NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

ELECTRONICS DIVISION TECHNICAL NOTE NO. 138

Title: **DECLINATION POINTING OF THE 300-FT TELESCOPE**

Author(s): Harry Payne

Date: December 10, 1986

DISTRIBUTION:

GB	CV	TU	VLA
GB Library	CV Library	Library Downtown	VLA Library
R. Norrod	H. Hvatum	Library Mountain	P. Napier
R. Weimer	M. Balister	J. Payne	J. Campbell
D. Schiebel	S. Weinreb	R. Freund	W. Brundage
E. Childers	C. Burgess	J. Lamb	
S. Srikanth	S-K. Pan		
C. Brockway	A. R. Kerr		
J. Coe	P. Siegel		
G. Behrens	L. D'Addario		
R. Mauzy			
R. Bradley			
R. Lacasse			
R. Fisher			
F. Crews			
B. Peery			
H. Payne			

Declination Pointing of the 300-foot Telescope

Harry Payne
9 December 1986

A number of factors make this a good time to reconsider the declination pointing of the 300-foot telescope. Jim Condon has performed a re-analysis of the pointing, motivated by the implementation of lateral focussing (Electronics Division Technical Note No. 137). An examination of some early memos written by Mike Davis reveals that the present functional form of the declination corrections (a power series in declination) is due to a historical accident -- it was simply the form Mike chose to represent some pointing offsets. Sebastian von Hoerner has long complained about the absence of a physical interpretation for this form, and Condon points out that it is numerically unstable, relying on the near cancellation of quadratic and cubic terms.

von Hoerner has argued that the proper form for the 300-foot pointing correction should be

$$\text{constant} + \text{gravity} + \text{refraction}. \tag{1}$$

He argues that the gravity term should be written

$$\sin(\ dec - dec0\ ) \tag{2}$$

where dec0 should be taken as a parameter to be determined by fitting rather than assumed to be equal to the declination of the zenith, decz = 38d 25' 46.3". Condon's analysis assumes dec0 equals decz and ignores refraction.

I have modified my fitting programs to allow measured pointing offsets to be fit by equations of form (1). The form of the refraction term is that given by von Hoerner in Engineering Report 101, <u>Refraction Correction for the 140 ft-Pointing</u>:

$$K*\sin(\ z\ )/(\ \cos(\ z\ ) + 0.00175*\tan(\ z - 2.5d\ )\ ) \tag{3}$$

where z = dec-decz is the zenith distance, and K is a weather-dependent correction. This form was selected to be well behaved at the very low elevations available to the 140-foot telescope. However, the elevation of the 300-foot telescope cannot go below 32 degrees, so this is not important, but the code to implement this correction in the H316 computer already exists at the 140-foot. At the minimum elevation, the correction due to refraction is about 100". Since the value of K measured at the 140-foot during pointing runs is almost always in the range from 0.96 to 1.04, the pointing error arising from setting K=1 and ignoring any weather dependence is only about 8" at the south limit or 4" at dec=0.

I have three sets of pointing data large enough to analyze: 21cm data taken with the L-band receiver in September 1983, 9cm data taken in March 1985, and 11cm data taken in September 1985. Some smaller data sets were analyzed only to determine a level curve.

I first examined the level curve. This is the nominal output of a tilt-meter that sits atop the east tower of the telescope. The output measures the telescope tilt as a function of declination. The level curve is best determined on windless nights to be free of thermal and wind effects. Any deviation from the level curve is considered a pointing error and is corrected for in real time. This reduces the effect of steady winds and a tilt due to differential heating by sunlight. The natural form of the level curve is

$$\text{constant + gravity.} \qquad (4)$$

I found that six level curves were all well fit by a function of the form

$$L1 + L2 * \sin(z) \qquad (5)$$

implying that dec0 can indeed be taken as decz in this case. The addition of dec0 as another parameter did not significantly improve the quality of the fit. All data were well fit by L2 = 38.1" +/- 2.6", but the value of L1 changes slowly with time, having increased from 72" in December 1982 to 172" in November 1986.

I began looking at the pointing data by fitting for dec0 but ignoring refraction. I should say that I did this by expanding sin(dec-dec0) into sines and cosines, fitting for the coefficients of sin(dec) and cos(dec), and forming the appropriate combinations of these two coefficients to obtain the coefficient of the sine term and dec0. Adequate fits were found in all three cases. The coefficient of the gravity term was close to that found by Condon, but dec0 was not close to the zenith. Assuming dec0 to be equal to the zenith and ignoring refraction did not give a good fit in any of the cases.

