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SPECIAL EVALUATION FOR PEDESTAL-LEVEL STABILITY OF HEIGHT-FINDE--ETC(U)
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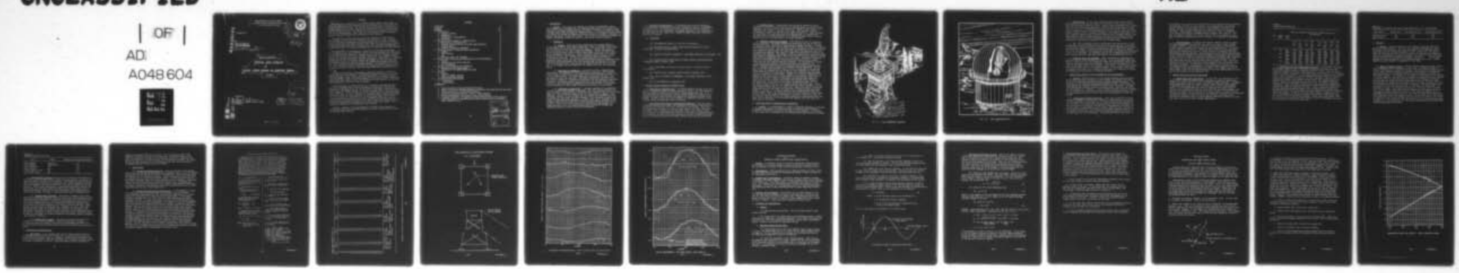

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DEPARTMENT OF THE AIR FORCE
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HILL AIR FORCE BASE, UTAH 84406

11 Feb 77

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SPECIAL EVALUATION for PEDESTAL - LEVEL STABILITY of HEIGHT - FINDER RADARS ON TEMPERATE TOWERS.

(77-05)

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SYNOPSIS

Pedestal-level stability of the AN/FPS-6 family height finder radars in ADCOM was investigated from September 1974 to February 1977 in connection with routine evaluation projects. The investigation was motivated by instability problems encountered at Z-96, Almaden AFS, California, during a routine height-finder evaluation project, and the data collected by the evaluation team were used in the investigation. Those data led the evaluation team to correctly conclude that solar heating was associated with the problem.

An instability problem had been previously observed at Z-129, MacDill AFB, Florida, in 1970, but was concluded to be caused by the tide. Because of this conclusion, measurements were subsequently taken to monitor possible shifts in the tower footings at several other radar sites rather than to detect solar-heating influences, and no problems with tower footings were detected at the other sites. No further investigations were made until the Z-96 incident.

During the 1974-77 investigation, pedestal-level instability problems were encountered only with temperate towers, which have exposed legs. Deviations of the pedestal plane exhibited a diurnal pattern that was strongly correlated with the sun, except at one site, Klamath, California. The information from Klamath was obtained separately from this study and is inconclusive. A plausible explanation for all the findings (neglecting Klamath) is that the tower legs are unequally exposed to the sun so that the unshaded legs expand more than the others, thereby shifting the antenna pedestal. This explanation fits well with the observations whereby deviations were greatest when the sun was high in the sky on clear, calm days, and excursions approached an angular value of 1 mil.

Effects of the shifts in the pedestal plane by as much as 1 mil are not significant from the standpoint of mechanical integrity; however, with a conventional height finder, height errors are produced as a function of target range and azimuth. When the antenna pedestal is not level, height errors vary sinusoidally with azimuth, and in the directions of peak effects, a 1 mil mis-level equates to a 1216 foot error at 200 NM.

Solar influences on pedestal level can be reduced by painting the tower legs with reflecting paint, thereby reducing the temperature differential between the legs directly in the sun and those in the shade. Another action can be taken, at minimal expense, to reduce the height errors that result from solar influences. It is the setting of the pedestal plane at an offset during nighttime so that the shift caused by the sun will produce a smaller deviation from level than if the starting point of the pedestal plane was at level. A more sophisticated solution to the solar problems and any other cause of pedestal-level instability is the use of a level sensor and circuitry for correcting the height data according to the output of the level sensor. This solution is employed for some European height finders.

Besides a summary of the investigation, this report also contains, as attachments, some rather detailed procedures of value to those who deal with the pedestal-level problem.

CONTENTS

1. Introduction:

a. Purpose. This report was prepared in response to ADCOM/KRLS tasking (see reference (7), paragraph 1d), and summarizes the results of a special study conducted to determine characteristics and causes of shifts in the pedestal plane of height-finder radar antennas on temperate towers. It provides sufficient information about the problem and feasible corrective action to be useful to managers of systems that employ height-finder radars. The report also documents procedures and general information of value to those who work in this field of interest.

b. Background:

(1) General. There are several reasons why the problem addressed in this report has not been widely recognized. First, the height errors caused by the problem vary with the time of day, amount of overcast that screens the sun, and location of the target (range and azimuth). Second, the magnitude of the resulting height errors seldom exceeds height errors from other causes, such as anomalies in refraction. Third, during the field phase of a routine evaluation project, only a single check is normally made for pedestal level of the radar/s involved. The check is commonly made during the daytime. Subsequent flight checks are also commonly accomplished during the daytime; hence, conditions affecting pedestal level are usually about the same for both times. Even if conditions differ, such as with one sunny day and the other a cloudy day, it is unlikely that the azimuth of the flights will fall in a worst-case sector.

(2) Experience at Almaden CA. In the fall of 1974 a height-finder evaluation of the AN/FPS-90 at Z-96, Almaden AFS, California, was terminated early because the pedestal did not remain within specifications for level (i.e., 0.4 mil, peak-to-peak). This instability may not have been noticed if only one check for level had been made. Additional measurements were made after the initial evidence of a problem was discovered, and the evaluation team noted a definite relationship between the deviations of the pedestal and the sun. This led to the investigation summarized in this paper to see if the problem occurred similarly at other radar stations and the nature of the problem.

(3) Experience at MacDill FL. A special evaluation of the AN/FPS-90 at Z-129, MacDill AFB, Florida, in November, 1970, was terminated before completion because of pedestal-level instability (see references (1) and (2) of paragraph 1d). The problem was studied, but the results did not suggest a solar influence; instead, it was concluded that the problem was caused by the tide disturbing the earth under the tower footings. This conclusion motivated the taking of tower-footing measurements at several other sites, including Z-117, Roanoke Rapids AFS, North Carolina, without finding evidence of shifts in the footings. There was no record found of an application of measurement techniques tailored to test for solar influence when the MacDill incident was researched during the current (1974-77) investigation.

c. Authority for Evaluation. The evaluation was verbally authorized to be conducted in conjunction with routine evaluation projects by ADCOM/KRLS in October, 1974. This authorization was confirmed and progress monitored in connection with the ADCOM/KRLS - 4754 RADES conferences. The authorization for this report is the January 1977, ADCOM/4754 RADES conference (reference para 1d (7) , below).

d. References:

(1) 4754 RADES EOI 100-12, 15 June 1972, Attachment 1.

(2) 4754/LOOAC Letter, Special Height-Finder Evaluation of Z-129, MacDill AFB, Florida, 29 December 1970.

(3) Item 30 of Minutes of ADC/DCES - 4754 RADES Conference, 4-6 February, 1975.

(4) 4754/DV Letter, Letter Report on Radar Pedestal Leveling Problem on Temperate Towers, October, 1974.

(5) 4754/DV Memo for Record, Milestone Report on Unstable Pedestal Level Problem.

(6) 4754/DV Letter, Pedestal Level Problem, 8 January, 1976.

(7) Item 8a of Minutes of ADCOM/KRLS - 4754 RADES Conference, 24-27 January, 1977.

(8) TO 31P3-2PFS6-165, paragraph 4-379.

