BELLCOMM, INC.

SUBJECT: Proposed Attitude of the Apollo Spacecraft and SIV-B During Post Injection from a Communications and Tracking Antenna Viewpoint. Case 215

DATE: August 24, 1964

FROM: H. Pinckernell

SUMMARY

Communication between the space vehicle and the ground stations during the post injection interval can be impaired by the deployment of the LEM adapter panels. (The exact deployment of these panels is currently being investigated.) This memorandum discusses three proposals that consider different attitudes of the Apollo space vehicle during the post injection phase of a lunar mission. One of the alternatives is chosen based on maximum exposure of the space vehicle antenna to the ground network.

The deployment of the LEM adapter panels necessitated an attitude positioning strategy of the space vehicle that would permit the feasibility of uninterrupted communications with the MSFN sites. The objective of this strategy was to maximize the space vehicle antenna utilization and at the same time minimize the number of attitude changes. Three alternative post injection attitudes were examined graphically. These were studied using a representative altitude profile beginning with the end of the injection burn and lasting for approximately 60 minutes.

The positioning strategy chosen required the space vehicle attitude to be reoriented two times during the 60 minute post injection period. The first change occurred immediately after termination of the burn interval, the second change 18 minutes later. These attitude changes are based on the LEM adapter panels being deployed to a position normal to the roll axis of the vehicle.

SUBJECT: Proposed Attitude of the Apollo Spacecraft and S-IVB during Post Injection from a Communications and Tracking Antenna Viewpoint - Case 215

DATE: August 24, 1964

FROM: H. Pinckernell

MEMORANDUM FOR FILE

1.0 INTRODUCTION

The communication and tracking objective after the second burn of the S-IVB is to provide communications (voice and telemetry) between the spacecraft and crew and the MSFN sites, and to telemeter status information of the space vehicle. Also, tracking for trajectory data of the space vehicle will aid the MSCC in making the decision of affirming the attempt of transposition.

The following discussion is concerned with that part of the nominal Apollo mission that begins with the termination of the second burn of the S-IVB and ends with the completion of the transposition maneuver. Throughout most of this phase of the mission it will be necessary for either the spacecraft or the S-IVB/IU to communicate with the MSFN. This objective is made difficult to achieve by the physical constraints imposed by the vehicle on the various antenna patterns and the interference imposed on portions of the antenna patterns with the deployment of the adapter that surrounds the LEM during the launch, earth parking orbit and injection burn phases. These difficulties can be ameliorated by orientating the space vehicle to a position that will minimize the interference portions of the antenna patterns and maximize the effective coverage.

This memorandum discusses various alternative post injection vehicle attitudes and suggests one which will enable the communications and tracking objectives to be met from the viewpoint of antenna coverage.

2.0 ANTENNA COVERAGE CONSIDERATIONS

The Apollo space vehicle, just prior to and during the CSM/LEM transposition maneuver, must be inertially stabilized. Prior to this, changes in attitude are anticipated. These events in addition to the deployment of the LEM adapter during transposition could affect the space vehicle total antenna coverage and thus limit the communications objectives.

The orientation of the space vehicle before transposition will have a direct effect on the effectiveness of the antenna coverage. Steerable type antennas could provide more coverage at almost any attitude, however, this solution would require an extensive redesign and is therefore not considered feasible at this time. The main coverage voids for the fixed position antennas will occur along the roll axis of the vehicle. Other pattern interference will be experienced because of the change in diameter of the vehicle from the CSM to the S-IVB/IU. This will cause the null towards the aft of the vehicle to have more effect on the CSM patterns than for the S-IVB/IU antenna system.

During the transposition operation, the adapter between the S-IVB/IU and CSM will be deployed. It is assumed that the adapter sections will be pivoted back towards the aft end of the vehicle to a position which is at 90° to the roll axis. (The exact deployment of these adapters is currently being investigated). These deployed adapter sections can cause significant changes in the fixed antenna coverage patterns of the CSM antenna systems. Similar effects can be experienced in the coverage patterns of the S-IVB/IU antennas. It is also assumed that the high gain steerable antenna on the SM will not be available until transposition is complete.

