Performance of the 64-meter-diameter Antenna Servo

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A 64-m-diameter antenna has been installed and tested at the Tidbinbilla Deep Space Station in Australia. Part of the final acceptance testing was demonstration of antenna servo performance. This report summarizes the major tests and the resulting data.

The antenna servo as implemented during these tests consisted of three feedback control loops: a current loop, a rate loop, and a manual position loop (Fig. 1).

The testing process started with frequency response tests of the closed current loop on each axis. For the complete response plots, see Figs. 2 and 3. The specification on the current loop was a bandwidth (defined as the frequency at which the response reaches 90 deg) greater than 150 Hz and less than 6 dB of peaking. Review of Figs. 2 and 3 shows that for the azimuth axis the bandwidth is 1100 Hz and the peaking is 4.5 dB; for the elevation axis the bandwidth is 1100 Hz and the peaking is 4.2 dB.

Open rate loop tests were then run to determine the frequency location of various resonances – hydraulic, natural structural, and other structural resonances, some of which are tabulated below:

Location	Azimuth, Hz	Elevation, Hz
Hydraulic	1.1	1.2
Natural (first) structural notch	1.5	2.1
Next	2.5	4.0
Next	3.0	8.0
Resonance	20.0	40.0

From these tests and data a compensation network was developed to close the loop with a bandwidth frequency of 5 Hz, minimum phase shift at the position loop bandwidth frequency, and maximum attenuation of peaking responses above 5 Hz.

The next test was the frequency response of the closed rate loop. For the complete response plots see Figs. 4 and 5. This test was run under two conditions: (1) a steady-state rate of 0.05 deg/s was applied to the antenna; (2) a zero steady-state rate condition. The specification on the rate loop is a nominal bandwidth of 5 Hz. Review of Figs. 6 and 7 shows that the following responses were achieved:

Axis	Zero rate, Hz	0.05-deg/s rate, Hz
Azimuth	5	5
Elevation	4.7	5

The last loop tested was the manual position loop, which corresponds to the closed loop used during normal spacecraft tracking. The position loop has two bandwidths available and was tested in both modes. The specification value for the high bandwidth mode is 0.2 Hz; in the low bandwidth mode the specification is 0.02 Hz. The frequency response plots for azimuth and elevation axes are shown in Figs. 6 and 7. Review of these plots shows that the following bandwidths were obtained:

Axis	High bandwidth, Hz	Low bandwidth, Hz
Azimuth	0.20	0.0135
Elevation	0.205	0.019

A further test was made to verify position loop stability under simulated conditions of wear, aging, and signal degradation by varying the position loop gain by +3 and −3 dB increments. Step responses under these conditions showed that control system stability was maintained.

Other tests of significance to antenna tracking performance are (1) tracking error with the antenna moving at a rate of 0.0015 deg/s, which corresponds approximately to a sidereal rate, (2) pointing jitter under a static position command, and (3) the minimum velocity the antenna is capable of maintaining. These results are tabulated below:

Test	Azimuth	Elevation
Tracking error		
maximum peak-peak	0.00082 deg	0.00101 deg
average	0.00006 deg	0.00005 deg
Pointing jitter	±0.00012 deg	±0.00032 deg
Minimum velocity	0.0002 deg/s	0.0005 deg/s

Various other tests were also performed: full speed (0.5 deg/s) tests through the complete travel range; verification of the two sets of electrical travel limit switches as well as the "deadman" emergency hydraulic limit valves; and tests on the control logic circuits involved in turning on (and off) the antenna drive and hydrostatic bearing hydraulic systems, which were performed to ensure satisfactory operation and "fail-safe" shutdown characteristics.

The antenna servo and the associated controls were completely tested and found to be achieving satisfactory specification performance.