2. Physical Factors Related to Pedestal Level:

a. Definition of Pedestal Level. An antenna pedestal is said to be level when the "horizontal plane of antenna rotation is level." The term "pedestal level" is simply shorthand for this exact, though cumbersome, term. It is understandable that the shorthand term was adopted because the pedestal is a physical structure which supports the bearing for horizontal rotation of the antenna. A shift in the tilt of the pedestal is transmitted directly to the bearing, thereby shifting the plane of rotation.

b. Pedestal Mislevel Effect on Antenna Beam Elevation. When the plane of antenna rotation is not level, the pointing of the antenna rises and falls, completing one sinusoidal cycle each revolution of the antenna. Along the axis of mislevel the effect is zero; at right angles to the axis, the effect is maximum. With a conventional height-finder radar, this produces height errors because the height-measuring elements of the radar are designed assuming level pedestal, but when the antenna pointing is shifted by pedestal mislevel, there is a difference between the assumed radiation path and the actual path.

c. Antenna Towers. Antenna pedestals are usually mounted on towers. Accordingly, tower motion is coupled to the antenna plane of rotation via the pedestal. Two types of towers are provided for AN/FPS-6 family radars, and extensions may be added to elevate either type. The temperate tower is illustrated in figure 2-1 and the arctic tower in figure 2-2. Further details are available in the applicable TOs (31P3-2FPS-125 and -5, respectively). An arctic tower is always provided for the AN/FPS-26 height finder, and this explains why it is not subjected to the solar influence.

d. Pedestal Instability Phenomena. Only static factors are considered in this paragraph. The dynamic factors are associated with the inertia and acceleration forces developed during elevation scanning (nodding). Virtually any movement of the tower affects pedestal level because the pedestal is attached to the top of the tower. The temperate tower is susceptable to more influences than the arctic tower because the supporting legs of the temperate tower and the antenna are exposed. Both types of towers are susceptable to settling and heaving of the footings. The temperate tower is placed on four concrete footings which cover 25 square feet each. The arctic tower is on three concrete footings (that affect the pedestal), 42 1/4 square feet each. Settling or heaving is usually a very gradual process unless caused by factors such as a nearby large tank that is filled and emptied frequently. If the settling or heaving is the same at each footing, the pedestal plane is not affected. An apparent pedestal problem can also be caused by cone bearing irregularities, such as excessive play and broken or malformed bearing components. In this type of problem, the horizontal plane of motion is affected by the bearing rather than the pedestal, and can obviously occur regardless of tower type. cone-bearing wear may be more rapid, however, with temperate-tower antennas because of exposure to wind loading. Because of its lack of protection, the temperate tower installation is susceptable to sun and wind. Loose bolts holding the structure together exacerbates the situation. Some temperate towers with 25 foot or greater extensions, particularly those located in hurricane areas, are fitted with guy wires for wind protection. The sun can disturb the pedestal level by unequally heating the tower legs. As the sun appears higher in the sky, the shadow from the cubicle shelter on top the tower extends further down on the shady side. Hence, the legs in the sun get warmer than those in the shade and expand more, thereby tilting the antenna pedestal. The side of the tower facing the sun is generally the high side of the pedestal plane. The temperate tower is also susceptable to some random effects, such as the weight of personnel on the tower. The arctic tower is not similarly affected because the antenna pedestal is supported by three legs which are not connected to the structure that supports the tower floor and other parts of the tower.

3. Detecting Causes of Pedestal-Level Instability:

a. General. An understanding of pedestal instability phenomena is utilized in designing strategies for detecting causes of pedestal-level instability. A complete investigation requires a strategy for each phenomena. A data-collection scheme can be employed that will simultaneously apply several strategies.

