MULTIPLE MIRROR TELESCOPE OBSERVATORY

TECHNICAL REPORT NO. 7

MMT BUILDING AZIMUTH DRIVE SYSTEM

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JUNE 1980

TABLE OF CONTENTS

ABSTRACT

The basic principles of operation of the Multiple Mirror Telescope building drive system are described. Measurements are presented which characterize the dynamic behavior of the servos for comparison with calculated values from the design study (attached as an appendix). The current performances in terms of tracking accuracy and frequency response are qualiitatively and quantitatively described. "As built" parameters are listed, as are suggestions for improvements.

I. INTRODUCTION

The purpose of this paper is to describe the state of the building drive system of the Multiple Mirror Telescope as of May, 1980. A general description of the design is given as well as specific performance tests and suggestions for improvement of the system.

II. SYSTEM DESCRIPTION

The building drive system is a slightly modified drive for a large radio telescope and has been used successfully in several installations of that type. The overall control system configuration is described in detail in two articles by H. Smith which are included in the MMT Documentation. The first is entitled "Azimuth Drive System Capabilities", dated September 16, 1975, and the second, "Azimuth Rotational Control System Design and Performance Analysis", dated January 29, 1976, which is included as an appendix to this report. There has been difficulty in locating these papers as they are entitled "Azimuth" instead of "Building".

The basic design criteria have not been changed since the time of these papers, so only a general description and block diagram (Figure 1) are included here. Details of the components that were actually used in the construction are also provided since this information is not included in the design papers.

A. FEEDBACK LOOPS

The building drive system has three feedback loops. Figure 1 is a block diagram of the system and shows the various feedback paths. The innermost or torque loop feeds a voltage proportional to the current through the armature of the motors into the input of the power amplifier. This allows the amplifier to closely approximate a linear voltage to current amplifier, thus eliminating the effects of the back electromotive force (EMF) of the motor. The power amps use large silicon controlled rectifiers to control the output current and are therefore not truly linear. This nonlinearity is particularly strong as the signal crosses zero and is noted in some of the test results to follow.

The second loop is the velocity loop which feeds back the output of the motor tachometer into the velocity command node. The third loop or position loop feeds back a signal proportional to the error between the alignment of the building and the azimuth of the telescope.

1. TORQUE LOOP

The building is powered by two 15 HP DC motors controlled by an armature current feedback loop. Power is provided by a 3 phase silcon controlled rectifier power amplifier which shows definite nonlinearities around zero crossover. This loop is designed to have a -3 dB bandwidth of 8 Hz. A torque limit circuit is also provided for each motor. The original designer, H. Smith, found the nonlinearities of this power amp to be sufficiently small to use linear systems analysis techniques. These nonlinearities do, however, add a substantial complication to deriving the required mathematical formulas, particularly for the flow diagram blocks involving the amplifiers.

2. VELOCITY LOOP

The second loop is a simple velocity loop with a design -3 dB bandwidth of 1.5 Hz. The tachometers are mounted directly on the motor shafts before the transmission and are properly proportioned so that whey they are added to the velocity command a velocity error signal is developed. The compensation for this loop and for the current feedback loop is an integral part of the SCR firing circuits and again nonlinearities are involved.

There is also a minor loop called the differential velocity loop that is intended to prevent motor runaway if a wheel should slip or coupling break. In this loop the two tachometer voltages are subtracted and this differential velocity signal is fed back with opposite signs to the two motors. A motor bias voltage is also added at this point. This loop damps out resonances between the two motors.

3. POSITION LOOP

The building is slaved to the mount using a linear variable difference transformer (LVDT) which measures the relative mechanical position between the mount yoke and the building's steel structure. This loop includes a lead-lag compensation network and an integrater (shown in Figure 1) which are intended to bring the overall position loop up to a Type 2 system. The basic loop acceleration error constant (K_A) is designed to be 1.0 $(^\circ/S^2)/^\circ$. An acceleration limit and velocity limit are also provided in this loop along with an addition port for a mount velocity feed forward command which will be discussed in more detail under Recommendations For Improvement.

B. NAME PLATE DATA

A list of the name plate data from the components actually installed is provided in Table I. Several mechanical parameters important to the drive analysis are listed in Table II. This information was taken largely from the drawings but was checked to be sure that the measurements are "as built".

III. PERFORMANCE TESTS

The following tests of the performance of the building drive system were run on May 1 and 7, 1980. The primary test instrument was a Hewlett Packard 8 channel chart recorder connected to points in the building control rack, the mount drive control rack, and the Winfied Hill interface by means of RF59 coaxial cables. The specific test conditions will be described for each test. The settings of the chart recorder are given on each channel of the test data charts.

A. REPOSITION COMMAND

The building and mount drive were turned on and placed in the normal computer controlled mode. The acceleration constant for azimuth (ACON) was set at 10,000 which gives a maximum acceleration for the azimuth of $.115^\circ$ per $\sec^2$. A reposition command was given to the telescope to move from 200° to 165° in azimuth (see Figure 2). The system achieved an acceleration rate of $.109^\circ$ per $\sec^2$, which resulted in a building to telescope error of $.084^\circ$. This results in a measured loop acceleration error constant (K_A) of 1.3 $(^\circ/S^2)/^\circ$ to be compared with a calculated value of 1.0 $(^\circ/S^2)/^\circ$. These values are in reasonable agreement given the level of accuracy of the test. The chart recordings are shown in Figure 2. For this test the velocity feed forward signal was disconnected.

B. INCREMENTAL TRACK

With all drives on and in the normal operating mode, the telescope was given an acquire command requiring it to reposition 3° and go into incremental track (see Figure 3). This resulted in a tracking rate in azimuth of $.0225^\circ$ per sec and a tracking error between the building and mount of 3.4 arcsec peak-to-peak. The wind was light. This represents excellent tracking of the azimuth by the building and demonstrates the good performance of the building drive system.

C. SINUSOIDAL VELOCITY COMMAND

In this test, shown in Figure 4, a sinusoidal velocity command was injected into the building drive system at the point in Figure 1 labeled Mount Velocity Feed Forward. The building and mount drives were on and the mount had just been given a reposition command in azimuth. This leaves the telescope system in a configuration which tries to maintain the last given position. The velocity command was of sufficient amplitude to cause hard banging of the transmissions and therefore was sufficient to test both the frequency response of the entire closed loop system and the transfer of energy from the building to the telescope. The results (Figure 4) indicated a disturbance of the mount of an amplitude of 1.9 arcsec peak-to-peak at a frequency of .16 Hz when driven by a peak velocity command equivalent to $.3^{\circ}$ per second. There was also a second peak in the energy transfer at about .8 Hz with a disturbance amplitude of 1 arcsec peak-to-peak in telescope azimuth. Since this level of shaking of the building is quite high and would be experienced only in storm winds, this level of energy transfer is quite acceptable.

As to the frequency response of the position loop when driven by a velocity command signal, note that there is a small peak in the building-to-azimuth error signal at 0.16 Hz, a second at .82 Hz, and a third smaller one at approximately 1 Hz. Note also the nonlinearities in the building tach output at zero crossings.

D. VELOCITY LOOP RESPONSE

For this test the path of the velocity command coming from the position error integrater (See Figure 1) was open to allow the frequency