288

No

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTERNAL NOTE MSC - EG - 69 - 14

PROJECT APOLLO

LM LANDING RADAR TEST FOR THE F MISSION

SYSTEMS ANALYSIS BRANCH
GUIDANCE AND CONTROL DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

March 11, 1969

INTERNAL NOTE MSC-EG-69-14

PROJECT APOLLO

LM LANDING RADAR TEST FOR THE F MISSION

PREPARED BY

David A. Dyer

David A. Dyer

APPROVED BY

Kenneth J. Cox

Kenneth J. Cox
Chief, Systems Analysis Branch

Donald C. Cheatham

Donald C. Cheatham
Assistant Chief, Guidance and Control Division

R G Chilton

Robert G. Chilton
Deputy Chief, Guidance and Control Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

MARCH 11, 1969

SUMMARY

A study has been made to define procedures associated with the LM landing radar F mission test. The landing radar antenna position and LM attitude requirements have been determined. About 800 sec of data for beams 1, 2, and 4, and 400 sec of data for beam 3 can be expected from the test.

INTRODUCTION

Prior to actual spacecraft flight, the LM LR (landing radar) has undergone a series of tests - both static and dynamic. The dynamic, or flight tests, were conducted at the White Sands Missile Range on a helicopter and a fixed winged aircraft. The helicopter tests were designed to cover the range of velocities and altitudes encountered during the latter part of the LM descent. The aircraft tests were designed to test the radar at higher altitudes and velocities, but due to aircraft limitations, the radar could not be tested at the very high altitudes and velocities that occur during the early part of the LM descent. Of course, the flight tests were performed with the earth as the reflecting surface which may or may not have the same reflectivity characteristics as the lunar surface.

In order to test the LR at high altitudes and velocities and with the moon as the reflecting surface, a LR test has been scheduled for the F mission. The purpose of this report is to present the results of a study to establish procedures for the F mission LR test.

RESULTS AND DISCUSSIONS

The F mission is a lunar orbit mission with the pericynthion at approximately 50,000 ft. The LR test is scheduled around pericynthion between DOI (descent orbit insertion) and the phasing burn. There is a requirement to be in the phasing burn attitude approximately 250 sec prior to the ullage for the burn. With the latest F mission trajectory and the latest GAEC LR math model, a study was made to determine what the LM attitude requirements were to provide LR tracking.

Figure 1 presents the LR antenna beam configuration. The figure is for an antenna tilt angle of zero degrees, which is the antenna position recommended for the test. The reasons for this position will be explained later. With zero degrees, pitch, yaw, and roll, with respect to the local vertical, the velocity vector is in the plane defined by the X_B - Z_B body axis and is essentially along the Z_B axis. The relationship of the LR velocity beams (beams 1, 2, and 3) with respect to the velocity vector is one parameter that determines if the LR can track. If the angle between a beam and the velocity vector approaches 90 degrees, the beam reaches what is known as zero doppler and track will be lost. How close to 90 degrees the beam can approach before dropout occurs depends on the beam incidence angle and the range along the beam. Dropout can also occur when the velocity along a beam is large, and this dropout is due to either a large incidence angle, a large beam range, or both. This is because the signal power reflected from the surface toward the receiver is proportional to the cosine of incidence angle divided by the range along the beam squared. This type of dropout will be referred to as a signal-to-noise ratio dropout.

The preceding discussion on track loss was primarily velocity beam dropout. The altimeter beam (beam 4) does not have a zero doppler dropout, but if the velocity along beam 4 becomes large at the same time the range along beam 4 is large, then the altimeter designed bandwidth can be exceeded and dropout will occur. Figure 2 shows the region where the bandwidth will be exceeded if the combination of range and velocity becomes too large. Referring to figure 1, it can be seen that this dropout can occur for large positive pitch angles. Dropout of beam 4 can also occur either when the incidence angle becomes large, the range along the beam becomes large, or when they both become large. This type of dropout can occur even when the velocity along the beam is negative. This type of dropout will be referred to as a signal-to-noise ratio dropout.

