N80 23521

THE DESIGN AND APPLICATION OF AN ANTENNA POSITIONER MECHANISM FOR INTELSAT-V SERIES COMMUNICATION SATELLITE

Big Szeto
Ford Aerospace and Communication Corporation
Western Development Laboratories Division

SUMMARY

A two-axis Antenna Positioner Mechanism (APM) has been designed and qualified for use on the Intelsat-V series communication satellite. The APM will be used for positioning of Spot Beam Reflectors during the seven year mission.

INTRODUCTION

In operation, the East/West Spot Beam Reflectors on the Intelsat-V series communication satellite are required to satisfy; i) Initial precise-pointing to particular earth locations; ii) Repositioning and pointing to different earth locations as traffic changes dictate during the seven years mission.

Two 2-axis Antenna Positioner Mechanisms are utilized in fulfilling these requirements. The APM is specifically designed, developed and tested by Ford Aerospace and Communication Corporation, Western Development Laboratories Division (FACC).

The APM is comprised of three components which consist of one center pivot and two linear actuators rather than an integral two-axis gimbal design. The step resolution of the APM can be adjusted as required with the present design, at a step resolution of 0.002865 degrees.

In this paper, the design philosophy and considerations, test program and test results are discussed. Also, some major problems encountered during the course of testing along with their resolutions are detailed.

GENERAL DESCRIPTION

The APM which is shown in Figure 1 consists of three components which are:

a. One Center Pivot: A passive universal joint device which is capable of movement about two orthogonal axes in the same plane.

b. Two Linear Actuators: Two linear actuators are located at a distance of 25.4 cm (10 inches) and 90° apart from each other. Each actuator can be moved independently and linearly to provide rotary motion when coupled with the center pivot. The linear actuator consists of a stepper motor driving a jack-screw system which is supported by a pair of ABEC-7 ball bearings, ball joints at structure interface and reflector interface and a linear potentiometer for position telemetry.

The schematic arrangement of these components is illustrated in Figure 2.

The components of the APM are mounted to the same spacecraft structure at one end while the other interface is connected via the spot beam reflector to formulate the two-axis configuration. In operation, the actuators will be moved, one at a time, to locate the reflector at any location within the design constrained pattern. For this particular APM, the pattern is bounded within a square of 6.4 degrees which results in a square of 12.8° beam motion. The location of the reflector is fed back to ground via telemetry through the voltage readout of a linear potentiometer.

DESIGN PHILOSOPHY AND CONSIDERATION

The APM is designed, fabricated and tested to satisfy the primary and derived requirements as listed below:

a. Operational during the 7 year mission time.

b. Operational at extreme temperatures ranging between -85°C and +66°C with non-operating temperature ranging between -180°C and +100°C.

c. Withstand high launch loads without detrimental effect on the performance.

d. Minimum weight.

In the initial design stage, two design concepts were studied and traded off against each other. These two concepts were 1) APM and 2) Integral two-axis gimbal mechanism which utilized gear train to obtain high output torque. The APM concept was chosen because of the following reasons:

a. Higher load capacity with same mass property.

b. Simplicity in design.

c. Simplicity in fabrication.

d. Simplicity in assembly.

Linear Actuator Design

The external actuator configuration is shown in Figure 1. The actuator consists of a stepper motor driving a power screw which is supported by a pair of ABEC-7 ball bearings. The power screw as it turns drives a mating nut up and down in linear motion. Ball joints are utilized at reflector interface and structure interface to allow pivotal movements required for self-alignment. Solid lubrication, Molybdenum Disulfide, is used on the ball bearings, ball joints, screw-nut interface and other rubbing interfaces to provide low friction coefficient. The major design areas and considerations are described in the following paragraphs:

a. Driving Motor: A stepper motor is used to provide driving motion. This motor provides more than three-to-one running torque margin over the operating temperature range; also, detent torque is provided to prevent any potential back driving in one "g" condition. This motor is a dual, separately wound permanent magnet motor to provide redundancy with a step size of 1.8 degrees. The stepper motor was chosen over a DC motor because of relative simple control electronics required. This motor is designed and built by American Electronics, Inc.

b. Linear Motion Area: The heart of the linear motion is a jack screw principle. An ACME threaded power screw which is supported by a pair of ball bearings is connected to the motor's shaft, a mating power nut is moved in an up-and-down linear motion through a linear guide. For this particular design, a pitch of 0.254 cm (0.1 inch) is used. Thus, for each step of the motor, the linear movement is 0.00127 cm (0.0005 inch), with a corresponding angular motion of 0.002865 degree. The choice of the ACME threaded system over a ball screw system is based on; i) Lighter weight; ii) Less volume and iii) simplicity in design.

