

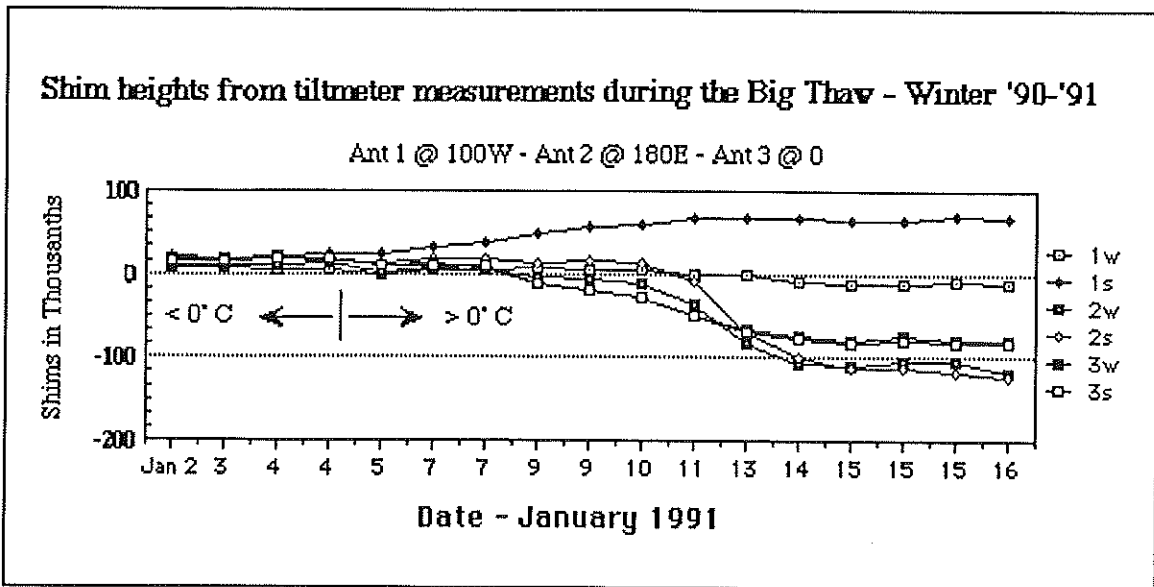
#5.

Tilt, Pointing & Baseline Variations at Hat Creek

JRF 2-Feb 91

SUMMARY This note discusses the large tilts observed with the Hat Creek telescopes during the winter of 1990-91, and describes an attempt to determine whether the cause is in the ground or the antenna structure. Theodolite measurements made during settled weather in February showed that tilts on the ground vary by ~15", comparable to tilts measured at the azimuth axis. However, no good correlation exists between the ground and azimuth axis tilts so it can only be concluded that both the ground and the telescope mounts tilt by ~15" under normal conditions. Tiltmeter measurements taken over four weeks in February show that normal tilts are correlated with ambient temperature and not sun direction. Antenna moves are characterized by a "settling-in" tilt of order 30" which occurs within 24 hours after shimming, and is followed by temperature-dependent variations of order 15". These time-variable tilts can account for the 0.5 arcmin pointing and 1-2 radian baseline instabilities present in Hat Creek interferometer data.

Tilts of order 5 arcmin were observed on all three antennas at Hat Creek during late Dec 1990 - early Jan 1991, causing substantial pointing and baseline changes. All three antennas were located on the EW track at the time: 100W, 180E and 0 (the T) for Ants 1, 2 and 3 respectively. When moved to these stations on 27 December the following shims were put in the W and S legs: #1(0, -30); #2(150, 165); #3(188, 126) - shim heights are in thousandths of an inch. Normally the required shims are between 20 and 90 thou. Ant 1 was located at station 240W before the move to 100W. At 240W Ant 1 tilted so that shims of (165, 50) were required by late December.