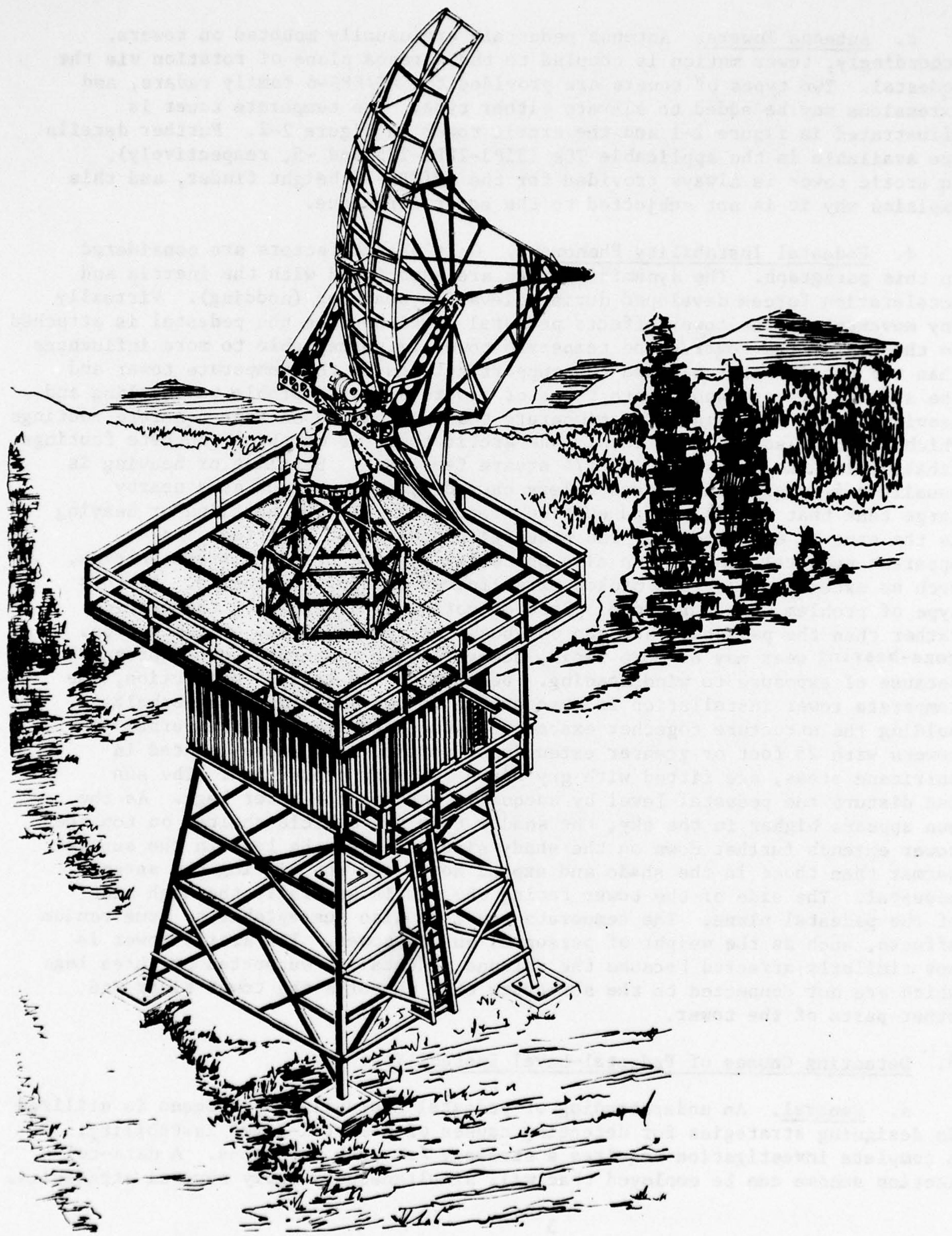


Fig. 2-1: *Tower AB-258/FPS-6 (Temperate)*

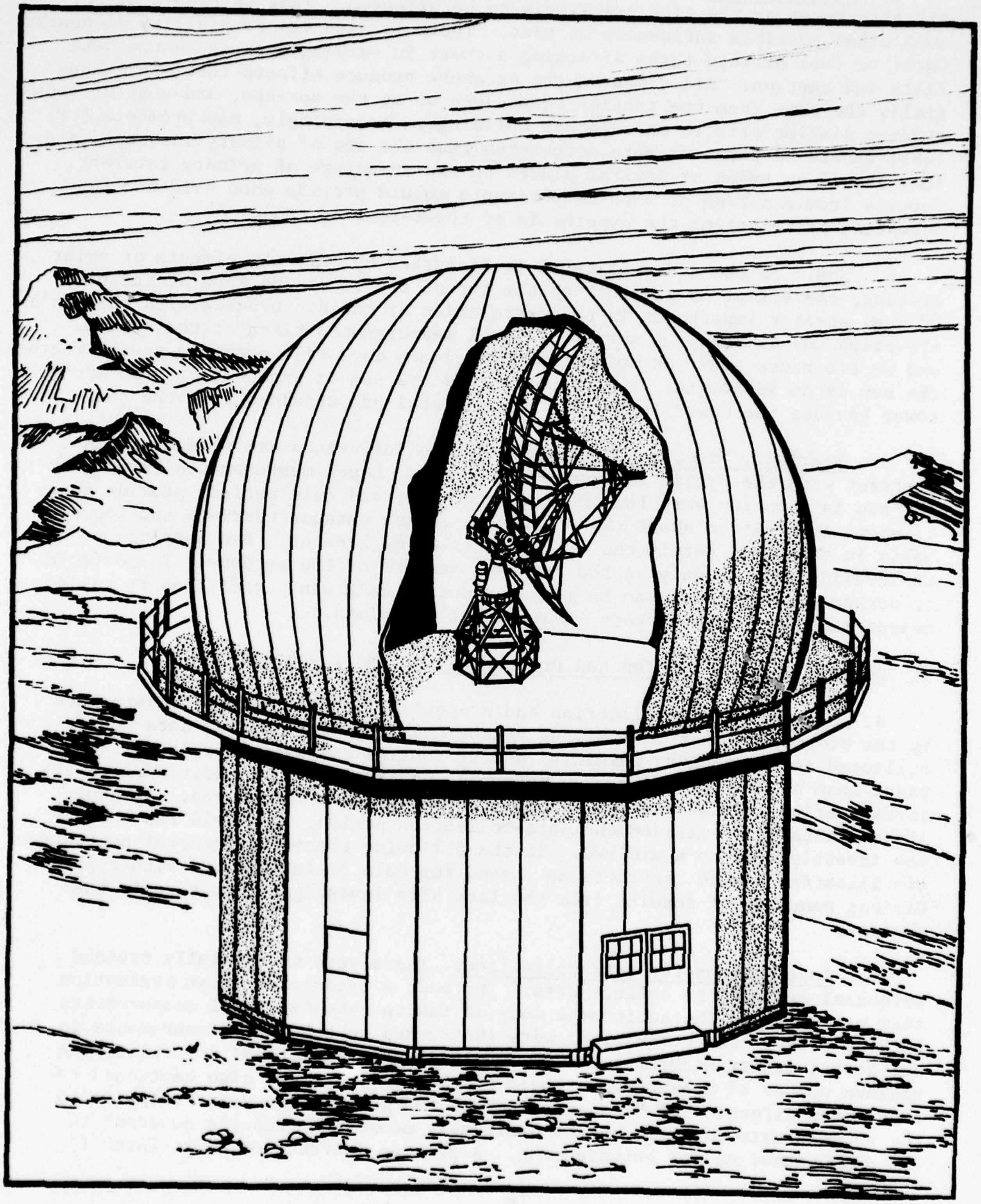


Fig. 2-2: *Tower AB-259/FPS-6 (Arctic)*

b. Tower Footing. If the tower footing is disturbed by earth tremors, all structures at the site are likely to be affected. This is also true for such other possible influences as tide. There is also the possibility of nearby water or fuel storage tanks affecting a tower in varying degrees as the tank fills and empties. All disturbances as above produce effects that are essentially the same from the footing themselves up to the antenna, and most of them produce similar effects on adjacent buildings. Accordingly, measurements for level should be taken at more structures than the one of primary interest, and they should be taken at several places on the structure of primary interest. Results from a series of such measurements should provide good evidence for accepting or rejecting the hypothesis of tower-footing cause.

c. Sun. If the pedestal level is disturbed by only the effects of solar heating, the effect is greatest at the top of the tower and zero at the base. Of even greater importance is the correlation of the disturbance with the sun's elevation and azimuth. A series of level measurements taken at the antenna one or two hours apart on both sunny and cloudy days will normally reveal whether the sun is an influence. No influence from the sun is expected with an arctic tower because the tower legs under the pedestal are shielded from the sun.

d. Bearings, Wind, and Personnel. These influences are irregular, in contrast with the cyclic influence of the sun. Level measurements taken when the sun is down (or very low) during both windy and calm periods provide quantitative information about these factors. Loose antenna bearings and loose bolts in the tower permit the wind effects to be greater. Bad bearings produce misleveling effects only at the rotating members of the antenna. The effects of workers on the tower can be measured during calm wind conditions by taking measurements with the workers in different positions.

4. General Data Collection and Processing for the Investigation:

a. General. Data collection and processing procedures were constrained by the scope and other limitations of the tasking. All general data were collected as opportunity permitted during routine evaluation projects. The radar must not be operating when measuring pedestal level. Additionally, the investigation was designed primarily to observe solar influences. Although these limitations extended the data-collection period, they held the cost of the investigation to a minimum. In the following treatment, general procedures are illustrated with instructions issued for data collection and with a sufficient sampling of results from the last site investigated to clarify the process.

b. Instructions for Data Collection. There were no specially trained personnel assigned to collect data. Instead, a technician on an evaluation team was assigned the additional duty of taking pedestal-level measurements for the study. The technicians were instructed to take the measurements in the normal manner according to EOI 100-12 if time permitted; otherwise, the minimum number of measurements could be taken. They were also cautioned to record the direction of "line-of-fire" of the gunner's quadrant relative to the antenna azimuth ring, and to preferably mount the gunner's quadrant in the same manner as for boresighting. A printed instruction sheet (Atch 1) was provided, but it was more concerned with data processing because technicians are generally qualified to take pedestal-level measurements in accordance with EOI 100-12. The data from a series of measurements consisted of the azimuth and value of each reading and the time that each set of readings was taken. Environmental conditions were also noted. This is illustrated by the Point Arena series of readings taken 2 February 1977, (Atch 2). Note that the gunner's quadrant can only be reliably read to the nearest 0.1 mil. Tower orientation information was also obtained, as illustrated in Attachment 3.

c. Data Processing. Evaluation team members commonly plotted the pedestal-level measurements for in-field use, such as to insure a level pedestal on flight azimuths. An example of a series of plots taken 2 February 1977, at Point Arena, California, is provided for illustration (Atch 4). Deviations clearly correlate with the sun. Additional data reduction was accomplished, with results illustrated in Atch 5, to fit the data to sinusoidal equations, affording more precise analysis. The mathematics of curve fitting are provided in the procedural standards for measuring antenna pedestal-shift characteristics (Atch 6), and the process was partially automated on the Monroe 1666 calculator, as noted in Atch 1. The raw data and fitted curves corresponded well with each other when mislevel values exceeded several tenths of a mil. The correspondence was not as good otherwise, because random effects predominate under near-level situations. Fitted curves are overlayed on raw data in Atch 5 to illustrate typical correspondence. From each equation the peak amplitude and azimuth of peak upslope amplitude are evident. For example, for the top curve (1200L, 1 Feb 77), the peak amplitude is 0.556 mil (peak-to-peak is 1.112 mil) and the azimuth of peak upslope is 194°.

5. Special Data Collection and Processing:

c a. Height-Error Data From Almaden. In late 1974, site personnel at Z-96 cooperated by collecting height-error information on targets of opportunity. Results were reported at the 4-6 Feb 75 ADCOM/4754 RADES conference. In summary, height measurements taken at random times and target azimuths were compared to estimated true height (per Mode C returns and D value) to obtain height errors. It was hypothesized that shifts in pedestal level would produce a pattern in the correlation of height errors with time and target azimuth. The data did not exhibit any pattern, as can be seen in table 5-1, and no further attempts were made to use this method of investigation. The results were considered inconclusive because of lack of control over the data collection process and lack of information about the environmental conditions (presence of clouds, fog, wind, etc.) at the time of height measurements.

TABLE 5-1
ALMADEN HEIGHT-ERROR DATA

Set	Range (NM)	Day Night	N 315° - 44° Avg	N Std Dev	E 45° - 134° Avg	E Std Dev	S 135° - 224° Avg	S Std Dev	W 225° - 315° Avg	W Std Dev
			Mean and Standard Deviation of Height Errors (ft) by Quadrants							
1	100	Day	-112	708	-196	775	-193	762	-516	818
		Night	-251	1036	-176	1420	+49	1020	-301	1258
	100	Day	-384	1718	-201	1123	+217	1338	-311	1257
		Night	+186	1569	+256	1456	-118	1259	-22	1315
2	100	Day	+150	481	-294	849	+250	502	-450	869
		Night	-300	844	-268	718	-133	710	-540	1024
	100	Day	-256	1577	-195	1052	-129	1087	-750	1322
		Night	-167	1251	+32	1271	-245	1272	-150	1462

b. Research of the 4754 RADES Height Data Bank. In late 1975, 4754 RADES/DO personnel suggested that a comparison be made between height-error data from AN/FPS-6 family radars on temperate and arctic towers. This was accomplished by computer processing, 28 November 1975, and reported at the following ADCOM/ 4754 RADES conference. It was hypothesized that inasmuch as the temperate tower is more susceptable to antenna pedestal instability that the evaluation flight results should be influenced. No effort was made to group data by azimuth; accordingly, only average absolute errors and standard deviation of signed errors are of significance (see table 5-2). The computer printout, however, listed all the normal statistics, but they revealed no significant differences. There are several reasons why a greater difference between data from the two types of towers did not exist. First, evaluation flights are normally conducted during the daytime, as are pedestal-level checks; hence, the pedestals had been leveled under conditions similar to those that prevailed during the flights. Second, even if there were pedestal deviations at the time of the flights, the flight azimuths would seldom be in directions where the effects of the deviations were maximum. Third, when large height errors were observed and a reason was found (such as an error in boresight correction) the data were not placed in the data bank.

