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INVESTIGATIONS TO PROVIDE IMPROVED GLIDE SLOPE OPERATION DURING PERIODS OF GROUND-PLANE SNOW COVER

Volume I - Summary and Conclusions

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16. Abstract

A summary of conclusions and recommendations is given for providing improved operation of image glide slopes during periods when the reflecting ground plane is covered with snow. These conclusions and recommendations have been derived from theory developed and experiments conducted during nine years of investigation.

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I. PREFACE

The principal purpose of this report is to present conclusions and recommendations concerning the operation and monitoring of image glide slopes during times when snow covers exist on the ground plane. These conclusions and recommendations are based on theoretical and experimental work that has been done at Ohio University continually during the past nine years.

During these years much work has been devoted to theoretically determining the effects of ground plane snow covers on the image glide slopes. Four mathematical models have been used to predict the path changes due to the snow. Also, extensive experimental facilities have been used to gather data from systems operating in the presence of heavy snow covers. Methods using 800-foot towers and specially instrumented aircraft have been employed to obtain representative readings of path conditions in the far-field. Reference is made to previous SRDS reports RD 65-30, RD 66-39, RD 68-60, RD 70-9, RD 71-30, RD 72-71, RD 72-85, and RD 74-69, II. Repetition of these materials is avoided in this report; however, the reader is encouraged to become familiar with that background.

All available information and experience to date has been applied to providing the best answer for minimizing outage of glide slope facilities when snow covers exist on the ground. The recommendations presented are believed consistent with present day safety standards and should be quite useful in providing greater utilization of image systems. Careful consideration has been given to each of the three different types of image glide slopes, viz., null reference, capture effect, and sideband reference systems. Also, both near-field and integral monitoring has been investigated.

II. SUMMARY OF CONCLUSIONS RELATING TO THE OPERATION OF IMAGE GLIDE SLOPES WITH SNOW

Historically the operation of image glide slopes during winter seasons has been troubled with accumulation of snow layers on the reflecting ground plane. The following conclusions have been drawn based on the extensive theoretical and experimental investigations of the snow effects.

1. Integral, analog monitoring provides an excellent means for determining glide slope system performance. These monitors were found to be very representative during tests in practical cases with snow present for the cases of the null reference and capture effect systems. Although no experimental data is yet available for the sideband reference system, theoretical considerations would indicate that the integral monitor would be an asset for this type system also.

2. The present near-field monitoring schemes, while intuitively satisfying, do not represent far-field user conditions accurately in the presence of ground plane snow covers and other anomalous conditions. Fortunately from the standpoint of safety they give conservative representations; however, facility shutdowns that occur without the far-field being out-of-tolerance can be a very unsafe practice since these times may very well be those when the facility is needed most. With appropriate safeguards provided, use of the present near-field monitors can be discontinued as executive monitors.

3. Complete mathematical modeling of a given facility during practical winter-time operating conditions is too involved and expensive to consider as a solution to the monitoring problem. Acquisition of the necessary values of the critical parameters of the site is quite difficult and painstaking. The complex dielectric constant values for the earth, the complex dielectric constant for the snow which frequently occurs in layers (vertical inhomogenity), and the snow layer depth variation over the reflecting plane (lateral inhomogenity) are all critical in predicting the near-field monitor values. They are not as critical in determining the path in space where the aircraft is operating.

4. The most practical approach for improved monitoring is to look at worst case conditions for far-field effects and identify when these occur. Alternate supplementary measurements need be made at these times. It is also necessary to identify threshold conditions which have been confirmed in practice, that is to say, specify those values below which experience has shown no significant effects take place. At present the indications are that this number is 10 inches of snow depth.

5. Experience has shown that snow cover may cause the far-field path angle to increase several tenths of one degree but no evidence exists of snow causing significant ($> 0.1°$) decreases in path angle. Therefore a greater maximum allowable upper tolerance bounds should be identified. Consistent with safety of operations considering runway length the upper bound should be considered to be from 3.3 to 3.5 degrees. If the nominal path angle is say 2.5 degrees that would permit an increase of one degree without removal from service.

6. The integral monitor if augmented with periodic checks of path angle should permit complete elimination of the unrepresentative near-field monitors.

7. With integral monitoring a tilt switch alarm is desirable for installation with each transmitting antenna.

8. Environmental effect monitors should be implemented which may take the form of extendible towers, terrain cover sensors, and special flight checks.

9. Non-analog, discrete monitoring, could be used to provide an alert rather than a shutdown. When certain conditions occur, then special checks should be made within a given period of time.

III. RECOMMENDATIONS FOR OBTAINING GREATER UTILIZATION OF IMAGE GLIDE SLOPES DURING TIMES WHEN SNOW COVERS EXIST ON THE GROUND PLANES

The foregoing conclusions together with the experience of many years' work on investigating means of improving glide slope operations during periods of snowfall lead logically and practically to a set of definite recommendations. These are:

1. Implement integral analog monitoring for both path and width channels for each of the three types of glide-slope systems.

2. Install tilt monitors with each antenna element placement.

3. Implement supplementary monitoring for use when certain alert conditions are present. Supplementary monitors could take the form of extendible towers or flight checks using either FIDO aircraft or local aircraft with a special package and a theodolite.

4. Implement environmental alert monitors to indicate when supplemental monitoring should take place.

5. Disregard near-field indications that out-of-tolerance far-field path conditions are being caused by ground plane snow covers of 10 inches or less.

6. Remove present near-field monitors where snow exists and specify the following procedures for operation with more than 10 inches of snow covering more than 50% of the first fresnel zone.

   a) At a distance 3000 feet or greater on localizer center extend a tower with an antenna probe until .175 DDM and 0 DDM points are reached or the minimum path angle values are reached whichever is least. If these are found to be within allowable tolerance values then maintain the facility on the air and repeat the measurement when the snow depth changes by more than 25% from the value

existing at the time of the last supplemental monitoring reading or in 24 hours whichever is sooner.

b) A specially instrumented light aircraft can be used in place of a tower. A theodolite will be required to determine the precise angles.

7. Because there is considerable use being made of the image glide slopes and this will continue for many years, it is recommended that each year some type of snow monitoring facility be maintained by the FAA in a watchdog sense to seek out any anomalous conditions that might come to exist.

8. Maximum use should be made of data collected by others and a means of processing these data and integrating and implementing results into operational plans indicated by the data analysis. For example, the Canadians have acquired new equipment and are planning a systematic collection of data. This offers an opportunity for learning even more about snow effects and full use should be made of this information.

9. As a result of current projects and the increased number of glide slope installations in northern Michigan, the Michigan Technological University in Houghton, Michigan, in cooperation with the Michigan Commission for Aeronautics is planning measurements of snow effects utilizing the new glide slope at Houghton County Airport. Full use should be made of this data.