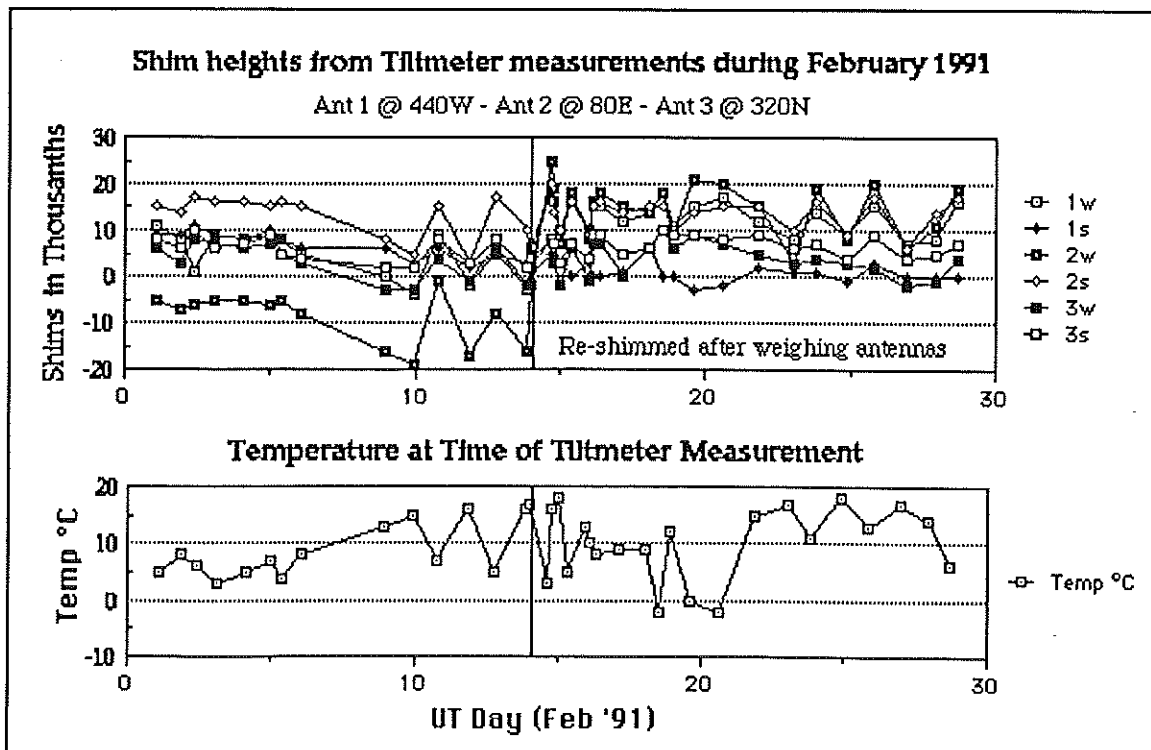
The above figure shows the shim heights derived for the W and S legs from tiltmeter measurements during the first half of January. Air temperatures during November and December had been below



freezing; after 5 January the daytime temperatures were mostly above freezing. By 15 Jan. the shim heights for Ants 2 & 3 stabilized at about -100 thou for the W and S legs, and Ant 1 at +70 thou for the S leg. Note that a shim of 100 thou translates the phase center by up to 5 mm and causes a pointing shift of about 2.5 arcmin. There is a good correlation between the W & S shims for Ants 2 & 3, indicating that either the N (reference) leg is changing or both the W and S legs are changing together. There is little correlation for Ant 1 - the plot suggests that in this case the S leg is varying.

It seems reasonable to suppose that the abnormally large shims required in December were due to either ground or structural distortions caused by extremely low temperatures in November and December. During the warming trend in January things thawed out or relaxed and the large shims were no longer required.