With these various factors affecting radar lock, the objective of this study is to determine the LM attitude requirements to maintain track in lunar orbit. It became obvious after several computer runs that there would be a requirement for the vehicle to track local vertical in order to provide continuous LR track over a period of time. Because of this requirement, it was felt that the LM maneuver required to track local vertical should be as simple as possible. It will be shown later how precisely this tracking must be.

Figure 3 presents the F mission altitude versus time from pericynthion plot. Various points along this profile were selected, and LR track regions were determined for various LM attitudes. Trajectory point number 1, which is approximately 60,000 ft above the lunar surface, is one of the points investigated. Figure 4 is a plot of beam incidence angle versus LM pitch from the local vertical. The regions where the beams are locked on and tracking are indicated by the broad lines. The dropout points on the various beams can be described as follows:

a. The dropouts on beams 1 and 2 at 42° and 38° pitch, respectively, are due to low signal-to-noise ratios.

b. The dropout points on beams 1 and 2 at 24°, 20°, and 22°, 18° pitch, respectively, are due to zero doppler.

c. The dropout points on beams 1, 2, and 3 at 2° pitch are due to low signal-to-noise ratios.

d. The dropout point on beam 3 at -20° pitch is due to zero doppler.

e. The dropout point on beam 4 at -12° pitch is due to low signal-to-noise ratio.

f. The dropout point on beam 4 at 18° pitch is due to exceeding the altimeter bandwidth.

As shown by the figure 4, there is not any pitch attitude where all four beams can be locked at the same time. Figure 5 is a plot of beam incidence angle versus pitch angle with a -15° vehicle roll (pilot yaw). The incidence angles for beams 1 and 3 have been reduced slightly, as compared to figure 4, but the beam 2 incidence angle is higher. Again, there is no pitch attitude where all four beams can be locked at the same time. There does not appear to be any advantage in rolling the LM, and it may be a disadvantage in that it could complicate the local vertical tracking.

The same trajectory point was investigated assuming the LM was yawed -10° (pilot roll) and then pitched about the LM Y-axis. Figure 6 shows the beam lock regions for this attitude maneuver. The lock regions on beams 2, 3, and 4 now cross at about 10° pitch, but all four beams cannot be locked at the same time; therefore, there does not appear to be any advantage to a LM yaw offset.

As the LM approaches pericynthion, the beam lock regions presented in figures 4, 5, and 6 will expand because of the decrease in altitude and the slight increase in velocity. Referring to figure 3, trajectory point 3 was investigated to determine the lock regions, and the increase is shown in figures 4, 5, and 6 by the crosshatched areas. Figure 4 indicates that if the LM vehicle were at an attitude of 0 degrees yaw, 0 degree roll, and 0 ± 4 degrees pitch from the local vertical, all four beams could be locked. Figure 5 indicates that all four beams could be locked at the same time but with a smaller attitude margin. Figure 6 indicates that there is no pitch attitude where all four beams can be locked at the same time. Therefore, the 0 degree yaw and 0 degree roll angles are recommended.

There are two ways in which the LM could get the LR in the correct attitude in order to lock all four beams. First, if the LR antenna were in position one (24 degrees back from the minus X_B axis), the LM could be pitched back (negative rotation about the Y_B axis) 24 degrees and all four beams should lock. Second, if the LR antenna were in position two (0 degree with respect to the minus X_B axis), the LM could be held at 0 degree with respect to the local vertical, and all four beams should lock. Also, the pilots would probably be able to make observations of the lunar surface. Therefore, LR antenna position two is recommended.

With the LR antenna in position two and 0 degree yaw and roll, the following is the recommended definition of the pitch variation during the test:

a. Trajectory point 1 (figure 3), 400 sec prior to pericynthion - the LM should be pitched back (positive rotation about the Y_B axis) 10 degrees from the local vertical. In this attitude, beams 1, 2, and 4 should lock (figure 4). The 10 degree angle, with respect to the local vertical, should be maintained within ± 2 degrees for 200 seconds.

b. Trajectory point 2, 200 sec prior to pericynthion - the LM should be pitched up to 0 deg with respect to the local vertical and maintained at this attitude within ± 1 deg for 400 seconds. In this attitude, all four beams should lock.

c. Trajectory point 5, 200 sec after pericynthion - the LM should be pitched back to 10 deg from the local vertical and maintained at this attitude within ± 2 deg for 200 seconds. In this attitude, beams 1, 2, and 4 should lock.

d. Trajectory point 5, 400 sec after pericynthion - the LR tracking of the lunar surface will be terminated because of the maneuver to the ullage attitude for the phasing burn.