c. Self-aligning pivots at the reflector interface and the structure interface are provided to allow rotary motion. Spherical bearings are used for this purpose.

d. Position Indication: The approximate position of the reflector is fed back to telemetry by means of the voltage readout of a linear potentiometer. This potentiometer has very high resolution with the linearity being ± 0.35%. It is designed and fabricated by Vernitech, a division of Vernitron Corporation.

e. Lubrication Scheme: Because of extreme temperature requirements, especially at the cold end (-85°C operating, -180°C non-operating), solid lubrication is used throughout the actuator and preferred over liquid lubrication. Molybdenum Disulfide, MOS_2, is used.

f. Materials Selection and Compatibility: The materials chosen for the actuator are based on; i) Light weight; ii) High strength and iii) Similar thermal expansion coefficients. Titanium Alloy, Ti-6 AL-4V, is used for main structure, with 440C stainless steel for bearing materials and 17-4 PH stainless steel for other interfacing parts with Titanium.

Center Pivot

The center pivot external configuration is shown in Figure 1. The center pivot is a passive two-orthogonal-axis gimbal. Each axis of movement is supported by two spherical bearings which are lubricated with MOS_2. The usage of spherical bearings over ball bearings and roller bearings is because of compact size yet very high load carrying capability.

QUALIFICATION ENVIRONMENTS AND TEST PROGRAM

Qualification Environment

The APM was designed to withstand the following qualification environments:

a. Barometric Pressure: Between sea level and 1×10^{-10} torr.

b. Random Vibration: 22.6 grms in three orthogonal axes, for 4 minutes per axis.

c. Static Load: 170 Newton-Meter (1500 in-lb); 890 Newton (200 lbs).

d. Temperatures: Operating: -85°C to +66°C
Non-Operating: -180°C to +100°C

Qualification Test Program

The APM has been qualified by means of a qualification test program which included the following test sequence:

a. Initial functional test.

b. Random vibration - non-operating.

c. Static load test - non-operating.

d. Post vibration functional test.

e. Thermal vacuum test.

f. Final functional test.

The step resolution and potentiometer voltage resolution were tested in each functional test to detect any discrepancy.

TEST RESULTS AND DISCUSSION

Typical results on step resolution and potentiometer voltage resolution for different test conditions are shown in Figures 3 and 4 respectively. The variations of these results are presented in Tables 1 and 2.

Step Resolution

The measurement of step resolution is from the actual angle of movement which is obtained by making optical measurements. The results show that the change of the actual angle of movement at different environments is by no more than 3.7%. It indicates a well repeated movement of the APM at different environmental conditions.

Potentiometer Voltage Resolution

The potentiometer voltage resolution as shown in Figure 4 and Table 2 shows a greater variation than the actual step resolution. The maximum variation at different environments is 13.5%. This high variation is attributed to the induced misalignment within the potentiometer due to the assembly which creates non-uniform friction at different conditions. This result indicates that the voltage output per step should be used as a guide and approximation only. For precise usage of the potentiometer voltage output, calibration during the ground test is incorporated. A better indication of the utilization of the potentiometer is also tested as hysteresis and repeatability as described below in the other test results.

Other Test Results

Other measurements have been performed on the APM. A few of these results are described here:

a. Repeatability and Hysteresis: This test is to measure the angle repeatability of the APM using the potentiometer voltage as reference. The actuator is initially set at nominal location with the voltage and angle as a reference. The actuator is then moved the whole operating range in an upward or downward direction and returned to the original voltage reading. The actual angle is measured and compared to the reference angle with the angle difference being repeatability and hysteresis. The maximum deviation has been found to be within 1.5 arc minutes.

b. Backlash: This measurement is to find the inherent backlash of the APM when reversing the direction of movement. The maximum has been found to be 1.7 arc minutes.

c. Motor Redundant Operation: Motor redundant operation has been performed satisfactorily under different environmental conditions.

d. Weight: Weight of the APM is measured to be 3.45 Kilograms.

PROBLEMS AND RESOLUTIONS

In the course of testing, two major problems surfaced which required some redesign of the actuator and potentiometer. These problems and their resolutions are described below.

Jamming Problem

After vibration, the linear actuator was found to be stuck at one particular location in the linear range which was away from the position during vibration. After extensive evaluation, the causes of the problem were determined to be:

a. The surface finish at the rubbing interface between the power nut and linear guide was not smooth enough.

b. The lubrication film was too thin.

c. The rubbing interface between the power nut and linear guide was used both to constrain linear motion and provide dynamic load carrying capability.

d. The material for power nut and linear guide was the same (Ti-6 AL-4V). Thus, when the lubrication film breaks down, galling action is introduced and jamming action occurs.

