NATIONAL RADIO ASTRONOMY OBSERVATORY
VERY LARGE ARRAY PROGRAM
SOCORRO, NEW MEXICO

VLA TEST MEMORANDUM NO. 138

ANTENNA THERMAL INSULATION

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I. INTRODUCTION

The VLA antenna pointing specification calls for < 15 arcsec overall RMS pointing error under conditions of wind velocity up to 18 mph and temperature differences up to 5 degrees Farenheit between any structural parts. Routine pointing tests show that this specification is being met. However, as discussed by Sebastion von Hoerner in VLA Test Memorandum No. 129 of January 1981, the temperature difference criterion is unrealistic in that daily differences of > 5 degrees Centigrade occur on 95% of all clear calm days, with resulting RMS pointing errors of 40 arcsec and peak errors of an arcminute or more while the large temperature differences exist. This memorandum reports the results of an evaluation of thermal insulation as a means of preventing the occurrence of these large thermal differences.

II. INSULATION CONFIGURATION

In consideration of various thermal analyses and practical factors such as manpower and cost, the VLA Pointing Committee determined that the optimum insulation configuration for minimizing pointing errors due to thermal deformation would involve protection of the pedestal tubes and yoke with one inch thick polyurethane foam. Insulation of the large I-beams in the triangular base was considered. However, a test in which one of these I-beams was heated via electric heaters to 10 degrees Centigrade warmer than the other two showed negligible tilt deviation of the azimuth axis as a result of the thermal deformation of the triangular base. In view of this result and the fire hazard presented by combustible insulation near ground level, it was decided that the I-beams should not be insulated.

Insulation was installed on the pedestal tubes and yoke of Antenna 22 in June 1981. It and Antenna 6 (an uninsulated control antenna) were instrumented with temperature sensors (as shown in Figure 1) and gravity sensing tiltmeters (Figure 2) for use in tests designed to evaluate the performance of the insulation.

III. TEMPERATURE MEASUREMENTS

From VLA Test Memorandum No. 129 (based on thermal analyses performed by Lee King), the expected tilt deviation coefficients induced by thermal deformation are 3.6 arcsec per degree Centigrade for the tubes and 5 arcsec per degree Centigrade for the yoke. The placement of temperature sensors (Figure 1) was intended to provide temperature difference measurements which could be used to determine expected tilt deviations via these coefficients. The maximum temperature differences (and corresponding expected tilt deviations) observed in tests during the period July 1981 through March 1982 are shown in the following table:

	Max Delta T among Tubes [Deg Cent]	Expected Tilt Dev [arcsec]	Max Delta T Yoke Faces [Deg Cent]	Expected Tilt Dev [arcsec]	Worst Case Tilt Dev (Tubes+Yoke) [arcsec]
Antenna 6 (uninsulated)	8.2	29.5	5.7	28.5	58.0
Antenna 22 (insulated)	2.2	7.9	1.5	7.5	15.4

The insulation is clearly effective in reducing temperature differences sufficiently that expected peak tilt deviations are within the overall RMS error of the pointing specification.

IV. POINTING ERROR MEASUREMENTS

Several tests were conducted using subarrays of a few antennas (including antennas 6 and 22) to observe bright point sources with accurately known positions in the interferometer pointing mode. This observing mode allows calculation of pointing errors for each antenna. In one case, significant differences were observed between the pointing errors for Antenna 22 and those of the uninsulated antennas. These results are shown in Figure 3 as plots of elevation error for each antenna as a function of time. Antenna 22 clearly shows better performance than the two uninsulated antennas.

In an attempt to assess long term effects of the insulation on pointing performance, data from routinely conducted pointing tests which are used to establish and update pointing parameters were examined. The averaged results of four night tests and three day tests conducted during the period August 1981 through January 1982 are listed in the following table:

	RMS Pointing Error [arcsec]			
	NIGHT		DAY	
	AZ	EL	AZ	EL
Antenna 6 (uninsulated)	9.5	11.5	14.3	18.0
Antenna 22 (insulated)	10.3	11.3	11.3	11.7

The uninsulated antenna shows significantly larger RMS pointing errors during solar heating conditions, whereas the insulated antenna shows essentially the same performance both day and night.