In summary, there should be 800 sec of data for beams 1, 2, and 4, and 400 sec of data for beam 3.

Landing Radar

CONCLUDING REMARKS

A LR test has been defined for the F mission. This test, to take place between DOI and the phasing burn, should provide about 800 sec of data for beams 1, 2, and 4, and 400 sec of data for beam 3. The LM attitude requirements for the test have been defined. The LR antenna should be placed in position two.

This study was based on the average characteristics of four landing radars. The averages of measured power outputs, antenna gains, waveguide losses, and noise levels from tests on four radars were used as input data to the GAEC math model. As soon as the characteristics of the radar that will be used on the F mission are available, this study will be updated to determine the amount of test data that can be expected.

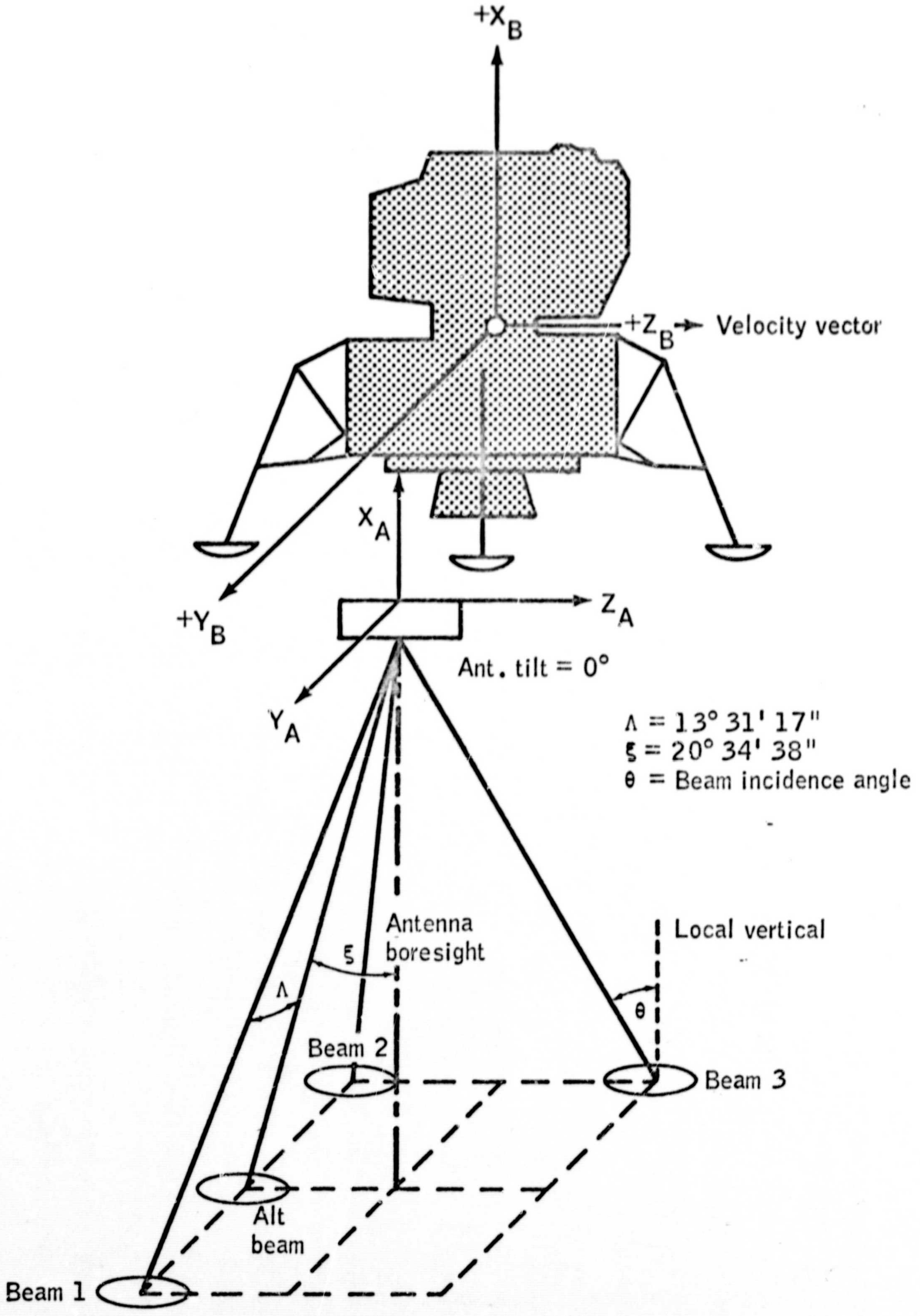

Figure 1.- Landing radar antenna beam configuration.

