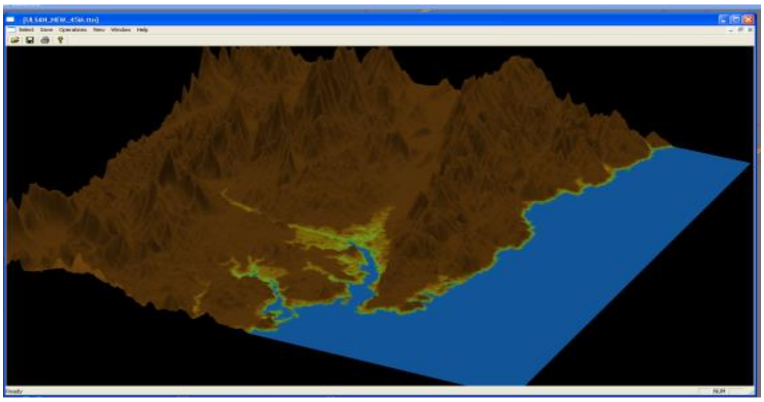
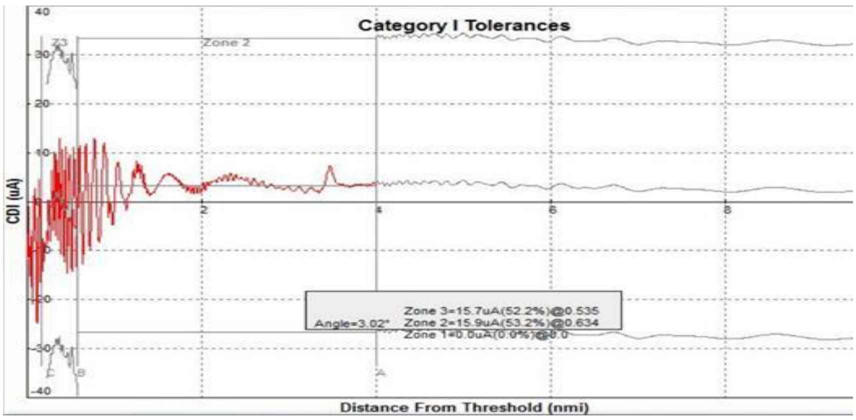


Figure 7. 3d Nasa Hgt Data Modeling

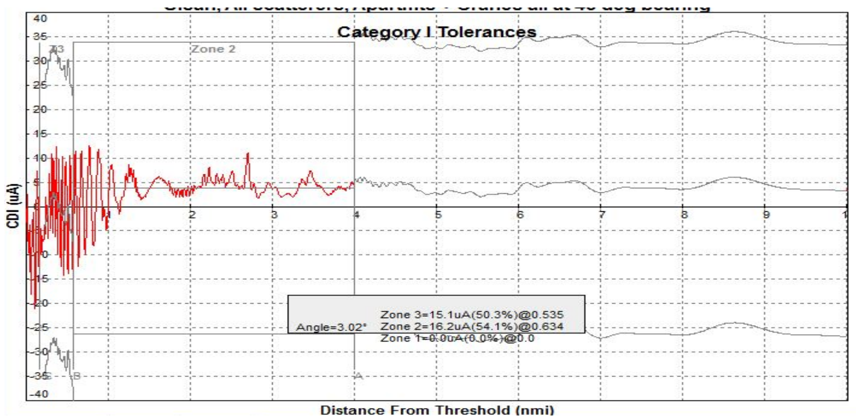
4. Simulation Results and Model Validation

Simulation results correlate with flight check results at 2 nm and less. Beyond 2 NM the simulation is showing less error than flight check results. With more time the simulation may be able to show additional error. But this error is not due to the apartments or cranes, which is the primary subject of this report. A slope reversal for the Glideslope occurs near the 1500 feet continuous slope maximum and should be ILS RWY 36 Simulation further analyzed. However, the reversal does not exceed 25 mA and therefore should be compliant. Note the Glideslope tower is too close to the runway and the perimeter fence is too close to the Glideslope, per siting criteria and maximum height allowance. This site should be confirmed with more accurate measured elevation data at the Glideslope tower and the runway centerline abeam the Glideslope tower location. It appears that the antenna heights may need to be lower than set in the field. There is some difficulty in the simulation to achieve exactly 3.0 degree and to correlate this between approach and level run simulations. However, flight check results have varied from 3.0 to 3.02+ degrees and the simulation does the same.

Figure 8 shows the glide path level run mode simulation data. Approach, Level runs were modeled taking into account all identified potential signal reflectors. The graphs from simulation were changed to match 10NM max range of ILS intercept, and the vertical axis was reversed to place positive micro-amps above Zero and negative below Zero- same as flight check graphs. The result illustrates the predicted low approach structure trace. The grey lines above and below the trace in red represent the maximum structure distortion levels.



(A) Original Basic Circumstance



(B) Schematic Representation of the Obstacles WITH Apartments and Cranes

Figure 8. Glide Path Approach, Scatters Simulation Result

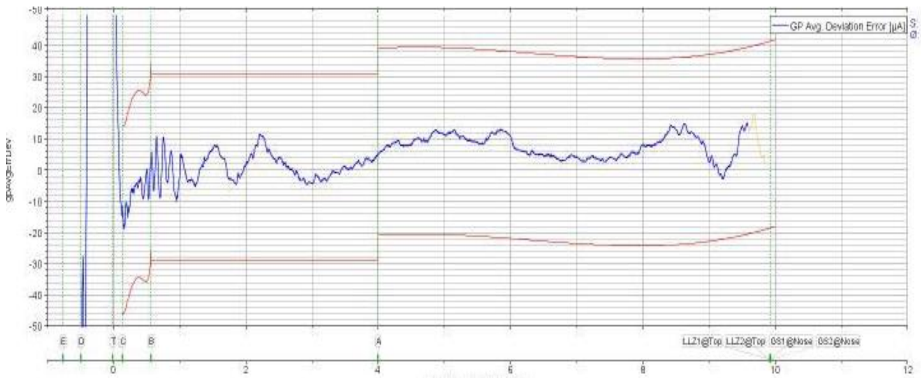


Figure 9. Flight Check Results Correlate with Simulated Result

Figure 9 shows that flight check results correlate with simulated result. Approximately ±10 micro-amps of deflection error occurs out to 1 NM, then ± 5 NM out to 1.5NM and then ± 3 micro-amps. There is a deflection at 3.5 NM which corresponds to a hill area in the terrain.

5. Conclusion

This study aimed to improve efficiency in the quality control of agricultural

This paper points out that complexity of effects of the obstacle or rough terrain. The results were obtained by mathematical analysis, computer-based simulations. The theory and computer-based simulations correctly predicts the effect of obstacles. The glide path location is too close to runway and to perimeter fence.

The height when crossing above the threshold fully complies with the ICAO Annex 10. At the current location the glide path will fully comply with CAT I performances including the affects from the new planned apartment complex. The requirements as defined by ICAO Annex 10 are well within CAT I tolerances at zone1 from zone3 allowable for CAT I. The maximum distortion occurs in zone 3 and does not exceed 4% of the maximum allowable limit for CAT I. At the current location, planned new apartment complex is compliant with CAT I.

The current theory of the obstacle regarding multi interference error due to reflection has been proved by computer-based simulation and experimentation compare to mathematical analysis. The math modeling predicts full compliance with CAT I tolerances for Glide path at the current existing location, taking into account the proposed new apartment complex. Finally the obstacle effects must be taken into account actual site.

Notices

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