V. TILT DEVIATION MEASUREMENTS

Several tests were conducted in which antennas 6 and 22 were parked at specified azimuth and elevation positions for 24 hour periods (or longer) in order to directly measure thermally induced tilt deviations via the tiltmeters. A number of events were observed in which large tilt deviations occurred in the uninsulated antenna, but did not occur in the insulated antenna. An example is shown in Figure 4. The 12 arcsec excursion shown for the uninsulated antenna was caused by thermal deformation due to post-sunrise solar heating of the inside face of the yoke arm on which the tilmeters are mounted. The corresponding data for the insulated antenna is noisier because of malfunctioning integrating electronics, but it clearly shows the absence of such an excursion.

Long term tilt deviation data had to be determined from tiltmeter measurements taken during periods of astronomical observing. This required determination of the unperturbed tilt of the azimuth axis and subtraction of its effects (as a function of antenna azimuth) on the tiltmeter data to obtain tilt deviations from this unperturbed tilt. Software was developed to do this, and all of the tiltmeter data from the months of November and December 1981 were analyzed. The results are shown in the form of a histogram in Figure 5. It shows that the uninsulated antenna had tilt deviations which exceed the overall RMS error of the pointing specification (15 arcsec) for 27.9% of the two-month period, as opposed to only 6.8% for the insulated antenna. It should be pointed out that tilt deviations due to effects other than thermal deformation (such as wind deformation) are also included in the histogram.

VI. CONCLUSIONS

It is concluded that the thermal insulation currently installed on Antenna 22 is effective in precluding thermal deformations which produce tilt deviations which exceed the antenna pointing specification. In view of the indication that tilt deviations which exceed the pointing specification exist in uninsulated antennas about a fourth of the time (at least in winter months), it is recommended that thermal insulation similar to that on Antenna 22 be installed on the remaining 27 VLA antennas. Testing should continue to determine the feasibility of providing additional pointing improvements by the use of active corrections from the electronic tiltmeters.