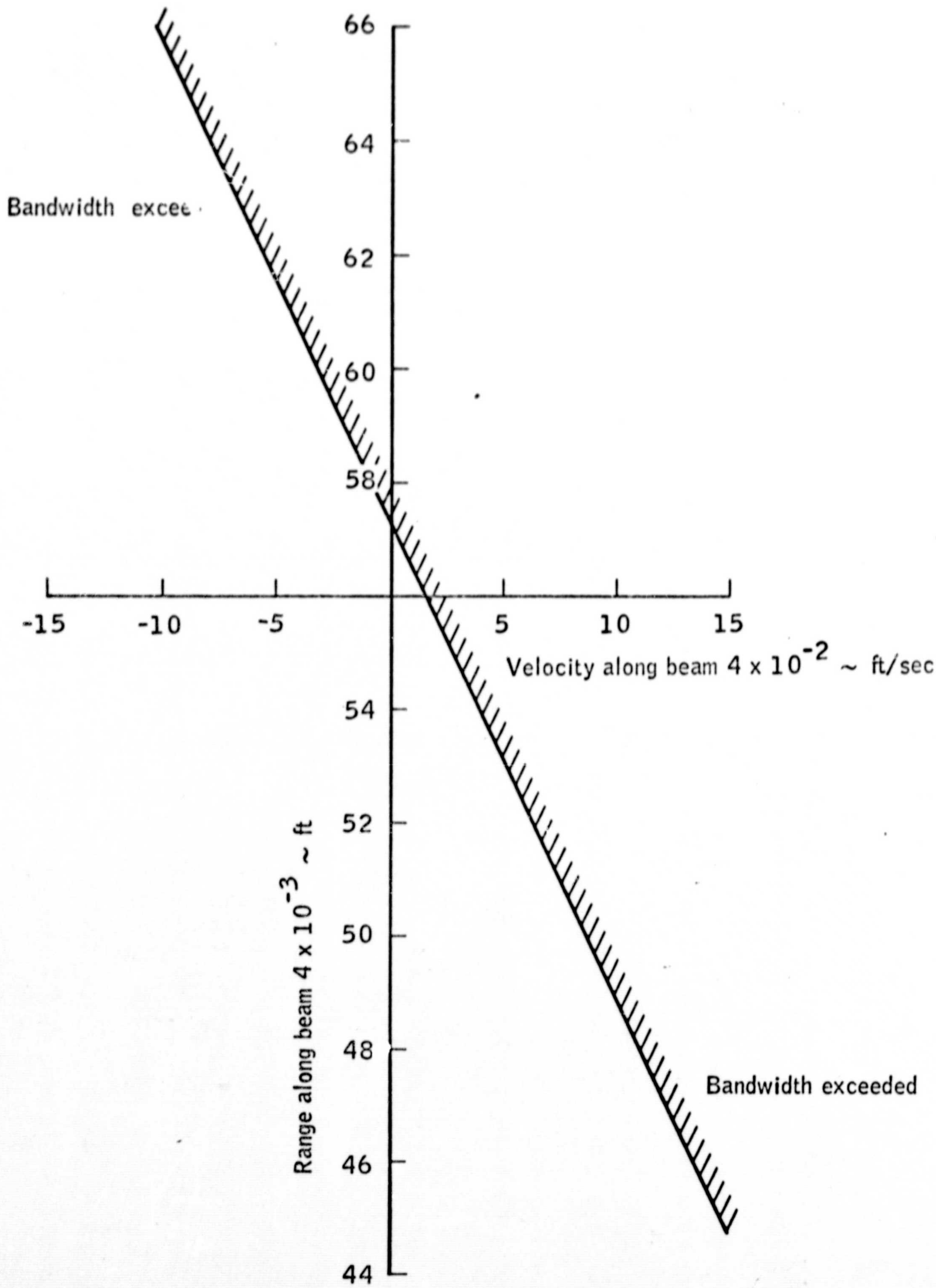

Figure 2. - Definition of region where altimeter bandwidth is exceeded (limit 133 kc).