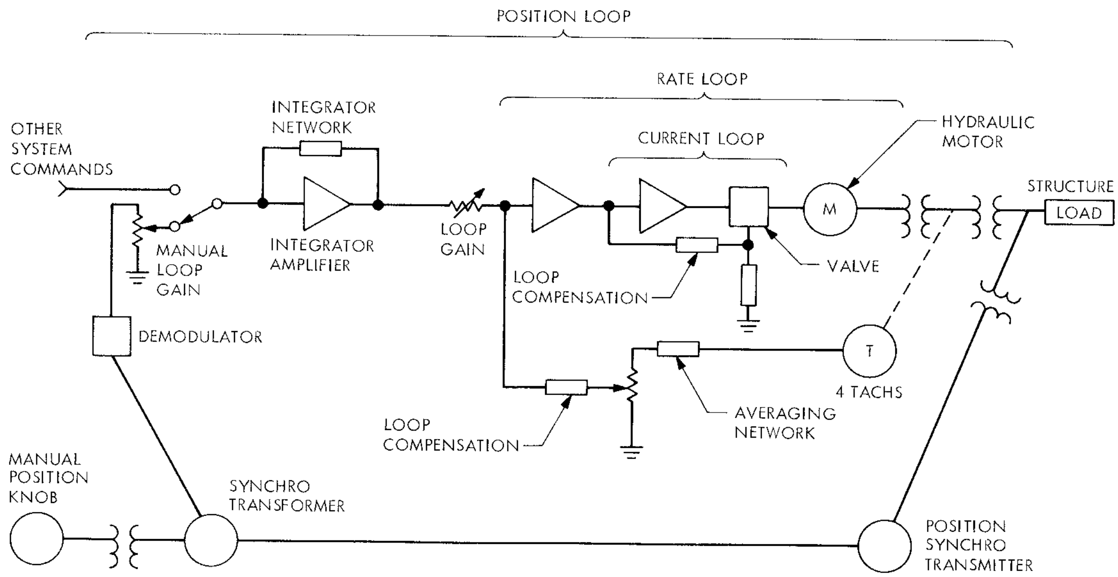

Fig. 1. Manual position loop block diagram

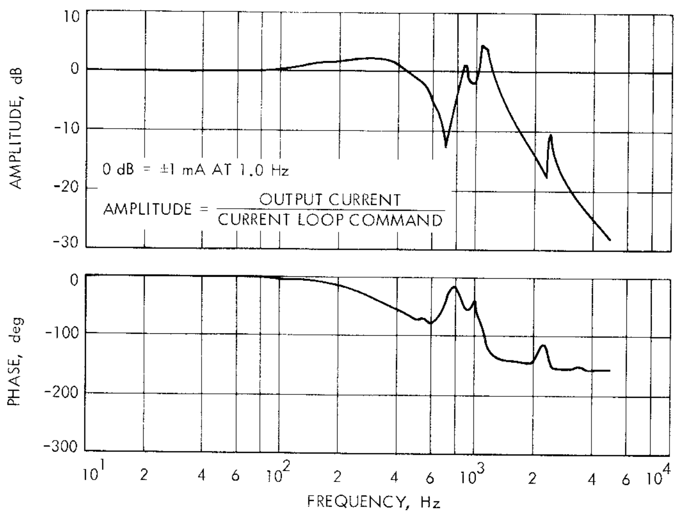

Fig. 2. Azimuth current loop frequency response

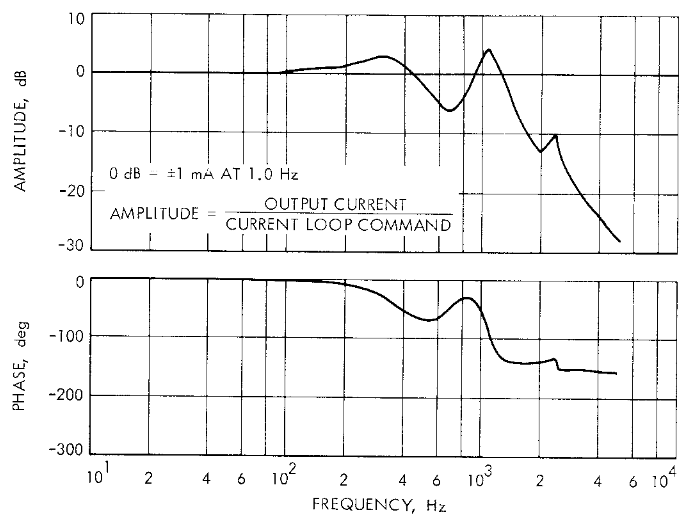

Fig. 3. Elevation current loop frequency response

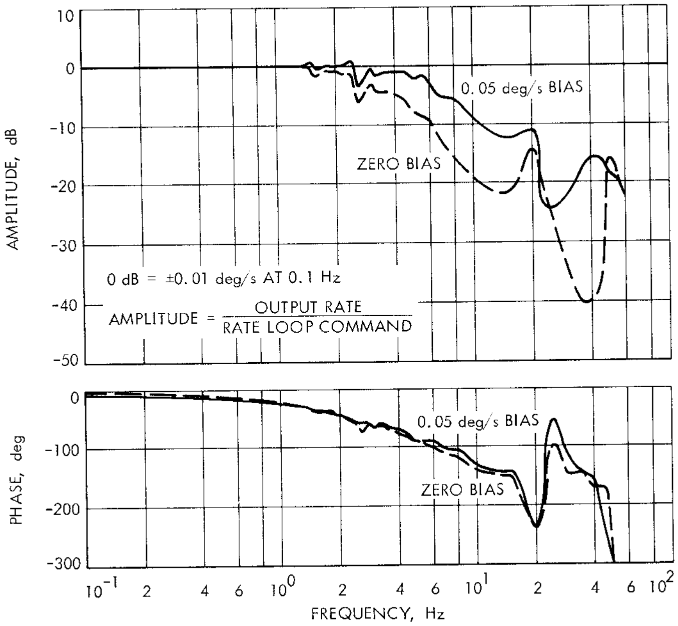