These limitations and obstructions to the antenna patterns will necessitate a positioning strategy that will permit the feasibility of uninterrupted communications with the MSFN sites.

3.0 ALTERNATIVE POST INJECTION ATTITUDES

The purpose of the positioning strategy was to maximize the space vehicle antenna utilization and at the same time minimize the number of attitude changes. Three alternative post injection attitudes were examined graphically. These were studied using a representative altitude profile[1)] beginning with the end of burn of the S-IVB and lasting for approximately 60 minutes. A plot of this profile is shown in Figure 1.

[1)] Lunar Orbit Rendezvous Reference Trajectory Data Package (U) prepared under Contract No. 10001 by S.T.L. to Bellcomm, Inc., Issue 2 - Sept. 30, 1963

One alternative that was studied considered the space vehicle to be pitch stabilized in the direction of the velocity vector to a time just prior to the start of LEM transposition. The pitch stabilization correction can be applied either continuously or intermittently depending on the RCS fuel consumption limitations. When the vehicle reached the transposition phase the corrections were terminated. The attitude of the vehicle over the entire interval of concern always had line of sight contact with the tracking network. The look angles between the vehicle and the MSFN sites always were below and to the rear of the space vehicle.

During the post injection interval, communications between the S-IVB/IU and the MSFN sites is feasible with the use of a cosecant square antenna coverage characteristic with sufficient gain for the longer ranges. The assumed deployment of the LEM adapter sections should not significantly degrade the effectiveness of the S-IVB/IU antennas. Assuming that the RCS of the S-IVB is also effective after the separation of the spacecraft, communication contact between the S-IVB/IU and MSFN sites should continue.

Communications between the CSM and the MSFN sites during post injection will be affected by the orientation of the CM antenna system. As the space vehicle proceeds on its trajectory, the CSM contact is further degraded. When transposition starts communication contact with the MSFN sites should improve because of the turn-around of the CSM. This contact will again be degraded as the docking procedure is completed. At this point in the mission, the deployed LEM adapter and the S-IVB cause distortions in the CM antenna radiation pattern. Improvement in the CSM communication contact should occur when separation of the spacecraft from the S-IVB/IU takes place.

Another alternative that was considered assumed the space vehicle to be inertially stabilized at that attitude at the end of burn. This alternative imposes less of a demand on the RCS fuel usage although the communications contact becomes less desirable as the vehicle proceeds on its course.

After approximately ten minutes from the end of burn, the majority of the MSFN sites will be viewing the aft end of the space vehicle. This attitude choice would require two antenna systems on the S-IVB/IU, one to cover the lower radiating volume of the vehicle and one to cover the volume above and to the rear. Although continuous coverage through LEM transposition could be realized with proper antenna gains, implementation of a two antenna system on the S-IVB/IU would necessitate system requirement changes such as a transmitter power increase.

During the transposition phase, communications between the CSM and the ground stations will be doubtful. This condition is expected to persist through transposition until such time when the spacecraft separates from the S-IVB/IU. After separation, the high gain steerable antenna on the SM should provide all necessary contact.

The third alternative post injection attitude investigated considered two changes of space vehicle attitude. Immediately after the end of burn the space vehicle is pitched downward to approximately 16° below the normal to the local vertical. This orientation is held inertially fixed until approximately 18 minutes after the end of burn. At that time the space vehicle is pitched downward to approximately 18° below the normal to the local vertical. This orientation is held inertially fixed for the remainder of the post injection phase. These two attitudes approximate an average broadside positioning of the space vehicle with respect to the earth during the early and late segments of the post injection event.