The resolutions of this problem were:

a. Create a very smooth surface finish for the interface between the power nut and guide.

b. Apply a much thicker lubrication film at the interface.

c. Separate the load carrying function from the moving interface by creating a new load carrying interface.

d. Change the material of the guide to stainless steel so that any potential galling effect is minimized.

With the incorporation of the above changes, the APM has successfully passed the qualification test.

Potentiometer Problem

After vibration, the potentiometer indicated an open circuit at the vibrated location even though the actual movement of the APM was normal when measured by an optical instrument. This problem has been diagnosed as:

a. The material of the resistance substrate within the potentiometer was made of plastic material.

b. This material was indented at the repeated hammering action by the wiper during vibration and open circuit at this location is created.

This open circuit problem was solved by replacing the plastic substrate with ceramic material.

CONCLUSIONS

The two axis Antenna Positioner Mechanism (APM) has been successfully qualified for use to precisely position the spot beam reflectors on the

Intelsat-V series communication satellite.

The APM has been tested under extreme dynamic and environmental conditions and the results indicate good correlation between the actual data and the design analyses.

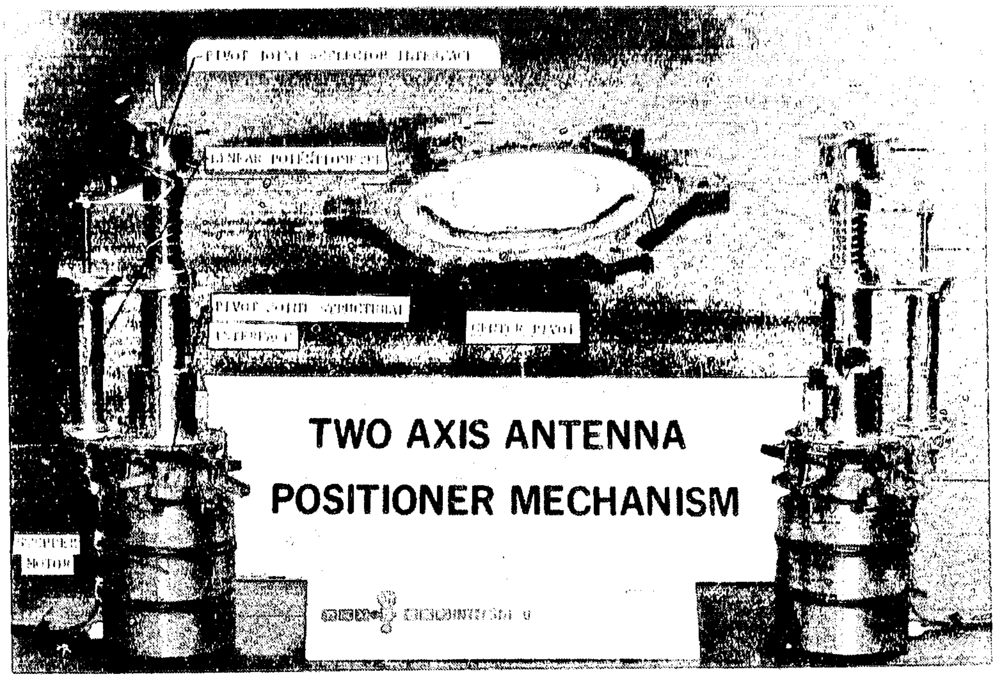
The APM has been designed and developed for this particular application. However, this APM can be used for other applications as well, such as one axis motion. Higher and lower step resolution can be obtained by adjusting the corresponding distance. With the same design, the measurement accuracy can be increased by tightening controls on the tolerances of the parts.

TABLE 1 - VARIATION IN STEP RESOLUTION

Description	Variation
Maximum variation in same functional test.	5.3%
Maximum variation in the same location.	3.7%
Maximum variation from theoretical value.	+1.7% -3.6%

TABLE 2 - VARIATION IN POTENTIOMETER VOLTAGE RESOLUTION

Description	Variation
Maximum variation in same functional test.	17.7%
Maximum variation in the same location.	13.5%
Maximum variation from theoretical value.	+11.3% -11%



Linear actuator #1 Linear actuator #2

Figure 1.- Two-axis antenna positioner mechanism.