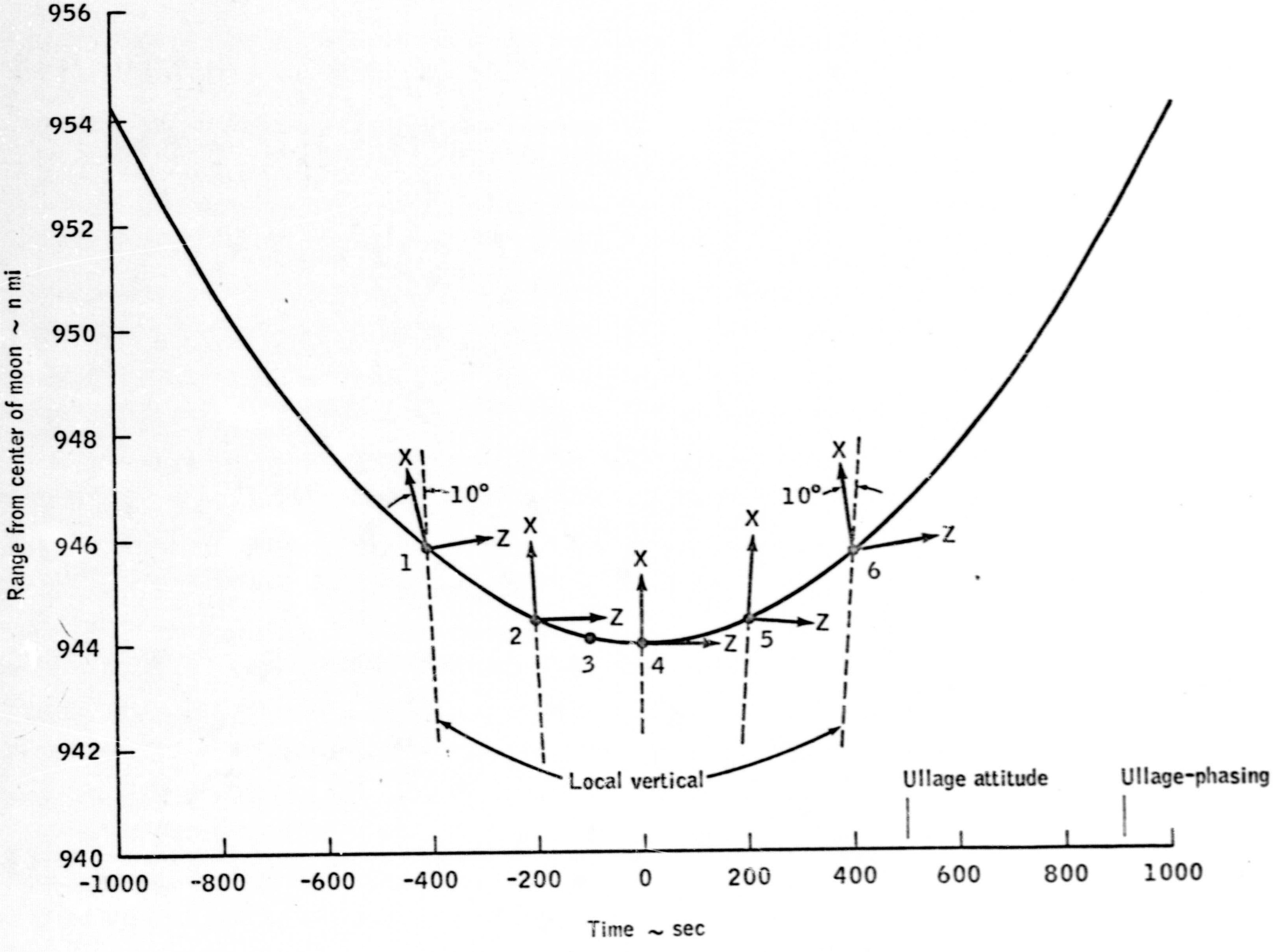

Figure 3. - F mission altitude vs time from percynthian.