Simultaneously fitting for the coefficient of the refraction term and either form of the gravity term ((2) or sin(z)) did not really help in any of these cases. The coefficient of the refraction term always came out with a nonsensical value. The problem is the similarity in form, and the high correlation coefficient when fitting, of the refraction term and the gravity term. These terms are essentially inseparable for a transit instrument.

I then assumed that the refraction correction could be predicted accurately. As I mentioned above, the refraction correction is known quite well in spite of the lack of the weather dependent factor. The coefficient of the refraction term can be measured at the 140-foot and has always given about the same result. von Hoerner quotes a value of 1.04 +/- 0.05 minutes of arc. I used the value 1.03 +/- 0.02 arcminutes obtained at 18 and 21cm with the L-band receiver. This is 62". Taking K, the weather dependent correction factor, to be 1.0, I applied a refraction correction to the pointing offsets before fitting.

I then performed fits to the data corrected for refraction, using both forms of the gravity term. Adequate fits were obtained, but in all three sets of data, the addition of dec0 as a free parameter made no significant improvement in the quality of the fit: there was no improvement in the rms of the residuals, and no improvement based on a visual inspection of the quality of the fit. The values of dec0 were not exactly at the zenith, but they were much closer to the zenith than in the data not corrected for refraction.

The uncertainty in the parameters is much smaller if dec0 is not a free parameter. This is because of the high correlation coefficient between the constant term and the cos(dec) term used in the fit for dec0. However, the constant and sin(z) terms are essentially uncorrelated. The proposed form of the declination pointing curve is

```
C1 + C2*sin( z )
+ 62"*sin( z )/( cos( z ) + 0.00175*tan( z-2.5d ) )     (6)
```

C1 and C2 still appear to depend on the receiver in use. The values obtained for C2 were 200.7", 180.4", and 201.6" for the 9cm, 21cm, and 11cm receivers, respectively. It should not be too difficult to recast older pointing curves, for which the raw data are no longer available, into this form.

Condon proposes that there be an additional pointing correction based on the indicated position of the lateral focus mechanism. The pointing correction that arises from tracking the optimum focus is much larger than the correction discussed above, so it makes sense to keep them separate. It also makes sense to have the correction made automatically since that way the observer would not have to change the pointing curve coefficients depending on whether the lateral focus was engaged or disengaged. Condon proposes that the pointing correction be made automatically so that the results are incorporated into the positions written out with the data. The amount of correction is -117" per inch of lateral focus motion. That is, for every inch that the receiver moves north on the telescope, the declination of the beam moves south by 117".

The conclusions are these:

1. A new form is proposed for the level curve:

   $$L1 + L2 * \sin(z)$$

   where z is the (signed) zenith distance dec-decz, where decz is 38d 25' 46.3". Current values of the coefficients appear to be

   L1 = 171.9" +/- 2.1"
   L2 = 38.1" +/- 2.6"

   One advantage of this form over the current one is that L1 is now the level reading with the telescope at zenith, which can be obtained whenever the telescope is stowed, such as every maintenance period.

2. A new form is proposed for the declination pointing curve:

   $$C1 + C2*\sin(z) + C3*\sin(z)/(\cos(z) + 0.00175*\tan(z-2.5d))$$

   where C3 has the value 62". The terms in this equation are corrections for a constant offset, gravity, and refraction, respectively. Although the refraction term should depend on the weather, the information for making such a correction is not available in the H316 computer, and would require an interface like that at the 140-foot telescope. However, the 300-foot cannot go to very low elevations, and so the weather dependent term is not required.

3. It is proposed that an additional declination correction be made automatically so that positions recorded with the data are adjusted for the indicated position of the lateral focus by the amount -117"/inch of travel.

The advantages of the new forms for the pointing curves are that the terms have a physical interpretation, the corrections are numerically well-behaved, and the coefficients can be determined accurately because the terms are not correlated, except for the coefficient of the refraction term, but refraction can be predicted accurately. The advantages of the third proposal are that positions recorded with the data are accurate even if the lateral focus is not where it is expected to be, and that the pointing curve coefficients do not depend on whether the lateral focus is being used or not. No new hardware is required to implement these changes. All of the changes require programming changes in the H316 computer.