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Cammatic: Automated Compensation for DSS-13 Antenna Gravity-Loading Performance Degradation

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Corrective forces are automatically applied to the DSS-13 main reflector backup structure to compensate for gravity-induced deformations. Efficiency improvements of up to 0.6 dB at Ka-band (32 GHz) are measured at low and high elevations. Measurements are consistent with finite element predictions.

I. Introduction

Evaluations of the initial RF performance of DSS 13 were disappointing.[1] It was determined that the bypass beam-waveguide shroud was introducing significant forces into the main reflector backup structure. Both holographic and theodolite measurements of surface accuracy showed large asymmetric and nonhomologous distortions that could be attributed directly to the interaction of the bypass shroud and the backup structure. After removal of the shroud, the antenna still did not meet predicted performance. Further examination showed that the bypass shroud was compensating, somewhat, for the gravity-induced astigmatism that is characteristic of large microwave antenna structures. It was recognized that introducing forces similar to those caused by the now-removed shroud could correct some of this astigmatism.

Performance sensitivities were obtained using the JPL-IDEAS finite element program [1], and optimal force-versus-elevation curves were obtained analytically. A series of tests was conducted in which varying loads were applied to the antenna structure during precision efficiency measurements. These tests confirmed the hypothesis and the model predictions [2]. It was then decided to automate the application of the corrective forces.

II. Implementation

The implementation of the automatic compensation system (dubbed "cammatic") was begun in the spring of 1994 as one of four competing systems, the others being actuated main-reflector panels, a deformable subreflector, and a deformable beam-waveguide mirror. Cammatic is the simplest and least expensive of the three to implement but also promised the smallest gain.

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[1] R. Levy, *DSS 13 Antenna Structure Measurements and Evaluation*, JPL D-8947 (internal document), Jet Propulsion Laboratory, Pasadena, California, October 1, 1991.

The nature of the gravity-induced astigmatism is that the antenna "folds up" about a horizontal axis parallel to the antenna elevation axis as the antenna is tipped from zenith to horizon. The top and bottom edges of the rim rise while the left and right edges droop relative to the RF axis. Figure 1 shows the placement of the actuators and the lever arms attached to the left and right sides of the bottom chords of the backup structure. The actuators push or pull symmetrically on the lever arms and react against the elevation bearing weldments. An outward compensating force on these lever arms will raise the left and right edges of the dish and lower the top and bottom edges.

The deformations are introduced into the reflector structure by a pair of custom Industrial Devices Corporation (IDC) actuators. These actuators comprise a stepper motor geared to a lead screw. The actuators are capable of forces of about 90,000 nt over a range of about 7.62 cm, though the required displacements are only about ± 0.533 cm. In addition, the actuator brackets are designed to fail before damaging loads could be transmitted to the antenna structure. Each actuator stepper motor is controlled by a separate IDC motion profiler that accepts commands over a serial port. These devices provide for sophisticated motion profiles but cannot guarantee an absolute position reference; therefore, the control of the actuator position is achieved through a program running on a PC.

Absolute position is monitored by Lucas–Schaevitz linear voltage displacement transformers (LVDTs) mounted in parallel to the actuators. The LVDTs are accurate to ± 0.00254 cm and, when used with the Lucas–Schaevitz model 500HCA interface unit, can resolve 0.000254 cm. LVDT, hence actuator, displacements can be obtained over a serial link to the 500HCA.

Fig. 1. Cammatic actuator locations.

The positioning and monitoring of the actuators are performed by the cammatic controller, an IBM PC clone running a C program. This program was derived from that which is used to control the DSS-13 M6 conscan mirror. The PC interfaces with the two IDC S5201 motor controllers, the 500HCA, and the antenna monitor and control (AMC) computer over serial lines. The communication to the actuator controllers comprises relative and absolute position commands and rate commands; that from the 500HCA absolute position data. The AMC supplies time and antenna elevation data at 1 Hz. The cammatic controller reports the time, commanded and actual positions, and a status bit back to the AMC. The status bit is derived from a simple heuristic: if, at the end of every move command (1 Hz), the position error is zero, everything must be all right. The commanded and actual positions and the status bit are returned to the DSS-13 monitor and control (M&C) by the AMC.