TABLE 5-2
COMPARISON OF TEMPERATE AND ARCTIC TOWER HEIGHT DATA (175 - 220 NM RANGE)

Data Source	Sample Size	Avg Abs Error (ft)	Std Deviation (ft)
Temperate Towers	631	736	917
Arctic Towers	635	640	831

6. Analysis:

a. General. Data were analyzed to some degree as they were generated because of several reasons. The first was to promptly determine the nature and extent of deviations in case they could impact on the evaluation project coincident with the pedestal-measurements effort at each site. The second reason (a temporary one) was to reach a decision on upgrading the operational status of the AN/FPS-90 at Almaden, California, which was placed on red status upon encountering the pedestal-level problem. The third re[illegible] was to report progress on the investigation at each ADCOM/4754 RADES conference. A final analysis was made during the preparation of this paper.

b. Impact on Height Accuracy. Pedestal mislevel impact on height accuracy is of immediate concern, regardless of the cause. The geometric model is readily established for theoretical analysis. When the plane of antenna rotation is not level (although assumed to be level), the elevation of the beam axis moves up and down in a sinousoidal pattern from the assumed level plane, as the antenna rotates. For example, if the plane is tilted upward in the direction of south, targets to the south will be measured low (negative errors), targets to the north will be seen high (positive errors), and accuracy of targets to the east and west (along the axis of mislevel) will not be affected. From the calculus, the average error (without concern for sign) is found to be 0.637 of the maximum error from the peak value of mislevel. A one-mil angular error translates to a one mile vertical error at 1,000 miles (by definition). As the model is linear, the foregoing translates to a 1216 foot error at 200 NM (i.e., 1/5 of 6080). There were only two instances of spot-checks during the investigation which encountered as much as 1 mil mislevel; however, it is reasonable to conclude that as much as 1 mil mislevel could occur under worst-case conditions at most continental US sites. At the sites where a time series of measurements were taken, maximum values and the time of the year are listed in table 6-1. Note that these were taken in the fall or winter when worst-case conditions are not experienced, and the greatest deviations were obtained where the most measurements were taken.

TABLE 6-1
MAXIMUM DEVIATIONS FROM LEVEL

Site	Month	Deviation (mils) (peak-to-peak)
Z-96, Almaden	Sept-Oct	1.6
Z-33, Klamath	Sept-Oct-Nov	1.9
Z-39, San Pedro	Dec	1.0
Z-247, Phoenix	Oct	1.2
Z-196, Dauphin Island	Dec	1.3
Z-37, Point Arena	Feb	1.2

c. Cause-and-Effect Analysis. This part of the analysis was motivated by the desire to find feasible ways of taking corrective action. An analysis of this sort begins with tests for association. For example, deviations in pedestal level can be tested for an association with various possible influences such as earthquakes, settling of the earth, the tide (at coastal sites), the sun, etc. Early in the investigation, a pronounced association with the sun was evident, and this association was found in all results except those of Klamath, California, which are not fully acceptable. The association with the sun was analyzed in respect to amplitude and azimuth of pedestal shift.

(1) Pedestal-Shift Amplitude. Excursions of pedestal-level shifts beyond specifications allowance of 0.2 mil (or 0.4 mil, peak-to-peak) occurred only under sunny conditions with temperate towers when the sun was well above sunrise and sunset positions. The series of measurements plotted in Atch 4 is a typical example that shows the association of mislevel amplitude with local time of day (time translates to the sun's position in the sky). There was also an association of amplitude with cloudiness and wind. Even light clouds and winds reduce the incident solar radiation on the antenna tower and produce less effect on pedestal level, and heavy clouds completely prevent the effect. An example of light clouds and wind influences is shown in Atch 5 in which the amplitude can be seen to diminish on successive days as cloudiness and windiness increased.

(2) Pedestal-Shift Azimuth. The axis of mislevel was found to be associated with the sun's azimuth, as typically illustrated by Atch 4. In every case where an adequate time series of measurements was taken, the axis of mislevel rotated clockwise during the day in correlation with the sun's motion.

7. Conclusions and Implications:

a. Conclusions. It is concluded that the sun causes thermal distortion of temperate tower structures which varies with the position of the sun and with modifying conditions, such as cloudiness. Judging from measurements taken during the investigation, worst-case conditions may contribute to height errors by as much as 1200 feet at 200 NM. Under more nearly average conditions at midday, they approach 600 feet at 200 NM. If the pedestal is level under quiescent conditions (such as during nighttime), the daytime height errors tend to be negative for targets to the south and positive for targets to the north; for targets to the east and west, daytime effects are small. The influence of the sun increases as it rises higher in the sky, and the direction of maximum influence follows the sun in azimuth.

b. Implications:

(1) Minimizing Thermal Distortion. From the conclusion that thermal effects from the sun produce deviations in the pedestal plane, it can be inferred that protection from the sun will reduce the deviations. Full protection could be provided only at considerable expense. Partial protection could be provided by painting the tower legs with reflective paint. If this were done only at the normal repainting time, little extra expense would be incurred. A representative of the Air Force Materials Laboratory, Dayton, Ohio, recommended MIL C 83286 with white paint, saying that this system includes surface preparation and primer, producing a very durable finish, and the important factor in reflecting the sun is the color (white being best).

(2) Revising Pedestal-Level Specifications. TO 31P3-2FPS6-2-1 (Figure 1-4A) specifies that the pedestal must be level within 0.4 mil extremes. The investigation determined that this specification (regardless of how interpreted) is not realistic for temperate tower installations. It was common to measure extremes well over 1 mil, and worst-case conditions can produce extremes of 2 mils. It would be desirable to replace the pedestal-level specifications with something more reasonable. For example, if the solar influences were to be ignored, the specification should constrain the time for checking pedestal level to the period from one-half hour before sunset to one hour after sunrise. The need for height accuracy in the present weapon milieu should also be assessed. The specification should also be made more clear than the present. For example, the specification should be for an actual angular amount of mislevel, such as 0.2 mil (which would produce an excursion of 0.4 mil in a series of instrument readings taken throughout one rotation of the antenna). Potential benefits from another revision to pedestal-level specifications may be weighed against the cost involved. The revision provides for offsetting the quiescent pedestal level to partially compensate for the daytime solar effects. If done according to the procedure in attachment 7, the required physical effort is expected to be but slightly greater than for routine leveling. Once done, the two bubble-levels located at the pedestal base should be centered to provide a simple aid for maintaining the desired offset.

COLLECTING AND PROCESSING PEDESTAL-LEVEL DATA

By ADCOM direction, 4754 RADES continues data collection for the pedestal-level study. For several reasons, including tight money, data are collected during the field phase of evaluation projects at sites with height finders on temperate towers. This increases responsibilities of teams on some trips, and is not technically ideal; hence, steps were taken to minimize the extra burden. First, phoning from field to 4754th is encouraged to resolve problems. Second, fast methods of data collection and reduction may be used in lieu of the norm with measurements taken every 15° of azimuth. The fastest method needs three measurements taken 120° apart, and are phoned in (like boresight measurements) for Monroe 1666 processing. Field processing is also possible, but much easier if four measurements are taken 90° apart. A Monroe program is also available for four-measurement processing; examples of both hand and Monroe processing, using real data, are given below.

Hand Processing

1. List measurements with highest reading first and the others in clockwise order: 65.8 mils at 90°, 64.9, 64.7, and 65.2.