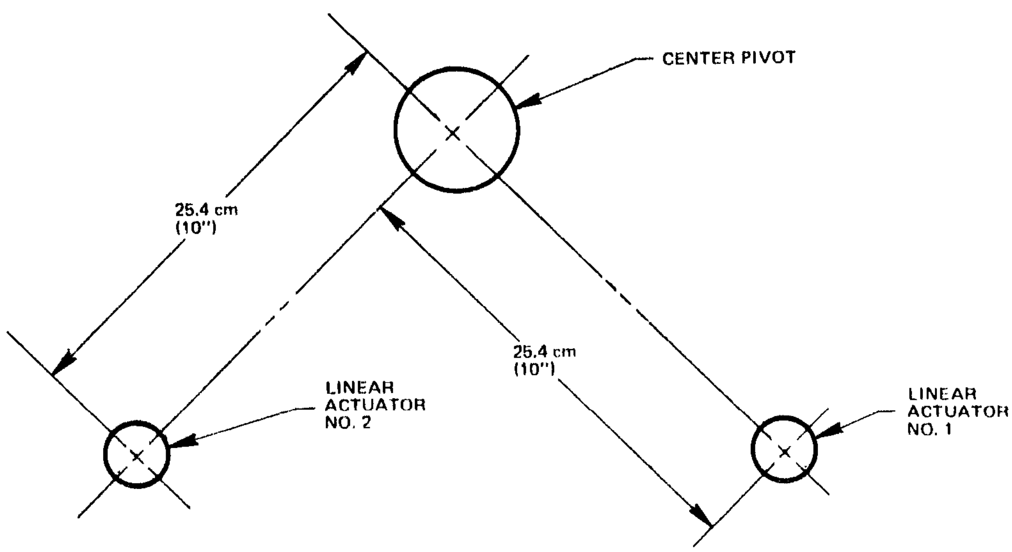


Figure 2.- APM schematic arrangement.