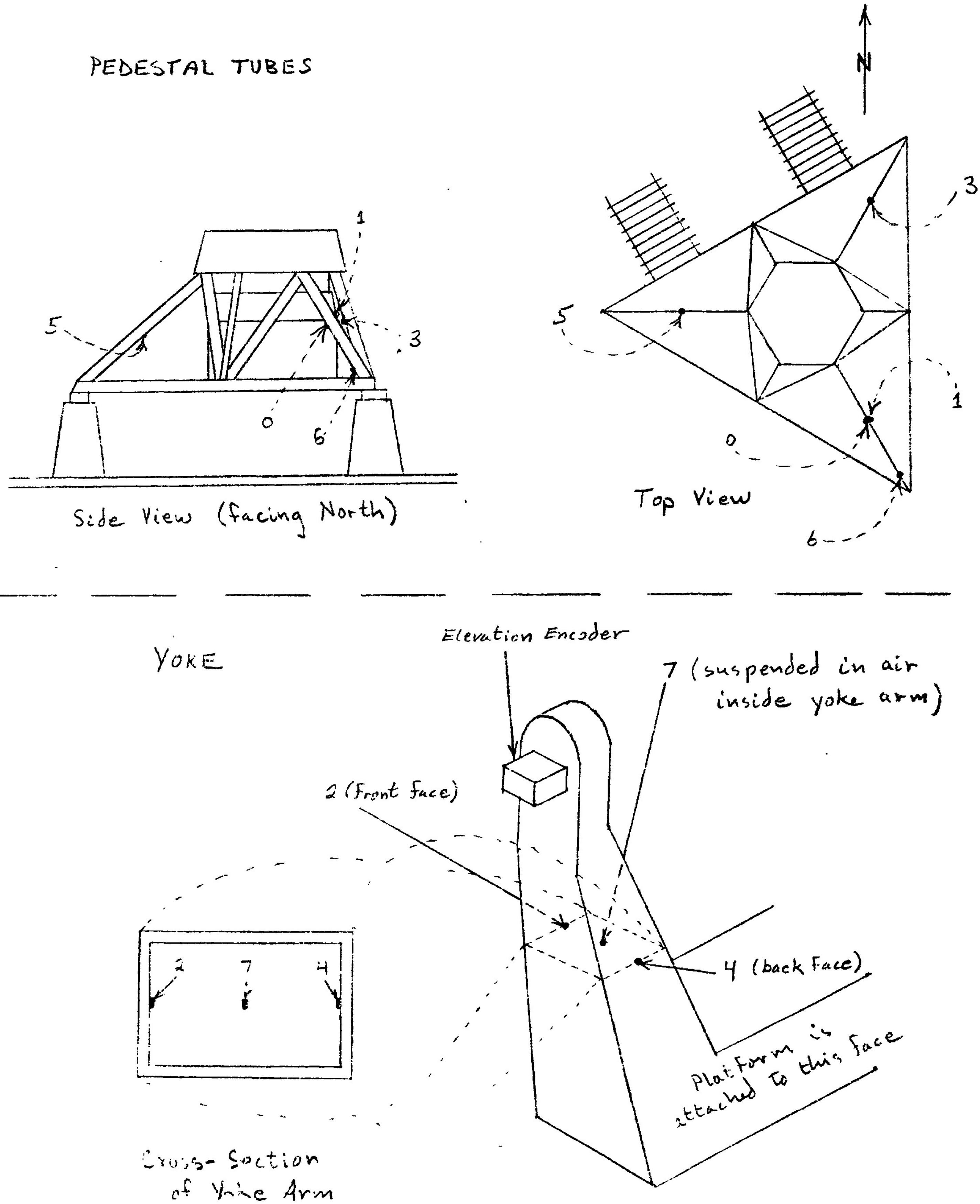