2. Calculate peak-to-peak mislevel:

$$\sqrt{(65.8-64.7)^2+(64.9-65.2)^2}$$

$$= \sqrt{1.3} = 1.14017 \text{ mils}$$

3. Calculate degrees (a) from highest reading to azimuth of peak-to-peak mislevel:

$$\tan a = \frac{64.a-65.2}{65.8-64.7} = -\frac{0.3}{1.1}$$

$\tan a = -0.2727272$, $a = -15.25511°$

4. Determine azimuth of peak-to-peak mislevel (Azp): Note, A2h is azimuth of highest reading.

$$Azp = A2h + a = 90° + (-15.2551)$$

$$= 74.74489°$$

NOTE: Make a sketch showing orientation of tower legs relative worth.

Monroe 1666 Processing

1. List measurements same as for hand processing.

2. Load program in machine. Print off, power switch on, thumb wheel to 5.

   a. Press "To", "0", "Load" keys.

   b. Run cards thru reader.

   c. Release "Load", press "To", "0", "Resume."

   d. Machine will print a number 1 on the tape and halt to indicate ready.

   e. Enter the azimuth of the highest measurement and press "Resume."

   f. Enter highest reading, "Resume", next reading in clockwise direction, "Resume", etc until all entered.

   g. Machine printouts answers for the set entered and halts after printing number 1, indicating ready for next set.

   h. The printout consists of the following, which is interpreted here for convenience.

1.	Machine is ready
90.00000 ·	azimuth of highest reading
65.80000 ·	highest reading
64.90000 ·	next clockwise reading (180°)
64.70000 ·	next clockwise reading (270°)
65.20000 ·	last reading (0°)
1.14017 A	peak-to-peak mislevel
15.25511 A	degrees from highest reading to where peak-to-peak occurs.
74.74488 A	azimuth where peak-to-peak occurs.
1.	ready for next set of data

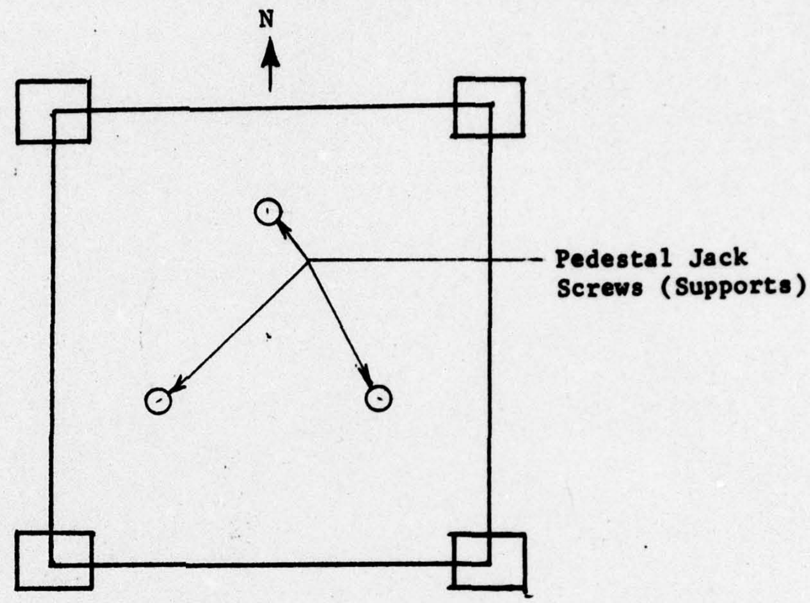
POINT ARENA VALUES (2 FEB 77)

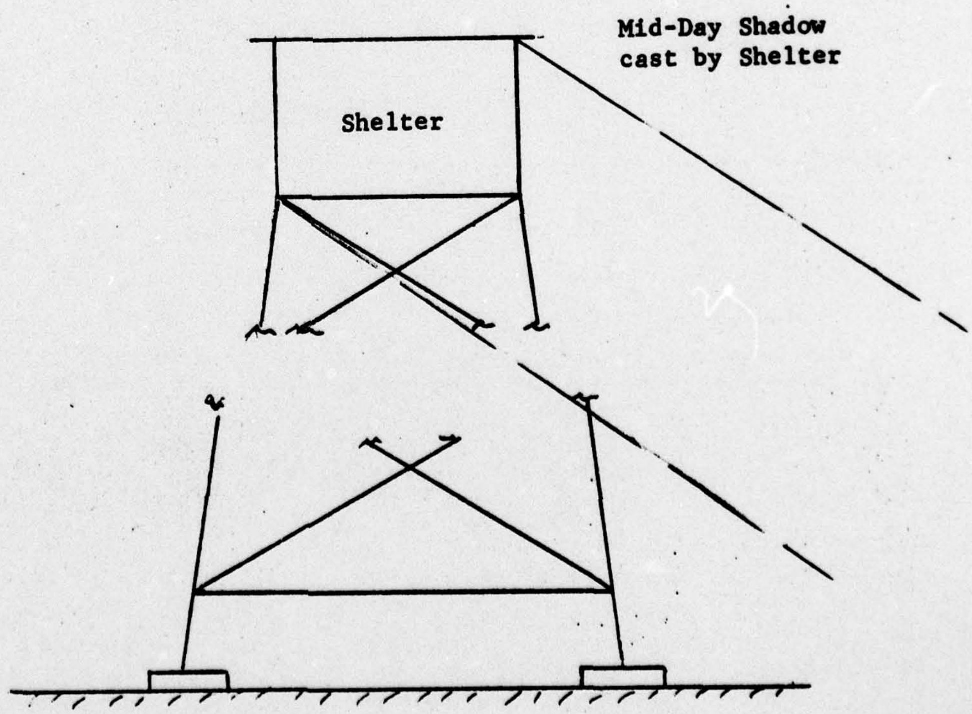
AZ	0630 L	0830 L	1000 L	1200 L	1400 L	1600 L	1800 L
0	3.7	3.8	4.0	1.6	2.1	4.1	4.2
15	3.7	3.8	4.0	1.6	2.1	4.0	4.1
30	3.7	3.8	4.0	1.6	2.0	4.0	4.1
45	3.7	3.8	4.1	1.7	2.0	3.9	4.1
60	3.7	3.9	4.1	1.7	2.0	3.9	4.1
75	3.7	3.9	4.3	1.8	2.0	3.9	4.1
90	3.7	3.9	4.4	2.0	1.9	3.9	4.0
105	3.7	4.0	4.4	2.1	2.0	3.9	3.9
120	3.6	3.8	4.6	2.2	2.0	3.9	3.9
135	3.5	3.8	4.6	2.3	2.0	3.9	3.9
150	3.5	3.8	4.6	2.3	2.1	4.0	3.9
165	3.5	3.8	4.5	2.3	2.1	4.1	3.9
180	3.5	3.8	4.5	2.4	2.3	4.1	3.9
195	3.6	3.8	4.5	2.3	2.3	4.2	3.9
210	3.6	3.7	4.4	2.3	2.4	4.3	4.0
225	3.7	3.7	4.2	2.3	2.4	4.3	4.0
240	3.7	3.7	4.2	2.2	2.4	4.4	4.1
255	3.8	3.8	4.1	2.1	2.4	4.5	4.1
270	3.8	3.7	4.0	2.0	2.4	4.5	4.2
285	3.8	3.7	4.0	1.8	2.4	4.5	4.2
300	3.8	3.7	3.8	1.8	2.3	4.5	4.2
315	3.8	3.7	3.8	1.7	2.3	4.5	4.2
330	3.8	3.8	3.8	1.6	2.2	4.4	4.2
345	3.8	3.8	3.8	1.6	2.1	4.3	4.2
	Clear (before sun comes up) 46° Temp Cool Breeze	51° Sun 50° Shade Clear Slight breeze from East	64° Sun 59° Shade Clear Slight breeze from East	64° Sun 60° Shade Partial Cloudy Slight Breeze West	55° Sun 55° Shade Cloudy Wind from West 10-15k	52° Sun 52° Shade Cloudy & Foggy Slight wind from West Sun on Occassion	48° "Dusk" Wind from West 10-15k (app)