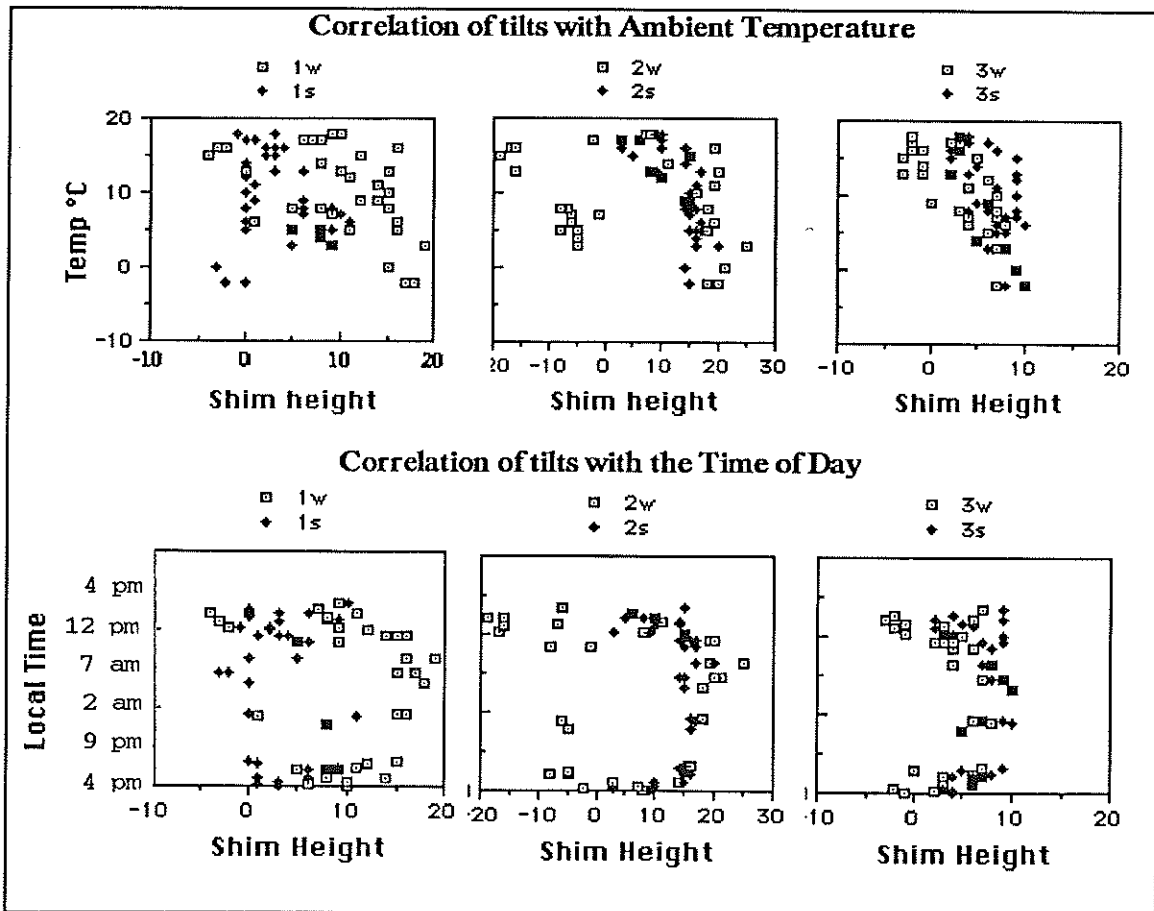
Two rapid configuration changes followed this episode, allowing little chance for stability monitoring. No configuration changes occurred in February however, owing to OSHA restrictions. Frequent tilt measurements were made during this period in an attempt to characterize the behavior of the antenna/station pairs in the A2.5 array (440W, 80E, 430N). The tiltmeter results are shown below, along with a record of the air temperature.



At the beginning of Feb shims of up to 20 thou were required for Ant 2 even though it was leveled to within 5 thou after the move on 30 Jan. On 13 Feb Ants 1 & 2 were re-shimmed after being weighed (OSHA), and within 16 hours these antennas had tilted so that about 20 thou shims were again required. Although difficult to see in the plot, Ant 3 remained vertical to within 10 thou throughout February.



After initial "settling-in" tilts for Ants 1 & 2 of ~20 thou, temporal variations up to 10 thou were seen for Ants 1 & 3, and up to 20 thou for Ant 2. The estimated maximum error in the tiltmeter results is ~5 thou, so these results are significant. An apparent correlation with air temperature is evident by comparing the shim and temperature plots, suggesting that either ambient temperature or direct solar heating effects may be important.