Communications contact from the S-IVB/IU to the ground sites can be made continuous throughout the post injection flight with a shaped beam antenna. Figure 2-a shows the required antenna radiation pattern. This figure is based on the profile shown in Figure 1 with two attitude changes. For the early phase of the flight, the slant range does not exceed 4000 n.mi. The antenna gain required for this phase can be equal to that of an omni type system. As the slant range increases the gain required increases in order to sustain communications contact. From the geometry in Figure 1, 150 degrees of coverage is needed in the pitch plane for the early phase of the post injection flight; this coverage angle reduces to about 80° for those slant ranges at 60 minutes after the end of burn. This general coverage angle requirement, when considering the change in range over the course of flight, defines the general shape of the antenna pattern for this post injection alternative. Also, that part of the radiation pattern normal to the pattern shown in Figure 2-a is shown in Figure 2-b. A 150 degree coverage angle is necessary for the low slant range cases while the coverage angle decreases to about 30 degrees at slant ranges 60 minutes after the end of burn. Deployment of the LEM adapter should not significantly affect the average antenna coverage for the S-IVB/IU.

Contact between the CSM and the earth sites will be acceptable from an antenna viewpoint during the early portions of each attitude position. Just prior to the second attitude change the CM antenna coverage becomes questionable. After the second attitude change, the limitation on the CM omni type antenna will involve range rather than orientation. During the transportation maneuvers the S-IVB/IU should not cause too great a distortion to the CM antennas except when docking occurs.

The general CM antenna radiation pattern shown in Figure 3 is a shape that has been assumed for all of the alternatives discussed. The composite shape of the antenna pattern is considered symmetrical about the roll axis of the vehicle.

4.0 SUGGESTED ATTITUDE PROFILE

The three alternatives discussed represent the possible ways the vehicle can be oriented for the purpose of obtaining optimal space vehicle antenna coverage. From a comparison of the three alternatives, the third possibility presents a more desirable communications situation. The first alternative presented questionable contact between the CSM and MSFN sites in addition to requiring a great number of pitch corrections. The second alternative presented questionable contact between the CSM with the need for an expanded antenna system on the S-IVB/IU.

The suggested attitude profile would then require the space vehicle to change attitude twice during its post injection flight. The first change, immediately after end of burn, would orient the vehicle approximately 16° below the normal to the local vertical. The second change, 18 minutes after end of burn, would place the vehicle approximately 18° below the normal to the local vertical. These angular positions are made at the times stated and held inertially fixed until the next change.

Figure 1 also shows the positioning of the space vehicle on the altitude profile. Figure 3 presents the omni-directional type antenna pattern considered for the CSM to earth site communications contact. If a situation should arise where the CSM antenna coverage characteristic should be reduced, a third repositioning of the space vehicle could be considered within reason. A third attitude change would not affect the required shape of the S-IVB/IU antenna system.

H. Pinckernell
H. Pinckernell

2021-HP-dfs

Copy to
Messrs.
D. Broome - NASA/MSC
M. Kingsley - NASA/MSC
H. C. Kyle - NASA/MSC
P. Vavra - NASA/MSC
T. A. Barr - NASA/MSFC
H. Golden - NASA/MSFC
J. T. McClanahan - NASA/MAO

R. K. Chen
E. M. Coombs
J. P. Downs
L. A. Ferrara, Jr.
J. J. Hibbert
J. A. Hornbeck
H. Kraus
J. P. Maloy
J. T. Raleigh
R. W. Sears
R. L. Selden
P. F. Sennewald
G. H. Speake
J. M. West
A. G. Weygand, Jr.