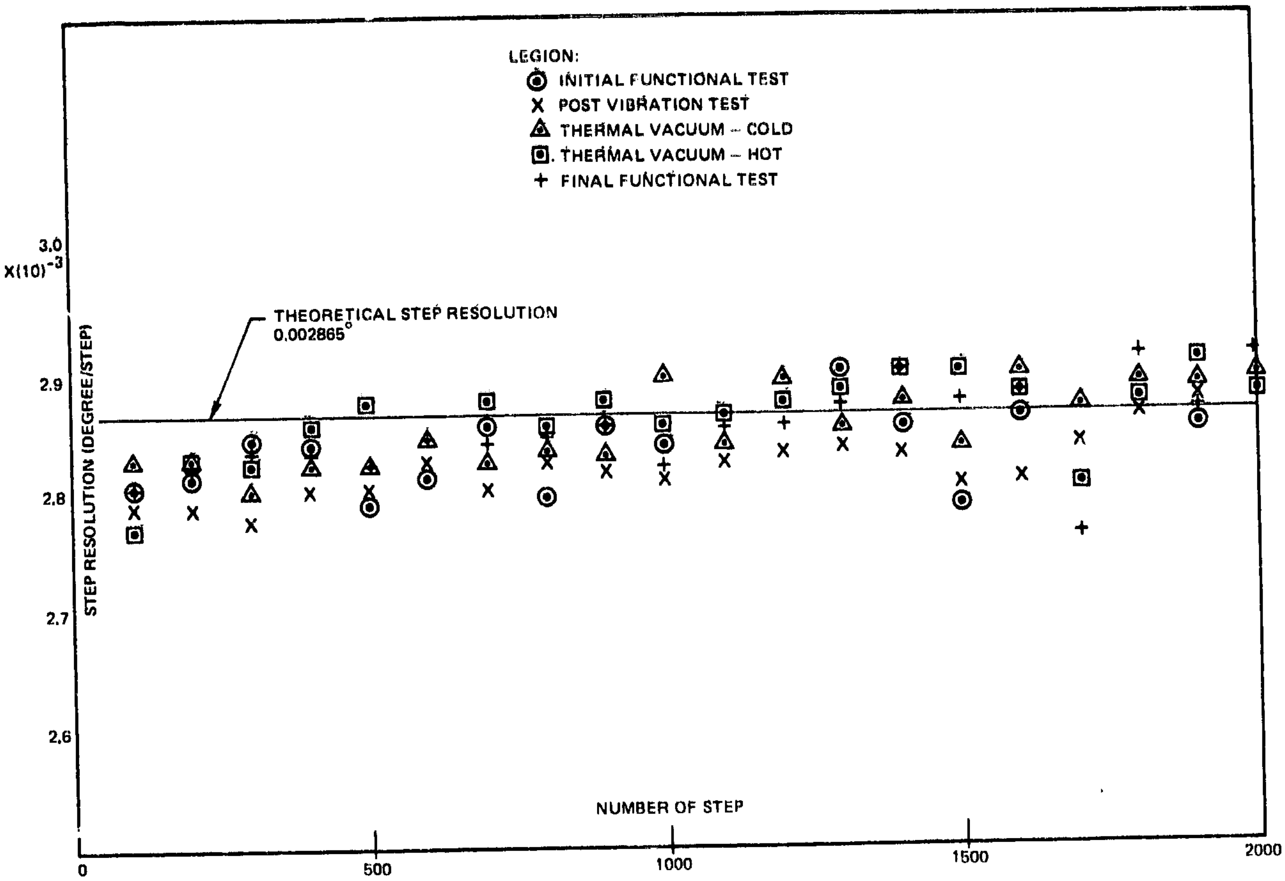


Figure 3.- Step resolution.

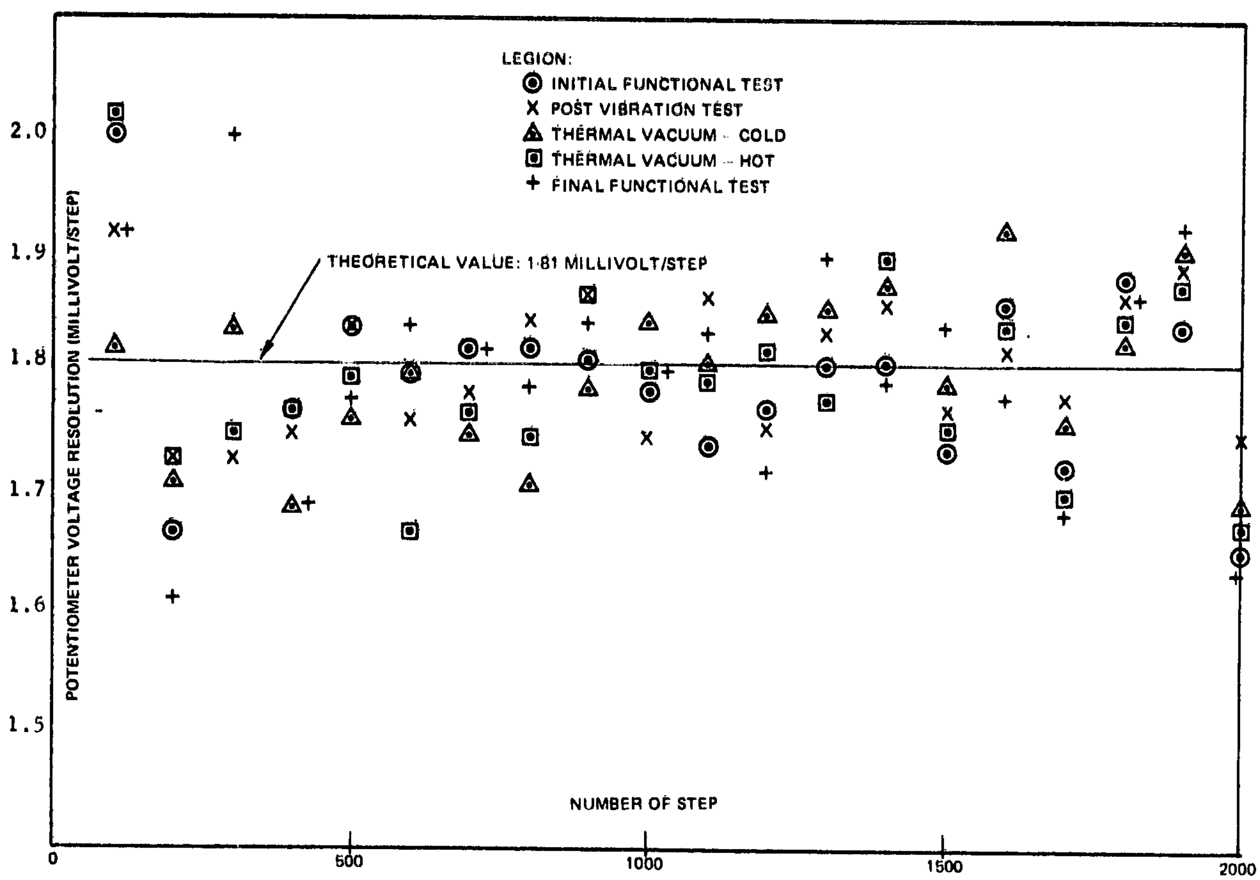


Figure 4.- Potentiometer voltage resolution.