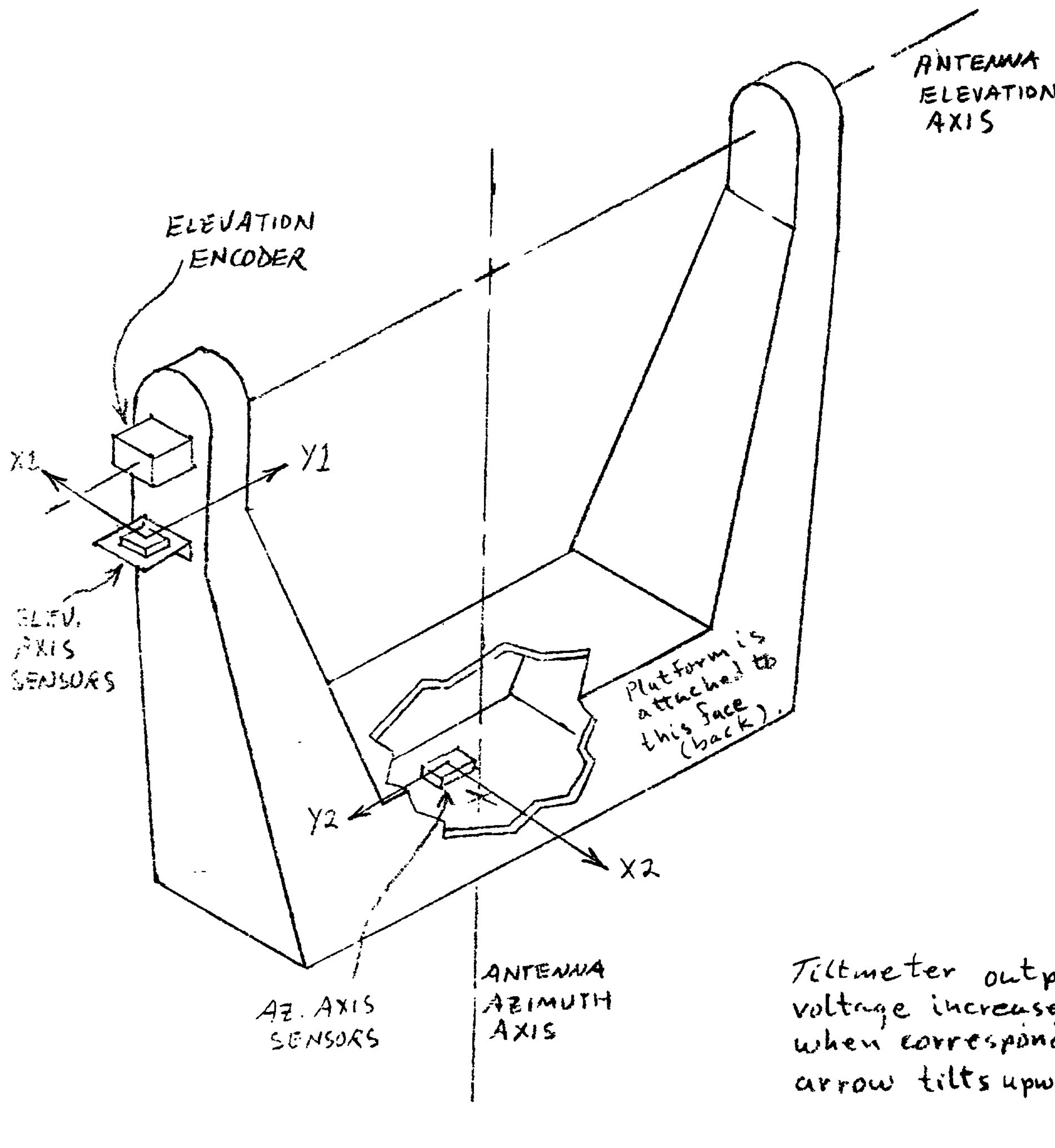


