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PROJECT APOLLO

A STUDY OF LANDING RADAR ANTENNA SWITCHING

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SUMMARY

A study has been made to determine the tradeoffs involved in defining a LR antenna switch point. A preliminary switch point for the one-phase guidance trajectory is presented. As the trajectory and/or radar changes, the switch point will be reevaluated.

INTRODUCTION

The LR (landing radar) antenna is fixed in either of two positions with respect to the LM body axis. For each antenna position, the LR has an operating region which is determined by the magnitude of range along a beam, the magnitude of the velocity along a beam, and the magnitude of the beam incidence angle. At any time during the descent, these three parameters can vary significantly with changes in LM attitude. Most attitude changes during the LM descent will be in the pitch plane. The pitch angle varies over a range of 90 degrees at PDI to zero degrees at touchdown. Because of this large range of pitch variation and because the antenna is fixed with respect to the body axis, there is a need to switch the antenna position to provide adequate operating margin.

The antenna switching point for the two-phase guidance trajectory coincided with the step change in pitch attitude when the guidance targeting was switched from the hi-gate target to the lo-gate target. The one-phase guidance trajectory provides a smooth transition of pitch attitude from PDI to touchdown. The smooth pitch profile allows the selection of an antenna switch point based on geometry rather than time. This study was made to examine the geometry and determine a preliminary switch point for the one-phase guidance trajectory.

RESULTS AND DISCUSSION

The results of this study are based on a one-phase guidance trajectory which was calculated using the targets from reference 1. The landing radar math model used in the study was the latest GAEC model presented to MSC on November 6, 1968 (reference 2). The study assumed that the switching logic is to be implemented by software changes only, and therefore, the 0.0 and 24 degree positions now in the hardware will not change.

With this constraint, the study consisted of determining the LR operating boundaries assuming the antenna was fixed in the 24 degree position for the entire descent and in the 0.0 degree position for the entire descent. Figure 1 shows the operating bounds on altitude and velocity information for the two antenna positions. The upper boundary on altitude information with the antenna in the 24 degree position is determined by low signal to noise ratio due to high altimeter beam incidence angle (measured with respect to the local vertical) for altitudes less than 35,000 ft. Above 35,000 ft, the boundary is set by the frequency design limit of the altimeter. Although the frequency limit translates into 57,000 ft range, it is exceeded because the doppler frequency component adds to the range frequency component. As the LM velocity decreases, the sum of the frequency components decreases to within the design limit. With the antenna in the 0.0 degree position, the design limit is not exceeded. The upper boundaries on velocity information is set because of low signal to noise ratio due to high velocity beam 3 incidence angle. The lower boundaries are determined by low signal to noise ratio due to low velocities along beams 1 and 2. These boundaries apply to velocity as well as altitude information because all LR data good discretes depend on the status of beams 1 and 2 (beams 1, 2, and 4 must be tracking to get altitude information - beams 1, 2, and 3 must be tracking to get velocity information).

With these two sets of boundaries, the objectives of picking a switch point are: (1) To rpovide as early acquisition on altitude and velocity as possible, (2) to provide continuous tracking, and (3) to provide as large an operating margin as possible.

To provide the early acquisition, the antenna should be left in the 24 degree position until after an altitude of 20,000 ft. To provide continuous tracking, the antenna should be switched sometime after an altitude of 13,800 ft and before an altitude of 4,000 ft. The upper altitude is 13,800 ft because if the antenna was switched before that point, beam 3 would lose track and velocity information would be lost. The lower altitude is 4,000 ft because if the antenna is not switched by then, either beam 1 and/or 2 will lose track and both altitude and velocity information would be lost. To provide the largest operating margin, a switch altitude of 10,000 ft was selected.

Figure 2 shows the boundaries for the entire trajectory assuming the antenna was switched at 10,000 ft. The operating margins are shown to be +10.5 degrees and -9.5 degrees from the nominal pitch attitude at the switching point. Reference 3 (PCR 246) provides that antenna be switched on pitch attitude and time-to-go criteria. The nominal attitude at 10,000 ft is 53 degrees and the nominal time-to-go is 214 sec. These numbers are preliminary and are subject to change as the trajectory changes. Both criteria are in erasable and will be updated for significant trajectory and/or radar changes.

Referring to figure 2, it should be pointed out that for the one-phase trajectory and latest LR model, the altimeter tracking threshold is reached at an altitude of 37,000 ft. Assuming a 30 sec delay for tracker sweep and pilot enable, the LGC could begin altitude updating at an altitude of 34,000 ft. The velocity tracker threshold is reached at an altitude of 20,200 ft. Assuming a 12 sec delay for tracker sweep, the LGC could begin velocity updating at an altitude of 19,200 ft. There is no pilot enable delay for velocity updating.