Central File
Dept. 2014

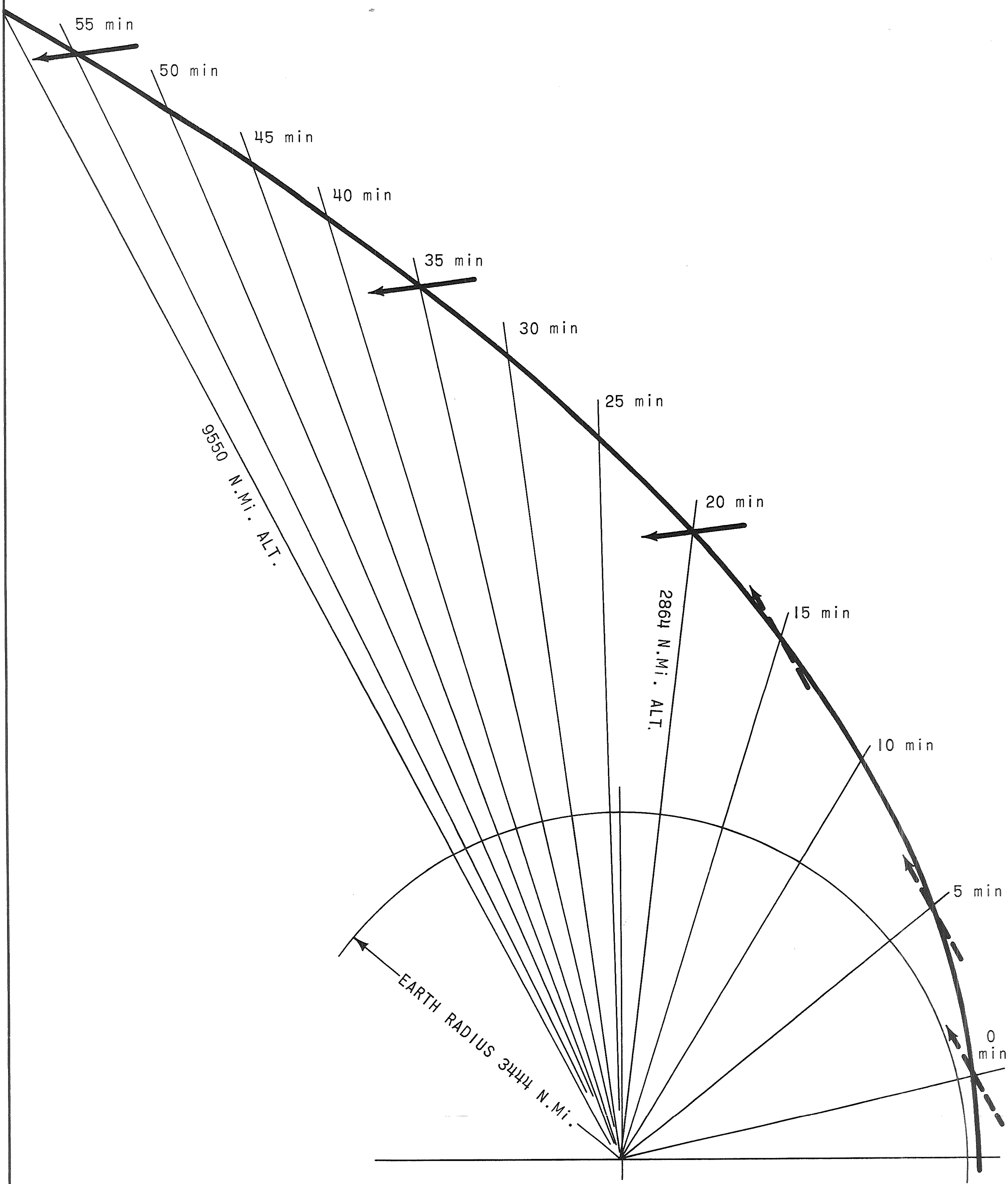