Figure 1. Antenna 3 and 12 Temperature Sensor Locations

TILTMETER MOUNTING LOCATIONS AND SENSING DIRECTIONS



Tiltmeter output voltage increases when corresponding arrow tilts upward.

Figure 2

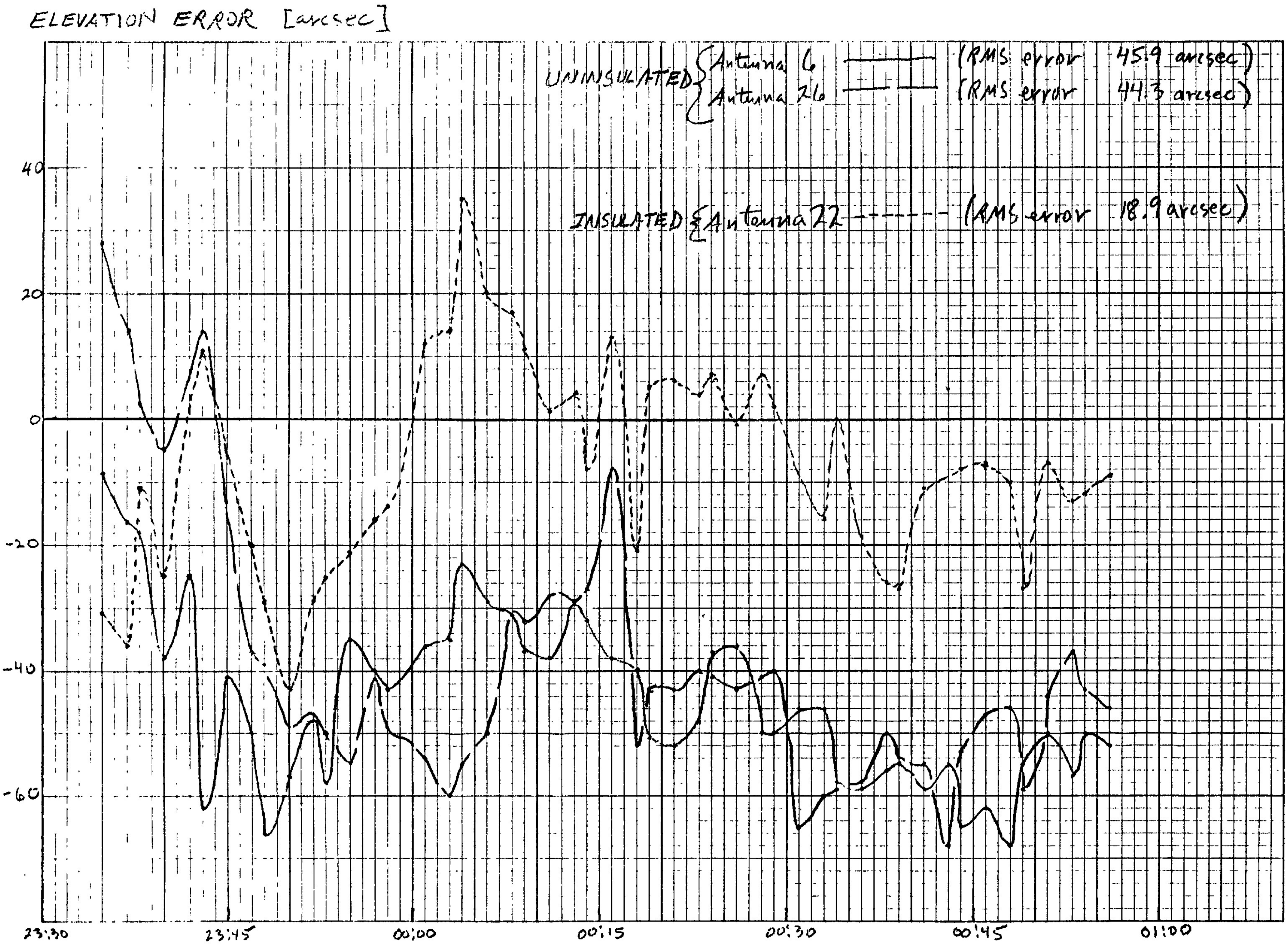

ELEVATION ERROR [arcsec]
UNINSULATED { Antenna 6 (RMS error 45.9 arcsec)
Antenna 26 (RMS error 44.3 arcsec)
INSULATED { Antenna 22 (RMS error 18.9 arcsec)
40
20
0
-20
-40
-60
23:30
81JUL24
23:45
00:00
81JUL25
00:15
00:30
00:45
01:00
IAT TIME