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This study has been based on nominal LR performance; that is, the mean value for the following parameters was assumed: Lunar surface reflectivity, power output, angenna gain, waveguide loss, and noise. The acquisition and dropout boundaries will vary, depending on the combination of the above parameters. A study is now in progress to define the minimum, mean, and maximum performance LR's.

CONCLUDING REMARKS

A study of LR antenna switching has been made and a preliminary switch point has been defined for the one-phase guidance trajectory. The nominal antenna switch point criteria is recommended to be 53 degrees in pitch attitude and 214 seconds in time-to-go.

REFERENCES

1. Alphin, J. H.: Interim targets for one-phase descent trajectory studies. MSC memorandum 68-FM22-156, October 3, 1968.

2. Dyer, David A.: Items discussed at LR meetings held on November 6 and 7. MSC memorandum EG23-68-243, November 12, 1968.

3. Bennett, F. V.: Landing radar antenna Switching. PCR 246, September 9, 1968.

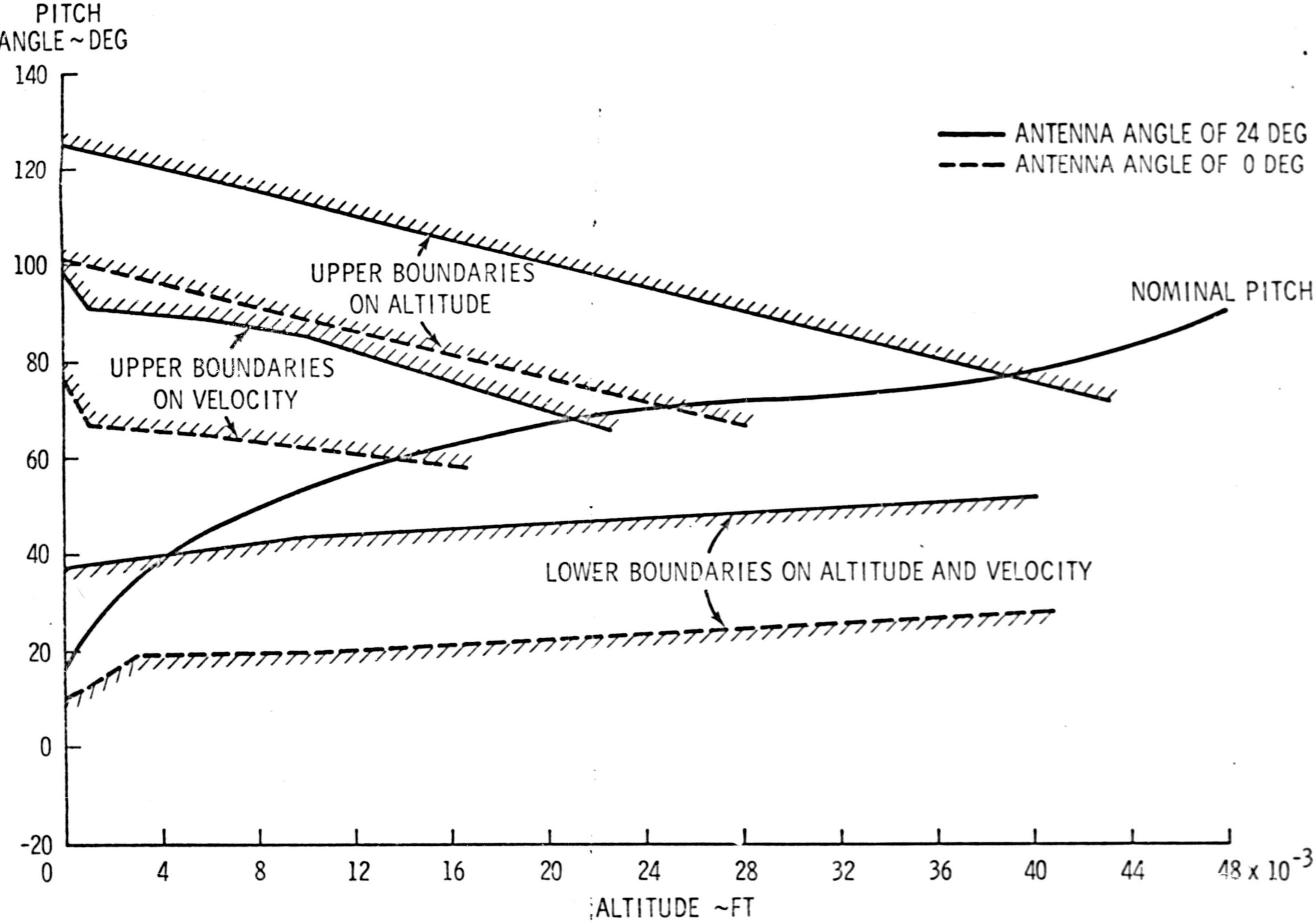

Figure I.- Radar operating boundaries for nominal one - phase trajectory with LR antenna in 24 and 0.0 degree positions.