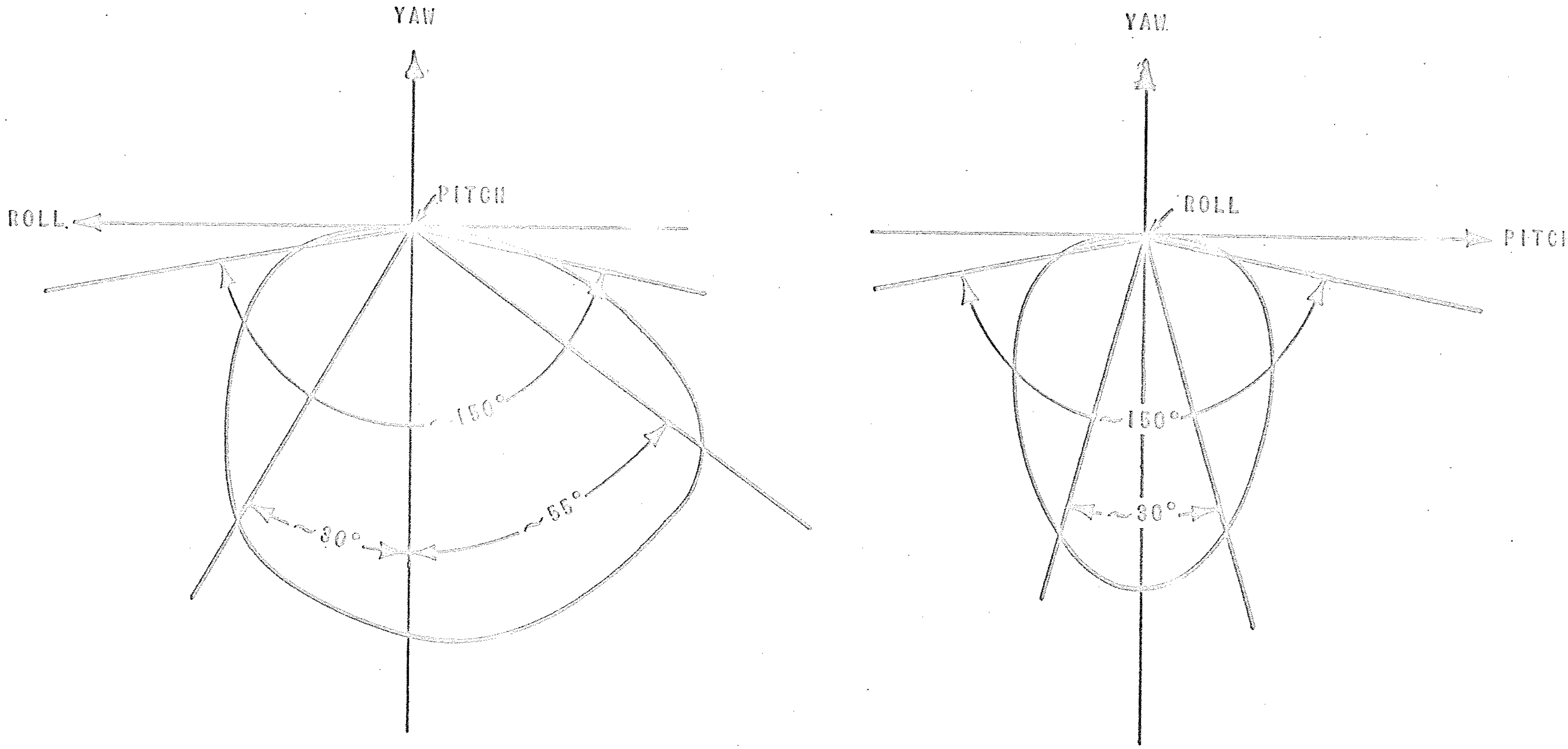