Figure 3

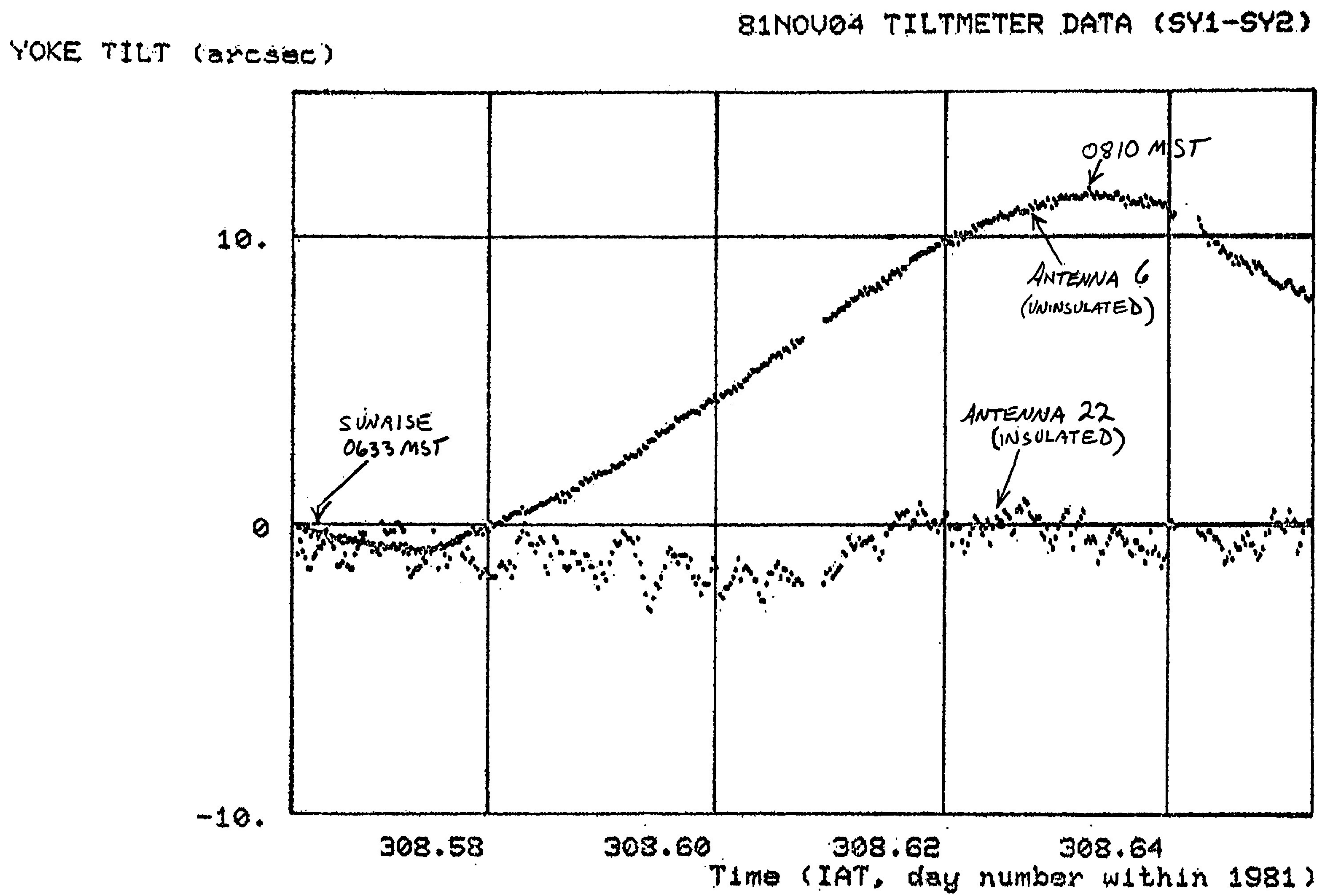

81NOV04 TILTMETER DATA (SY1-SY2)
YOKE TILT (arcsec)
10.
0
-10.
308.58
308.60
308.62
308.64
Time (IAT, day number within 1981)
0810 MST
ANTENNA 6
(UNINSULATED)
SUNRISE
0633 MST
ANTENNA 22
(INSULATED)