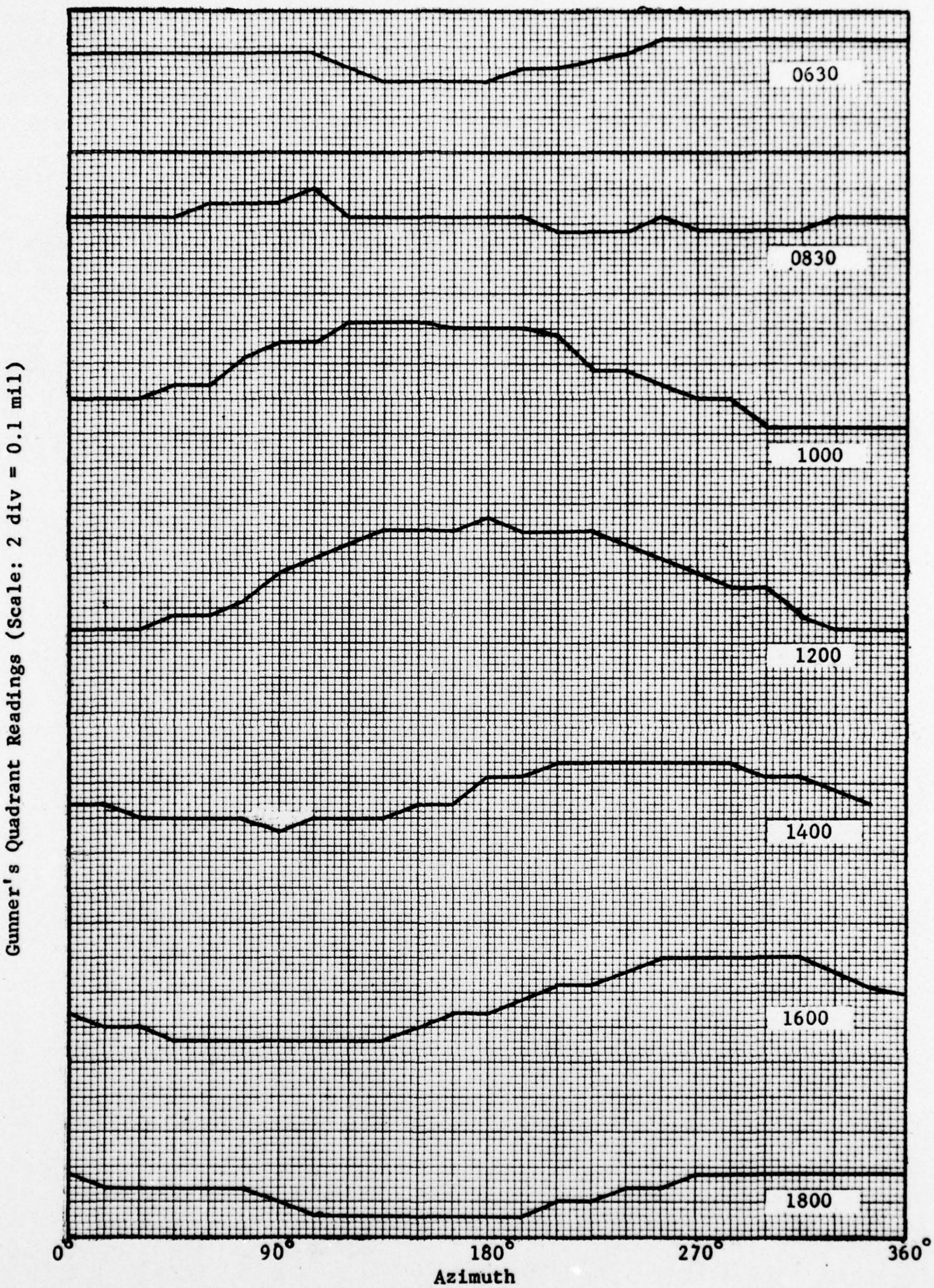
Example of Gunner's Quadrant Readings (mils) and Weather Data Reported from the Field.

TOWER ORIENTATION & LEVEL-READING STATIONS

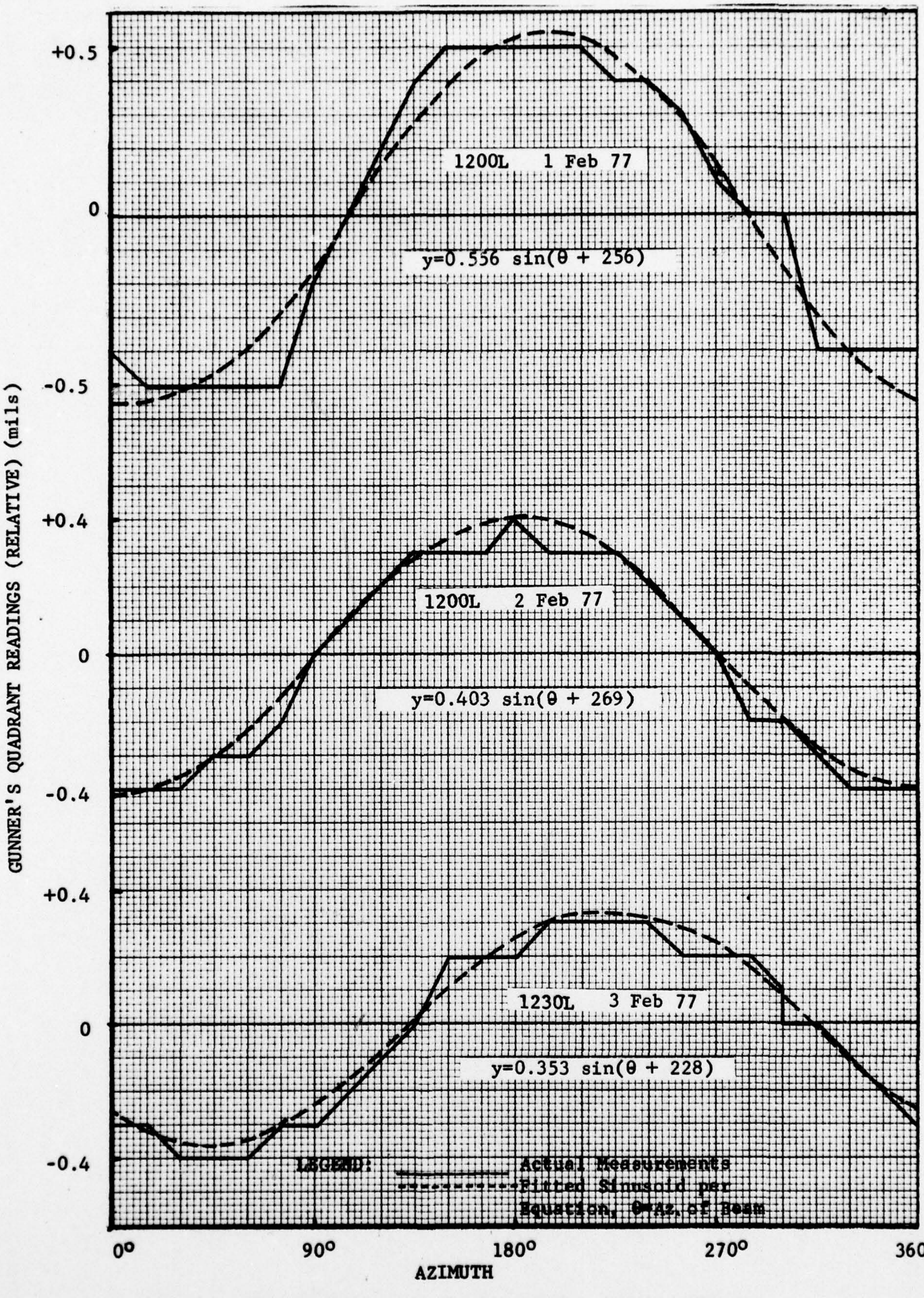
Site Point Arena







Azimuthal Plane Measurements, 2 Feb 77, Point Arena CA (local time)



MID-DAY MEASUREMENTS, AND FITTED CURVES, POINT ARENA CA

PROCEDURAL STANDARDS
for
MEASURING ANTENNA PEDESTAL-SHIFT CHARACTERISTICS

1. Purpose. To determine values of variables (measurable characteristics) and to identify attributes (general pattern and nature of pedestal shift). This information is needed to make valid decisions about corrective action.

2. Applicability. These procedures will be employed during the field phase of each height-finder evaluation (beginning and ending on dates specified in the implementing directive).