FIGURE 1 POST INJECTION ALTITUDE PROFILE

STL REFERENCE TRAJECTORY
ISSUE 2, SEPT. 1963



(a) (b)

FIGURE 2 GENERAL SIVB ANTENNA RADIATION PATTERNS
(THIRD ALTERNATIVE)

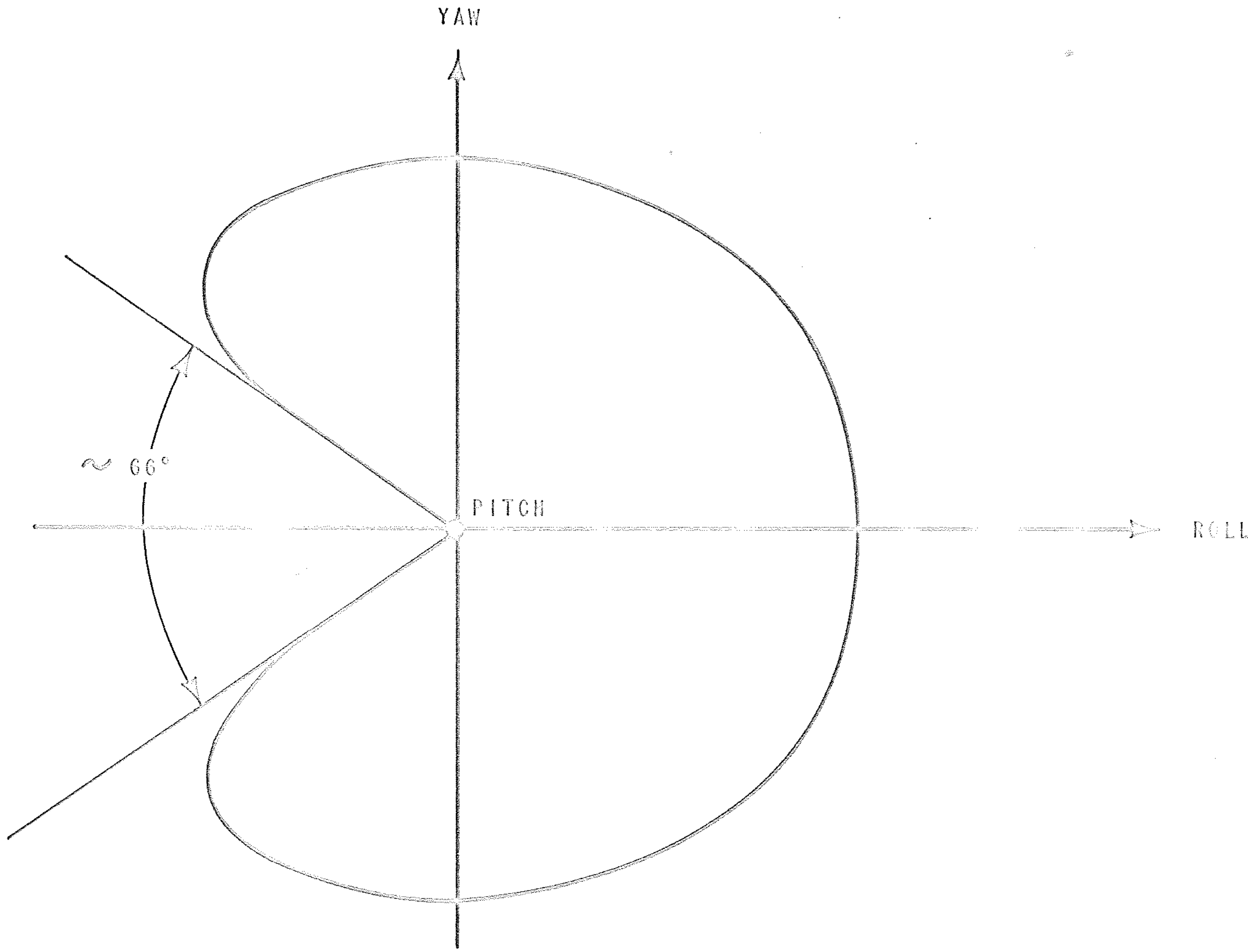


FIGURE 3 GENERAL CM ANTENNA RADIATION PATTERN