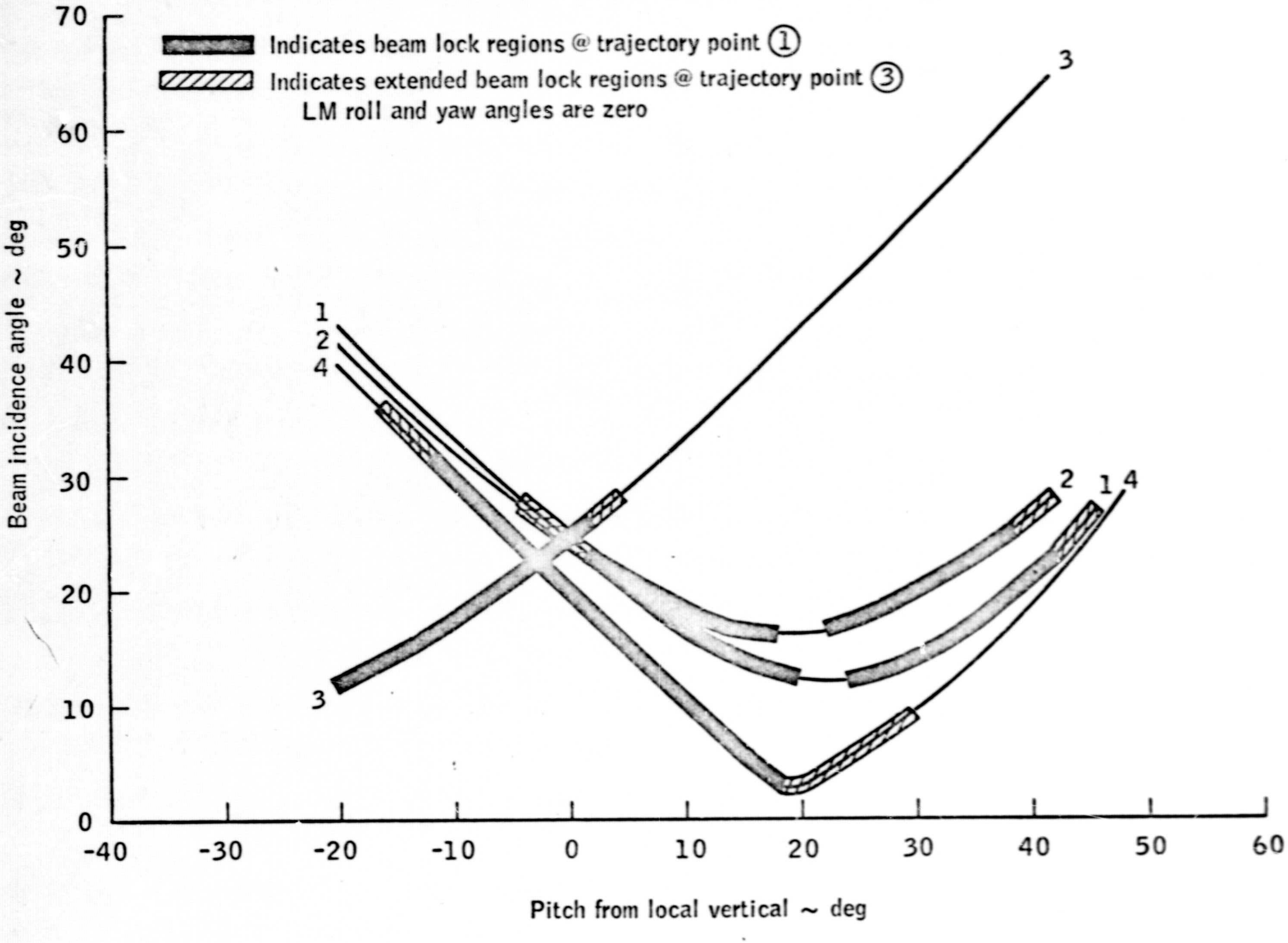

Figure 4. - LR beam incidence angle vs LM pitch from local vertical.