3. Minimum Sets of Measurements. Clinometer (gunner's quadrant) readings (hereafter, instrument readings) taken during a pedestal-level check constitute a measurement set. The entire action of a pedestal-level check is an observation. As a minimum, four observations will be taken each day for at least three days. The initial set of measurements will be a long-form observation. The remaining eleven or more observations may be either long form or short form.

4. Schedule for Measurements. Observations will be taken during not less than two days prior to making the antenna boresight-error correction, and not less than three days prior to flight tests. Observations will be made before and after each block of flight test time (commonly one block of time per day of flights). These tests will normally be of short form.

5. Procedures for Observations:

a. General:

(1) Observe safety precautions. Use tower safety switch. Move antenna by hand.

(2) Record start and ending time of the observation period. Observe environmental conditions, to include temperature in the shade, wind speed and direction, sky cover (for daytime observations), and any other influencing factor. Obtain a tide table for sites near the sea.

b. Long-Form Pedestal-Level Check:

(1) Assign identities to the three pedestal support legs relative to north. The northernmost leg is A; B and C are the legs clockwise from A, is sequence. Use the azimuth ring to estimate the pointing directions of the legs from an imaginary center of the pedestal.

(2) Mount the clinometer if not already mounted. Make sure the instrument is not distorted by the clamp. Record the line of fire direction of the instrument relative to the azimuth ring. In mounting the instrument, make sure it is mounted so that both plus and minus readings can be taken through a reasonable range.

(3) Rotate the antenna so the line of fire is at some multiple of 15° (normally, 0°). Record the instrument reading.

(4) Move the antenna in 15° steps and take readings at each step until the starting azimuth is reached. This will provide two readings at the start/end azimuth and one reading at each intervening azimuth.

(5) Compare the first and last readings. If they differ by more than 0.1 mil, check for causes and record findings. Possible causes are insecure clamping of the instrument, cone bearing play, tower sway from wind, etc.

(6) Determine the equation parameters of pedestal mislevel. This can be done locally or by phoning the instrument readings to 4754 RADES/RNTS where the Monroe 1666 calculator is employed with the Pedestal-Level Program.

(7) A rough estimate of the pedestal mislevel equation is made by plotting the instrument readings (mils) on the vertical axis of a graph and azimuth on the horizontal axis. Sketch a sine curve through the plotted points. Use the graph to obtain values for the parameters in the equation.

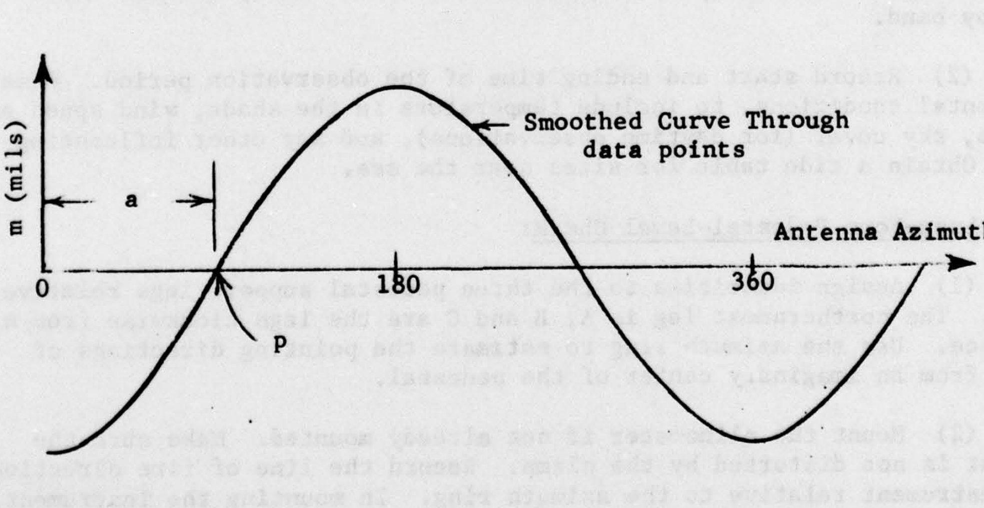
$$y = m \sin(b+a) \qquad (1)$$

where: y is the mislevel value in the direction of b.

m is the mislevel slope at maximum.

a is the correction required to relate the sine curve to the azimuth ring.

The use of the graph is illustrated in the figure below.



Illustrative Graph of Pedestal Mislevel Data

c. <u>Short-Form Pedestal-Level Check</u>. This is the same as the long form except readings are taken every 90° instead of every 15°. Where time is extremely critical and the readings can be phoned into the squadron, only three readings are required, at 120° intervals (preferably on the same azimuths as the legs). There are also differences from the long-form method in determining the parameters of the mislevel equation. Only the four-reading procedure is sufficiently simple for in-field application, and is as follows. In-field solutions are not required if the readings can be phoned into the 4754 RADES.

(1) Group the four readings into two groups. The pair in each group are from azimuths 180° apart. With each pair, subtract the smaller value from the larger to obtain the difference. Call one difference A and the other B, keeping track of the axis of each. Use A and B in equation (2) to solve for "m".

$$m = 1/2 \sqrt{A^2 + B^2} \qquad (2)$$

(2) Solve for "a" in the following steps.

(a) $$\tan d = \frac{e}{f} \qquad (3)$$

Where e is the smaller of the two highest of the four readings less the average of the four, and f is the larger of the two highest readings less the average of the four.

(b) From "d", find "a".

$$a = \pm d + 90° \qquad (4)$$

EXAMPLE: Assume readings at 0°, 90°, 180°, and 270° were 65.2, 65.8, 64.9, and 64.7, mils respectively. Solutions for "m" and "a" are:

$$A = 65.2 - 64.9 = 0.3, \; B = 65.8 - 64.7 = 1.1 \text{ mils}$$

$$m = 1/2 \sqrt{(0.3)^2 + (1.1)^2} = 1/2 \sqrt{1.3} = 1.14 \text{ mils}$$

$$d = \arctan \frac{65.2 - 65.15}{65.8 - 65.15} = \arctan \frac{0.05}{0.65} = 4.4°$$

$$a = + 4.4° + 90° = 94.4°$$

The assignment of a plus or minus to d is by inspection. If the larger of the two highest readings is nearest to the next larger reading by moving clockwise, assign the minus sign. Assign a plus for the opposite situation. Results can be checked by drawing a graph to find point "p" in the previous sine-curve diagram.

6. <u>Isolating Causes for Level Shifts</u>. Observations are analyzed for symptoms which are produced by the various causes of level shift. Solar heating of the tower tends to expand (and raise) the south side more than the north. Hence, arctic towers are not subject to this factor because the structure is shielded from the sun. Wind deflection is also limited to temperate towers, and symptoms therefrom correlate with gusts and wind direction. Distributed underfooting movement, such as caused by tides, usually affect all structures located fairly close together. But simple settling of footings do not produce periodic symptoms, and settling is usually different even with nearby structures. Also, level shifts not caused by solar heating will continue to occur during nights and periods of heavy overcast. The following checklist is useful for isolating causes of level shifts.

a. Check results from level-shift measurements (pedestal level checks) for a periodic change in mislevel axis and magnitude.

b. If level shift is periodic, compare the time period with the apparent travel of the sun. If the period does not correlate with the sun, test for correlation with other local factors as applicable, such as the tide, filling and emptying water of tanks, etc.

c. If the level shift is periodic with correlation with the tide or other general influence, make additional level-shift measurements on two or more towers at the site. A general influence will usually produce similar shifts from level on all towers at the site.

d. If the level shift appears *random and* can't be reasonably associated with wind, and other towers on the site are not similarly effected, a settling of the footings can be suspected.

e. List the symptoms exhibited by the level shifts, draw a conclusion from the symptoms, and describe the reasoning that led to the conclusion.