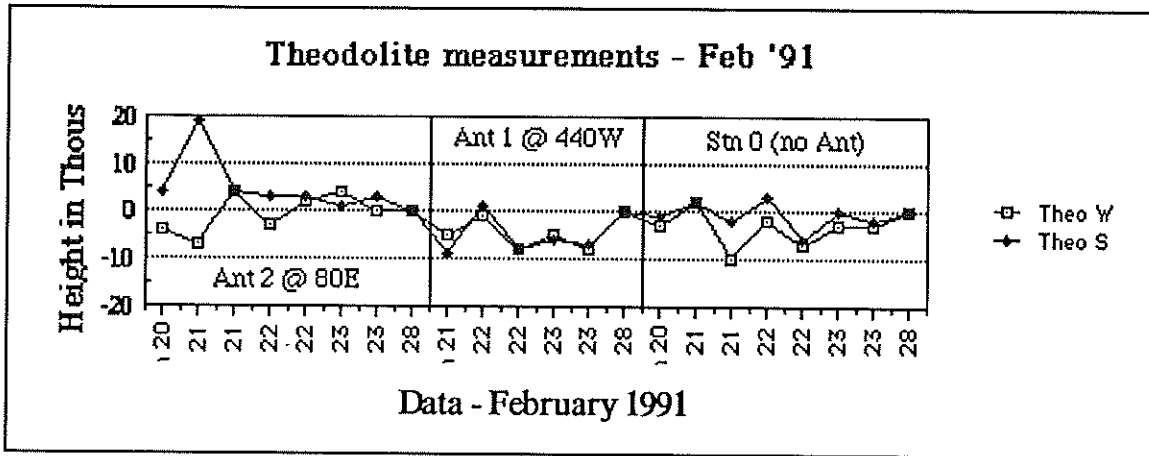


The above plots show scatter diagrams of the tiltmeter results versus air temperature and local time. Unfortunately they are somewhat confused by the re-shimming on 13 Feb, but a correlation is apparent between shim height and ambient temperature. A correlation with local time (*ie.* sun direction - which could cause differential heating of the antenna legs) is not apparent in these plots. An estimate of the temperature effect on shim height can be made from the graphs, amounting to ~1.0 thou/°C for the W legs of Ants 1 & 2 and ~0.6 thou/°C for the W leg of Ant 3. The S legs do not show as strong a correlation, but do appear to vary by about half the W leg values. All correlations are in the sense that smaller shims are needed as the temperature rises - *ie.* the W & S legs appear to expand (relative to the N leg) with temperature.

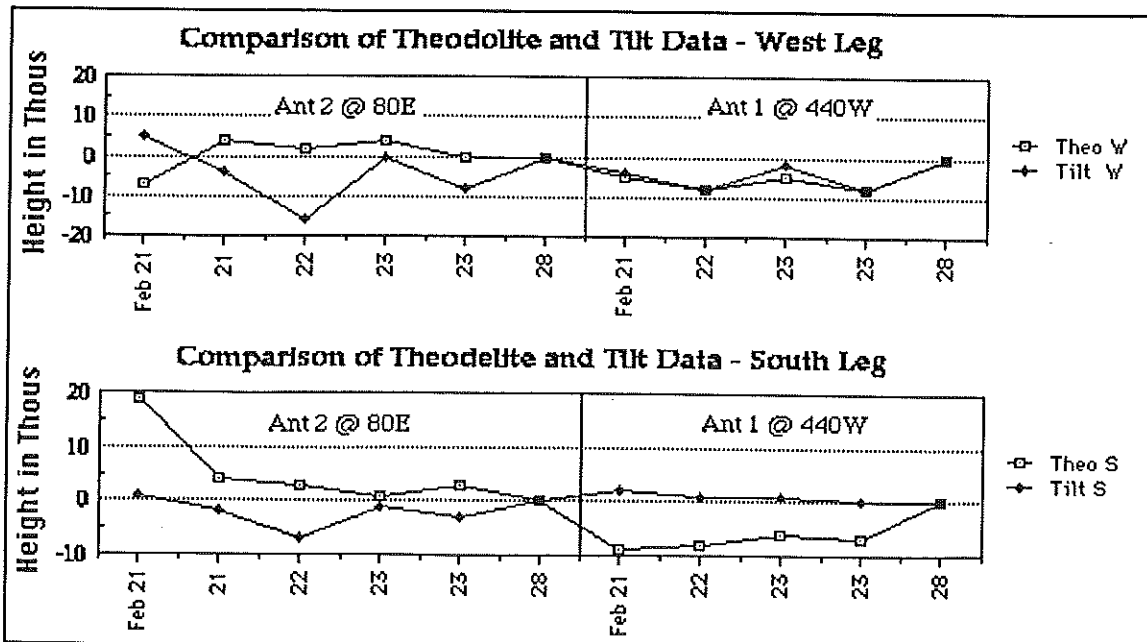
Although the tilts measured in February are an order of magnitude less than those observed in January, an attempt was made to determine whether these more normal instabilities are caused by distortions in the ground or on the antennas. During the last week