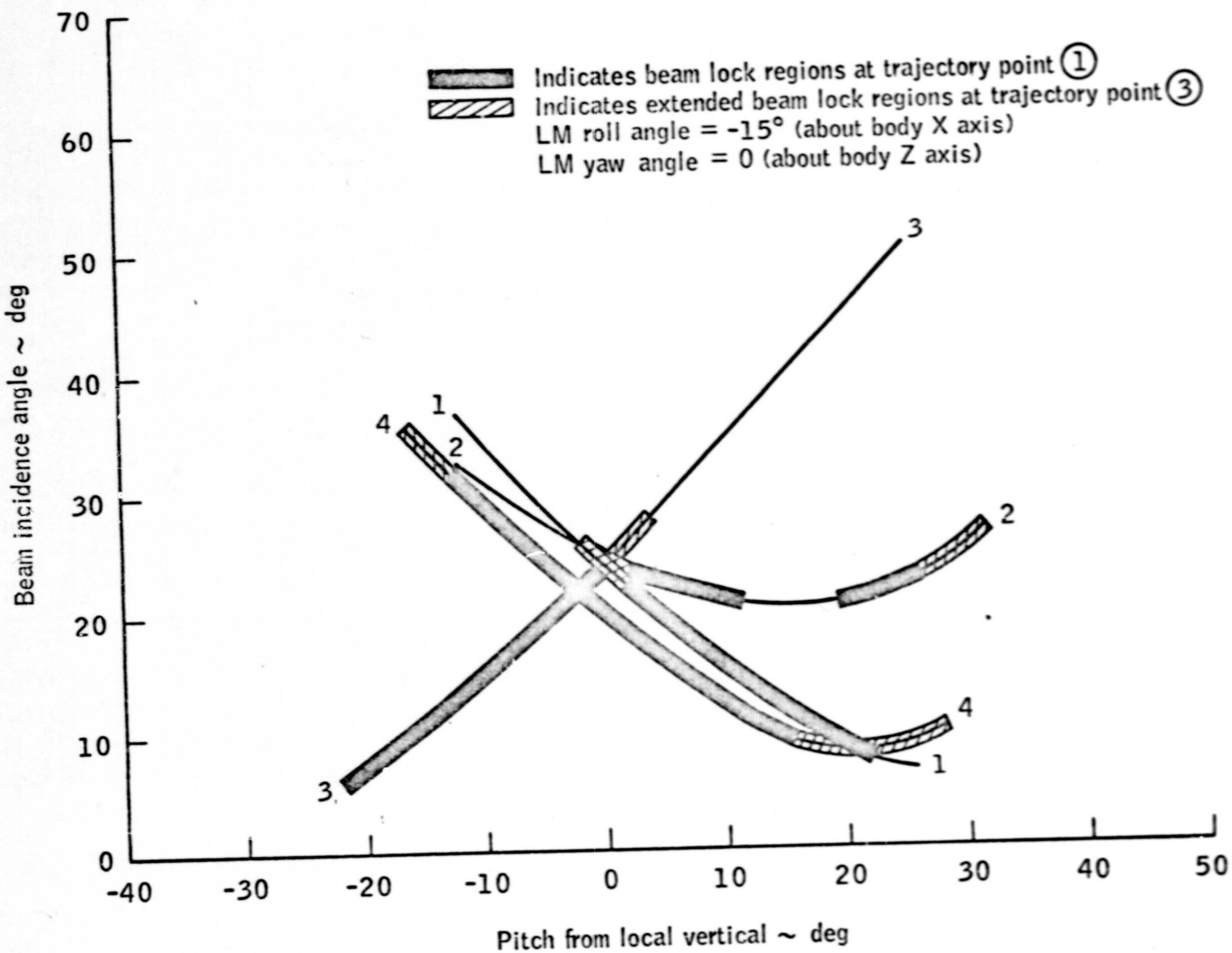

Figure 5. - Beam incidence angle vs pitch from local vertical.