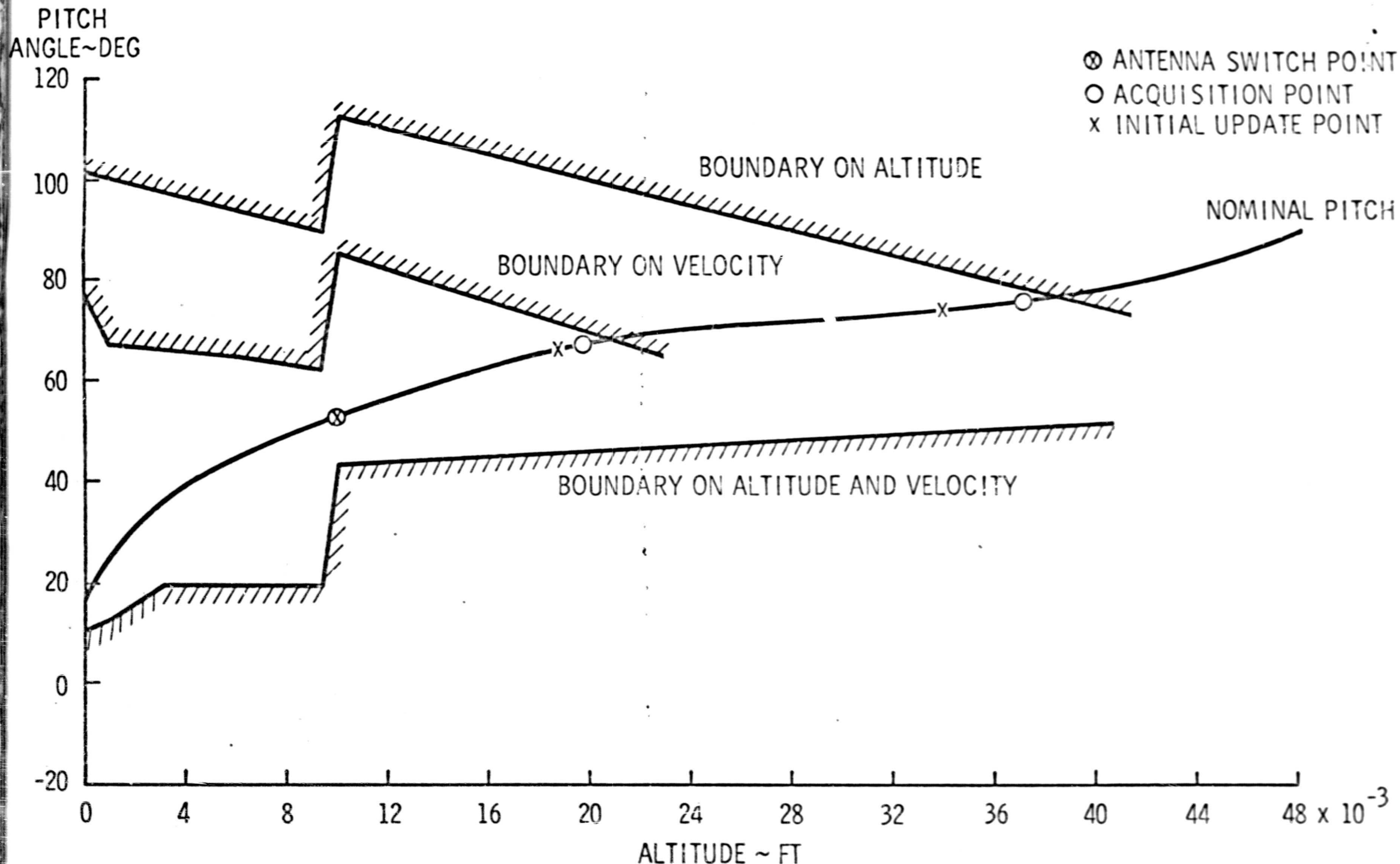

Figure 2.- LR boundaries assuming antenna is switched at 10,000 ft.