Figure 4

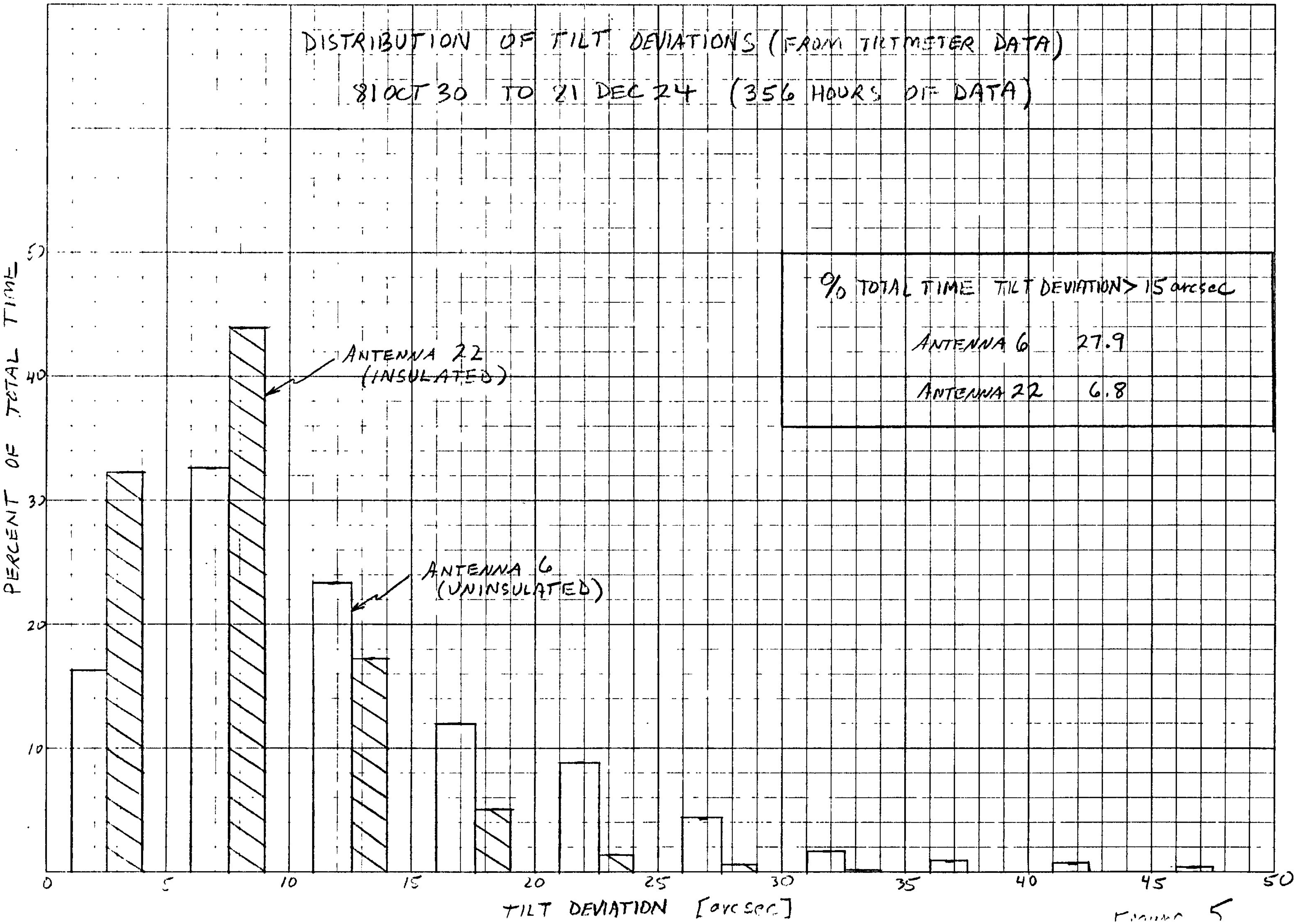

DISTRIBUTION OF TILT DEVIATIONS (FROM TILTMETER DATA)
81 OCT 30 TO 81 DEC 24 (356 HOURS OF DATA)
% TOTAL TIME TILT DEVIATION > 15 arcsec
ANTENNA 6 27.9
ANTENNA 22 6.8
ANTENNA 22 (INSULATED)
ANTENNA 6 (UNINSULATED)
PERCENT OF TOTAL TIME
TILT DEVIATION [arc sec]
0
5
10
15
20
25
30
35
40
45
50

Figure 5