Fig. 4. Azimuth rate loop frequency response

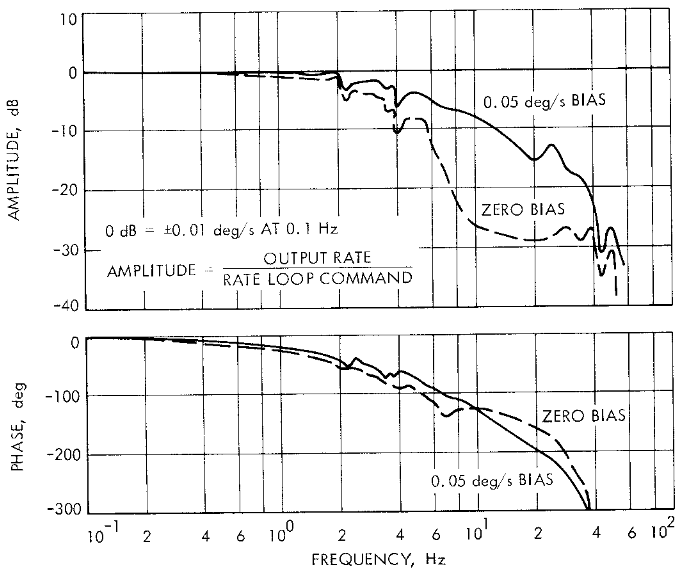

Fig. 5. Elevation rate loop frequency response

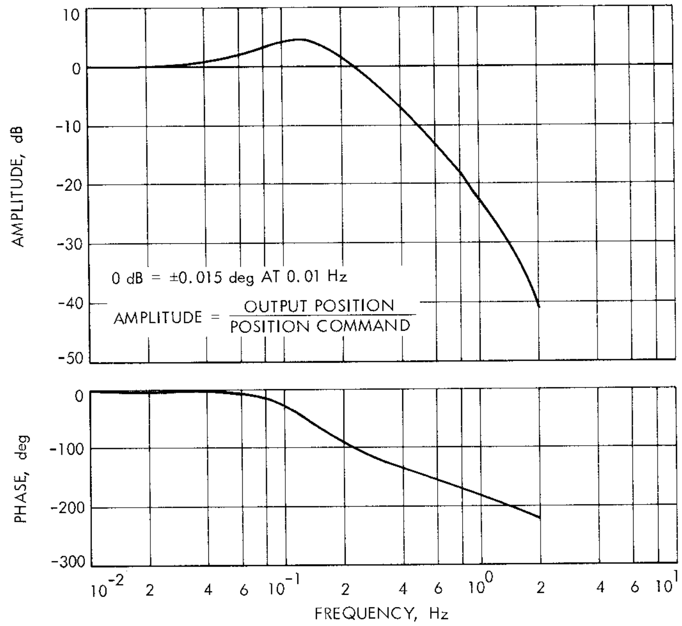

Fig. 6. Azimuth position loop frequency response

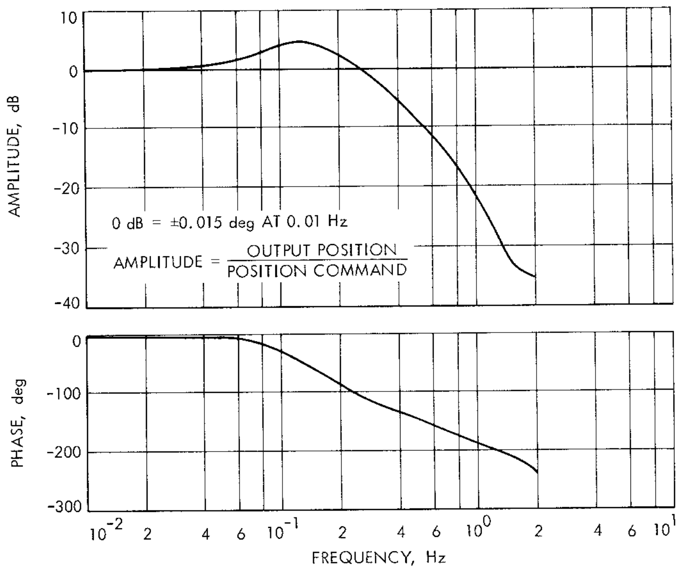

Fig. 7. Elevation position loop frequency response