in February tilts were measured at ground level using a theodolite, and at the level of the azimuth axis using the tiltmeters. In both cases the North leg was used as a reference. The theodolite measurements were made using a height gauge located at the foot of antennas 1 and 2 (stations 440W and 80E). Theodolite measurements were also made at station 0 (the T) which did not have an antenna on it. The full set of theodolite data are shown below; the W and S heights are referred to the height of the N foot, and all data are referred to the measurements on 28 February.



The above plot shows that height variations at ground level are similar in scale and character to variations at the azimuth axis, and amount to less than about 10 thou. Independent consistency checks and the good agreement between W & S measurements suggest that the maximum error in the theodolite measurements is ~5 thou, except for possible error in reading the level gauge (this may account for S2 on 21 Feb). Tiltmeter measurements were made at the time of the theodolite measurements on six occasions for Ant 2, and five occasions for Ant 1. The theodolite and tiltmeter results are compared below.





In order for tilts on the ground to account for the tilts at the azimuth axis, the theodolite and tiltmeter results should be equal and opposite. To some degree this is true for all except the W leg of Ant 1, since the theo and tilt measurements at least have opposite sign. However, the anti-correlation is not very good and the data cannot be taken to show that ground variations are responsible for the measured tilts. The nearly perfect correlation between the theo and tilt results for 1W is hard to understand and may be fortuitous.

CONCLUSIONS

The experiment to determine whether the variable tilts measured on the Hat Creek antennas occurs in the ground or in the antenna structure is inconclusive. Significant variations in ground height were measured, but they do not correlate well with tilts measured at the azimuth axis. Since only small (10 thou) variations were present during the measurement period, the experiment should be repeated when larger antenna tilts are present.

The Hat Creek antennas appear to tilt with temperature changes by about 1 thou/°C. A 10C variation can therefore produce a tilt of ~10 thou, corresponding to a 0.5mm (1 radian) shift of the phase center for an antenna pointed near the zenith. The corresponding pointing change is 15". This effect appears to be related to gradual changes in ambient temperature rather than the direction of the sun, and hence is probably not caused by differential heating of the antenna structure.

Antenna moves are characterized by a "settling-in" tilt of ~20 thou which occurs within 24 hours after leveling. All attempts at stress relieving the antennas during the shimming process have failed to eliminate this problem. This behavior is particularly annoying since it is during this period that the pointing and baseline calibration for the new configuration is obtained.

It is perhaps encouraging that the oldest antenna (Ant 2) exhibited the largest tilts in February, Ant 1 to a lesser extent, and Ant 3 the least. We can therefore hope that the new antennas will have better stability, provided the problem is in the antenna structure and not in the ground. However, the very large tilts measured in January affected all three antennas at a similar level. It is therefore important to determine the source of the large tilts as soon as possible in order to avoid similar problems with the expanded array.

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2 February, 1991

