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MATH MODELING STUDY OF THE RUNWAY 15R INSTRUMENT LANDING SYSTEM LOCALIZER AT LOGAN INTERNATIONAL AIRPORT, BOSTON, MASSACHUSETTS

by

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Purpose

This study was performed to provide computer modeled Instrument Landing System (ILS) localizer performance data for runway 15R of the Logan International Airport, Boston, Massachusetts as a basis for determining the most cost-effective approach to correct the problems with the centerline localizer.

Background

The centerline ILS localizer system installed for runway 15R at the Logan Airport, Boston, Massachussetts, has remained uncommissioned due to out-of-tolerance tide-correlated course shifts. This localizer system is installed on a platform approximately 800 feet from land in the Boston Harbor. The approach lighting system and an off-centerline service walkway exist between the site and land. These environmental features combined with the tidal changes on Boston Harbor prevent the formation of an in-tolerance localizer course. The New England Region (ANE-400) tried several solutions to the problem prior to deciding on the installation of a counterpoise in front of the site. At this point modeling of the site was requested to determine the most cost-effective counterpoise dimensions or an alternative solution.

This modeling study was performed under Technical Program Document 07-115, Subprogram Number 071-313, Project 071-313-840, ILS Math Models. The author of this technical letter report is Jesse D. Jones, ACT-140. The Technical Program Manager for this study is Edmund A. Zyzys, ACT-140. Additional information may be obtained by contacting the author at (609) 641-8200, ext. 3807 or FTS 346-3807.

Model Description

The mathematical model used for this simultion was the Ohio University Geometrical Theory of Diffraction (OUGTD) model obtained from Ohio University under an FAA Technical Center contract. This progam was written for Ohio University by Mr. Vichate Ungvichian to account for the interactions due to reflected and diffracted electromagnetic waves.

The OUGTD program utilizes the Geometrical Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) as the two basic theories used in computing the reflection and diffracton of the electromagnetic waves involved. The GTD and UTD techniques treat the electromagnetic fields as rays. This is possible due to the localized nature of wave interactions at very high frequencies (above 100 MHz). This treatment allows one to include the multiple interaction (i.e. doubly reflected, etc.) between neighboring ground with little computational effort; whereas, this is a very difficult task using the Physical Optics technique. The UTD is the theory applied for calculating the fields in the transition area and the GTD theory is applied in order to save computation time in the non-transition area.

Fourteen types of rays are considered in the model. These rays are the direct, singly reflected, singly diffracted, doubly reflected, reflected-diffracted, diffracted-reflected, doubly diffracted, reflected-reflected-diffracted, triple reflected, reflected-diffracted-reflected, diffracted-diffracted-reflected, reflected-diffracted-diffracted, diffracted-reflected-reflected, and diffracted-reflected-diffracted. Each ray is determined by the various terrain irregularities which might be encountered in the modeling area.

The psuedo-3D version of the model was used for this modeling effort. The 2D version uses a single terrain profile for all antennas and observation points. The psuedo-3D version utilizes a matrix of input values for the terrain to compute a new terrain profile for each observation point (simulated aircraft position). The term"psuedo 3D" is used to emphasize the fact that the model is not truly 3-dimensional. For each observation point and its associated terrain profile, the simulated Course Deviation Indication (CDI) is computed from the various possible combinations of direct, reflected, and diffracted rays.

Since the localizer and glide slope antennas are both horizontally polarized, the model's author has stated that with appropriate modifications, the OUGTD model can be used to model the effects of terrain on a localizer system. Since the problems at Logan Airport are related to an irregular and varying ground-plane, this was the type of model required.

The following modifications were developed and included in the model. First, a modification was made to compute the profile of each localizer antenna array element from the base of that element since all computed glide slope profiles originate at the base of the antenna mast. Second, a pattern multiplication subroutine was added to take into account the directional characteristics of the localizer array and its individual elements since the glide slope antenna is assumed to be omnidirectional in the area of interest. As modeling progressed a few additional minor changes to the model were made such as expanding some of the array dimensions to handle the eight antenna elements instead of the three elements for a glide slope.

Model Input Data

Input data required by the model consists of two files. One data file is a matrix of X (distance perpendicular to the runway), Y (distance parallel to the runway centerline), and Z (elevation) values referenced to the origin (usually one of the runway thresholds). The other input file is data describing the antenna locations and the currents (amplitude and phase) fed to each element of the array along with other selected site and flight path data.

Discussion

To verify the operation of the modified model, an approach and partial orbit over flat earth were simulated. These simulations provided the expected clearance pattern and a perfect course structure. Next, the Logan Airport localizer antenna was simulated, without the walkway or counterpoise, for three tidal conditions: mean low tide, mid tide, and mean high tide. Since the above tidal conditions were modeled with only the tidal effects, they also resulted in a perfect course structure and the standard clearance pattern. This is to be expected with a terrain profile that is uniform perpendicular to the runway centerline.

At this point the modifications to the model appeared successful and the walkway was added to the input matrix. With the walkway added, abrupt, unrealistic discontinuities appeared in the simulated course structure output and various attempts to eliminate them by changing the input terrain data matrix were unsuccessful. Similar discontinuities also occurred when attempts were made to model a counterpoise with the walkway extending from the end of the counterpoise to land. Modeling of any counterpoise that is symmetrical about centerline, but without the walkway, yielded a perfect course structure and a clearance pattern with reversals. However, anything that is modeled with symmetry about the centerline results in a perfect course, and, as a result, no useful information concerning the required counterpoise length could be determined. The modeling effort was discontinued at this point.

Analysis

The modeling of only a counterpoise (without the walkway) results in a good course structure, but with some reversals in the clearances. The addition of the walkway between the land and the counterpoise, or the walkway alone, yields course structures and clearances with discontinuities. For realistic modeling of the Logan Airport 15R localizer, the walkway must be a part of the input data. The model output data with discontinuities is misleading, unreliable, and can not be the basis upon which to draw any conclusions.

It is the collective opinion of individuals at the Technical Center knowledgeable in ILS, that the installation of a counterpoise as proposed by the New England Region is the only viable solution to resolve the Logan Airport runway 15R centerline localizer problem.