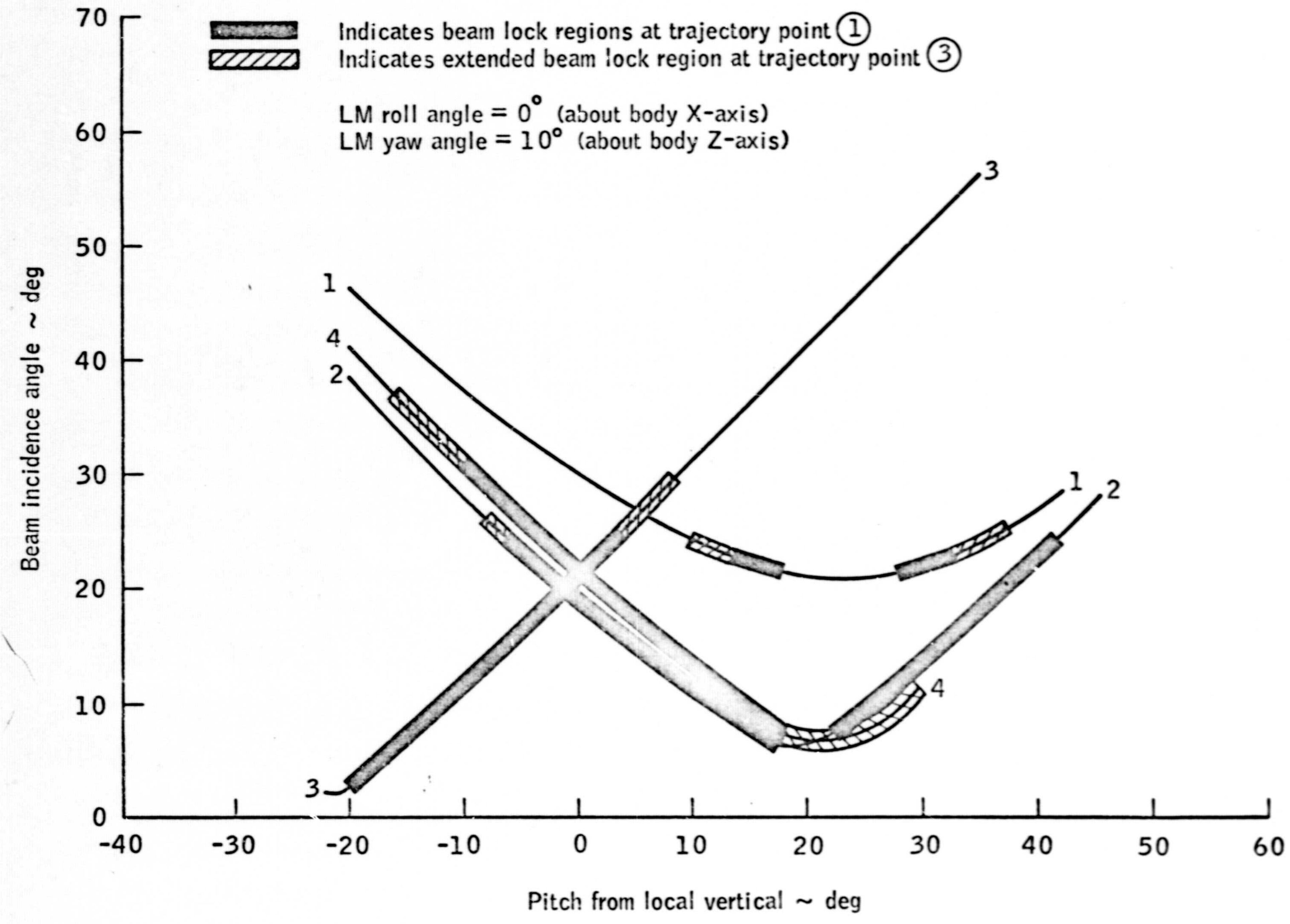

Figure 6. - Beam incidence angle vs pitch from local vertical.