When the actuators are not connected to the antenna structure, the relative motion of the actuator attachment points is about 0.42 cm over the antenna elevation range of from 10 to 90 deg. Since the lead screw design of the actuators has a large inherent back-drive force of about 6700 nt, the actuators must be disconnected from the antenna structure when cammatic is not in use in order to prevent performance degradation. Because of the accuracy required, an expandable bushing (pin), which provides zero clearance when in place and is easily removed, is used at each actuator. The cammatic controller is programmed to stow the actuators at antenna elevation angles greater than 89.5 deg. At this position, the actuators are positioned such that there is no force exerted by the actuators. The pins then can be inserted or removed by hand.

Since the actuator pins must be removed to disable cammatic, and this cannot be done remotely, no control of cammatic is provided to M&C. In normal operation, however, there should be no need to disable the cammatic actuators.

The antenna mechanical setting and calibration are performed at 45 deg, and the cammatic actuator displacement-calibration curve passes through zero at this elevation as well. The calibration curve comprises a cubic polynomial best fitting the displacement-versus-efficiency data obtained in [2]. Below 45 deg, the actuators push out to about 0.60 cm at 6 deg. Above 45 deg, they pull in to about −0.51 cm at 89.4 deg. At stow (above 89.5 deg), they are positioned to about −0.12 cm. Positive values represent outward motions of the actuators.

III. Evaluation and Conclusion

Antenna efficiency was measured with and without cammatic as part of the Ka-band (32-GHz) antenna performance measurements. Figure 2 shows plots of Ka-band antenna efficiency-versus-elevation for numerous tracks of radio source calibrators.[2] The lower curve represents the efficiency of the antenna in its nominal configuration and the higher curve that when cammatic was enabled. The higher curve represents the ensemble of three different tracking passes. It can be seen that cammatic improved performance about 0.5 dB at 20 deg and about 0.3 dB at 70 deg. No pointing or other anomalies were noted during these and other tracks using the cammatic system.

[2] Presented in D. Morabito, "Ka-Band Experiment," *DSN Technology Program FY 1996 Annual Review*, Viewgraph Presentation (internal document), Jet Propulsion Laboratory, Pasadena, California, September 1996.

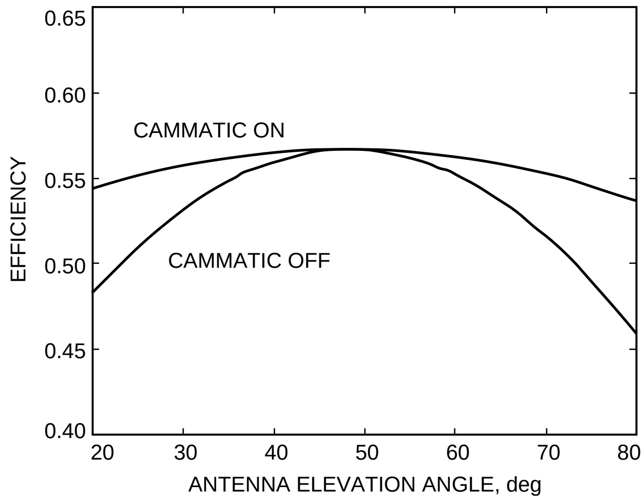

Fig. 2. Antenna efficiency versus elevation angle.

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References

[1] R. Levy and D. M. Strain, *User's Manual for the JPL-IDEAS Finite Element Analysis and Design Program*, COSMIC NPO-17783, NASA Software Technology Transfer Center, University of Georgia, Athens, Georgia, October 1988.

[2] R. Levy and D. Strain, "Cammatic: An Approach to Improve DSS 13 Antenna Gravity-Loading Performance," *The Telecommunications and Data Acquisition Progress Report 42-114, April–June 1993*, Jet Propulsion Laboratory, Pasadena, California, pp. 43–50, August 15, 1993.