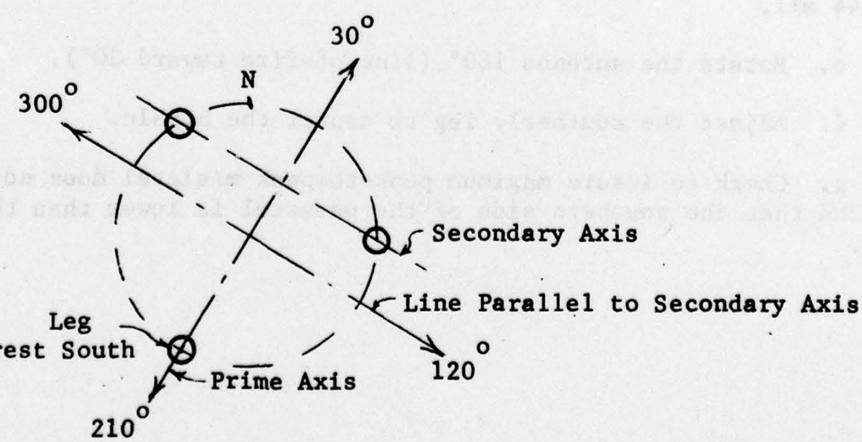
SIMPLIFIED METHOD
of
COMPENSATING FOR SOLAR PRODUCED SHIFTS
in
AN/FPS-6 FAMILY PEDESTAL LEVEL

Unequal expansion of temperate tower structural members on sunny days causes shifts in antenna pedestal level. By applying compensation, the length of time and the maximum amount that the level is out of specifications can be significantly decreased. This approach for holding pedestal level within specifications is attractive because there is virtually no cost involved, and the method described in this paper is almost as simple as for normal leveling.

Compensation consists of misleveling the antenna so the pedestal plane slopes to the south during darkness or near-darkness. Then, during the day, solar heating lifts the southern side of the plane. Most of the night-to-day excursions remain within specifications for level (i.e. 0.4 mil, peak-to-peak). A graph is provided for determining the amount of mislevel needed according to the locations of the three pedestal jack screws (legs). Adjustments for the needed amount of mislevel are made in a manner much like the leveling adjustments described in TO 31P3-2PFS6-165, paragraphs 4-92, 93, and 4-379. The following steps are taken.

1. Determine the location (azimuth) of the leg nearest south. It only needs to be within a few degrees. This is the prime axis.

2. Compute the azimuth of the secondary axis by adding 90° to the prime-axis azimuth. Note: these two directions and their reciprocals are used for the Gunner's Quadrant (or other inclinometer) when adjusting the jack screws (legs) for mislevel. EXAMPLE: In the figure, the southern-most leg is located at 210°, and its reciprocal is 30°. This identifies the prime axis. The secondary axis lies across the other two legs, and does not pass through the center of rotation like the prime axis.



3. Determine the peak-to-peak mislevel values for the two axes. If the southern-most leg is between 156° and 204°, only the prime axis is misleveled, and the value is 0.4 mil (CAUTION: do not exceed 0.4 mil). When the southern-most leg is outside the above use the attached graph to obtain the values. In rounding the values from the graph, round down. EXAMPLE: The graph reads slightly more than 0.34 mil for a prime axis pointing of 210°. Round to 0.34 mil. The value found on the graph for the secondary axis is 0.2 mil.

4. Adjust the screw jacks (legs) according to the mislevel values. The following terms apply to a Gunner's Quadrant. Clamp the Gunner's Quadrant in place (without placing a strain on the instrument). Rotate the antenna so the "line-of-fire" of the instrument is the westerly direction of the secondary axis. Center the bubble and record the setting. Adjust the instrument by adding the mislevel value for the secondary axis if the direction is greater than 270°. Otherwise, subtract it. Rotate the antenna 180° and adjust one of the two legs on the secondary axis to center the bubble. Next, adjust the prime axis. Rotate the antenna so the line of fire is along the prime axis (southerly). Center the bubble and record the setting. Adjust to a new setting, as above by adding the mislevel value for the prime axis. Rotate the antenna 180° and adjust the leg on the prime axis to center the bubble. Check to insure peak-to-peak mislevel is within tolerance (0.4 mil, maximum). EXAMPLE: Assume the same situation as given in the previous example.

a. With the line-of-fire pointing in the direction of 300°, assume the instrument reads 173.2 mils with the bubble centered. Add 0.2 mils to the setting (by turning the thimble).

b. Rotate antenna 180° (line-of-fire toward 120°).

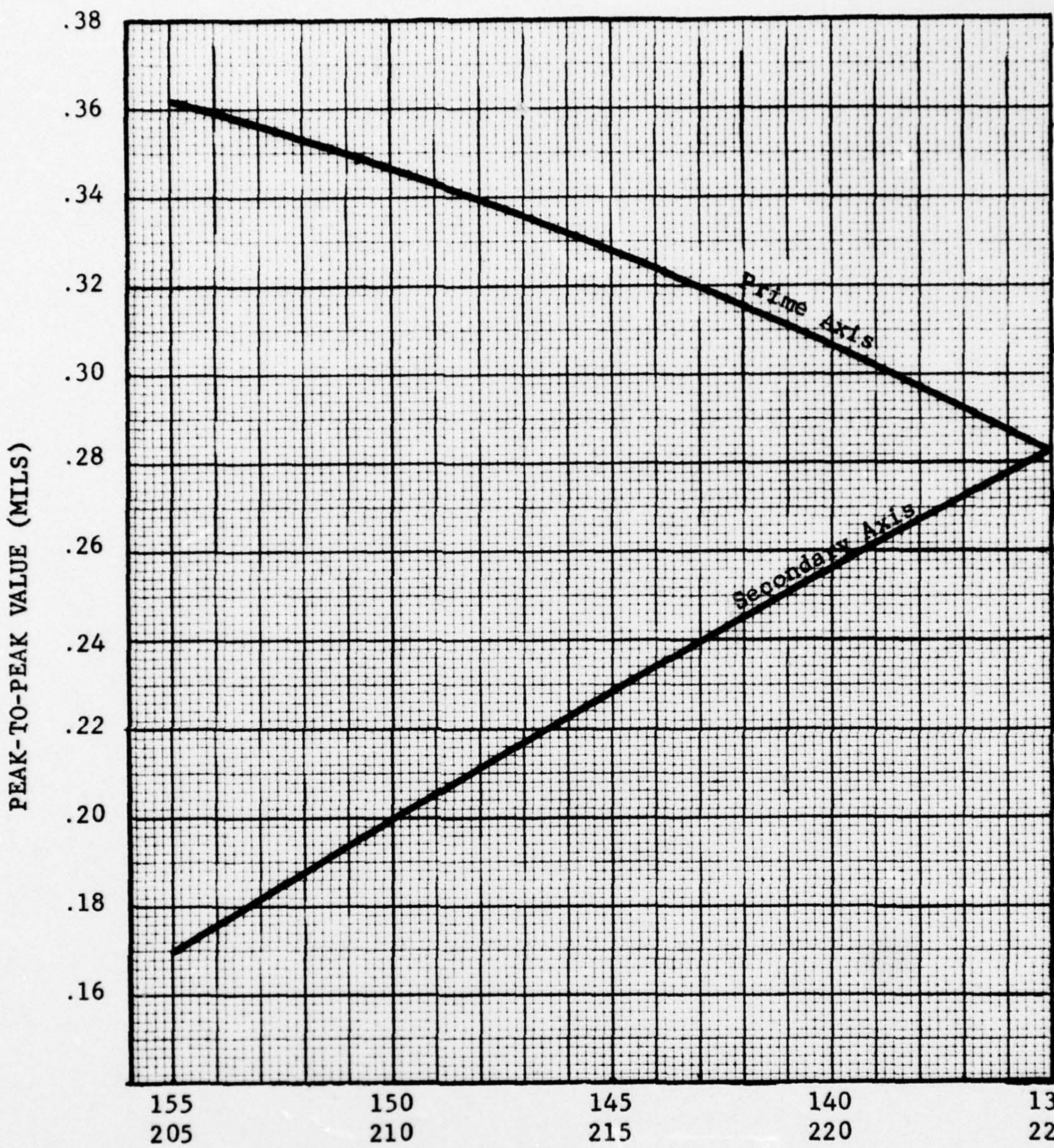
c. Adjust either the westerly leg or the easterly leg to center the bubble.

d. Rotate the antenna so the line-of-fire is toward 210°. Center the bubble and record the reading (assume it is 173.1 mil). Add 0.34 mil, giving 173.44 mil.

e. Rotate the antenna 180° (line-of-fire toward 30°).

f. Adjust the southerly leg to center the bubble.

g. Check to insure maximum peak-to-peak mislevel does not exceed 0.4 mil and that the southern side of the pedestal is lower than the northern side.



COMPENSATING VALUES FOR AN/FPS-6 - FAMILY PEDESTAL MISLEVEL