FOCUS and ROTATION

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This memo has two parts. The first describes the results from measurements of focus and rotation on Jan 16. The second is an analysis of the focus and rotation values in use in mid January.

JAN. 16 OBSERVATIONS:

On Jan 16, I took a long data set to measure focus and rotation positions at all VLBA sites at 1 and 2 cm. I used a 5 point pattern centered on the nominal focus and rotation with one offset point in each direction. Program ROTPAT was used to make this pattern and TSM and ROTANAL were used to analyze the results. Many of the antennas had bad weather, snow in the dish, or other problems. The results below are from those which seemed to work ok.

There are some global conclusions that can be reached from this data set. The first is that the focus variation with zenith angle seen at 1.3 cm is also there for 2 cm with essentially the same amplitude. This is also true, from Anton Zensus's work, for 7 mm. Therefore it is probably also true for all other frequencies. The peak-to-peak magnitude of the variation is 6 or 7 mm. The FWHM of the amplitude vs. focus curves are typically 20 mm at 1.3 cm and 35 mm at 2 cm. To keep any loss of amplitude below about 2 percent, the focus must be better than 1.7 mm at 1.3 cm and 3.0 mm at 2 cm (Note that the 2 cm data were taken at 12.4 GHz.). This constraint requires the use of the focus variation with elevation at both frequencies. At 4 cm (8.6 GHz), the FWHM of the focus curve will be 50 mm (scaling from 12.4 GHz). The amplitude loss will be less than 2 percent for focus errors up to 4.2 mm. A central value will keep focus offsets below this number. In fact, a carefully chosen value that keeps the errors below 3 mm would keep the amplitude errors below 1 percent. For geodesy, we need to think carefully about whether or not to use the focus variation with elevation since it surely affects the geometric path length through the antenna. Therefore, for now, I recommend that we use the variation for 2cm, 1cm, and 7mm but not for lower frequencies. Meanwhile we should explore what is the best course of action at 4 cm and 6 cm.

The second conclusion of the Jan 16 measurements is that there is no believable variation of best rotation with zenith angle at 1.3 cm while there is a suggestion of a variation of about 0.6 degrees over the full zenith angle range at 2 cm. The 2 cm result is certainly not yet secure and measurements at lower zenith angles are needed to help confirm it. No variation is expected at 1.3 cm because the feed is close to the azimuth axis and rotation variations are shifts in azimuth, not the dimension in which variations are expected. The 2 cm feed is half way between the azimuth and elevation axes, close to the 7 mm feed (which is closer to the elevation axis). Some variation might be expected here. The FWHM for rotation is 38 degrees at 2 cm (12.4 GHz), so any effect is negligible. At 7 mm, a rotation offset of 0.9 deg will cause an amplitude loss of 2 percent, so the rotation vs. elevation needs to be studied at the at that frequency.

While there does not appear to be a rotation change with elevation that needs to be dealt with, the data do show some disturbingly large offsets between the measured and the apriori rotation values. At several antennas, offsets of 2 degrees are seen. This would cause an amplitude loss of 2.5 percent at 1.3 cm and should be investigated. The worst case is for SC at 1.3 cm where the offset of 5.8 degrees is enough to cause a 20 percent amplitude loss! The raw data show that one of the offset positions in rotation had consistently higher amplitudes than the central position. Also the width of the peak in rotation is much wider at SC than at other sites. Something is clearly wrong. An offset of this magnitude is hard to understand. The relative apriori rotation angles at this site for 1.3 cm and all the other feeds are the same as at other sites, so it

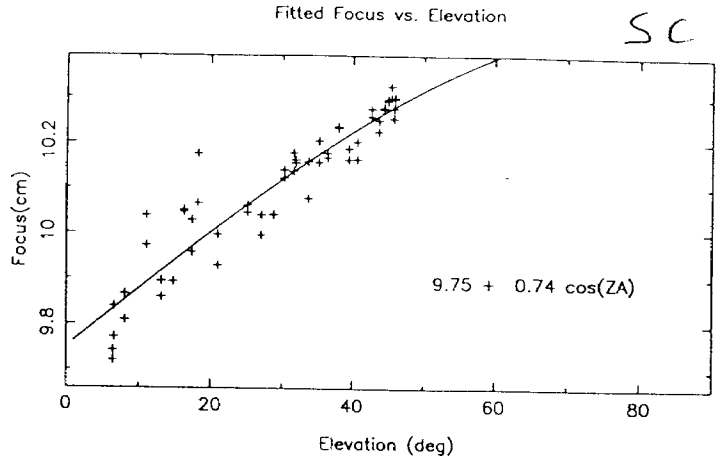
is as if the feed is in the wrong position - by over 8 cm! Could something else cause such a large shift? Note that the sensitivity at 1.3 cm at SC is low compared to other sites.

Below are the results of the Jan 16 test for stations that seemed to be working ok. Other stations either had weather problems or clearly very strange results that I don't believe (PT had a 25 mm peak-peak focus variation!). "Old" values refer to what was in the FEPARM screen at the time. All values are in mm and degrees. The rotation values are averages determined by eye from the plots. The program fit for a constant plus a cos(za) term which is the same equation used for focus. This was done in the absence of any understanding of what functional form would be appropriate so I don't want to tabulate the results.

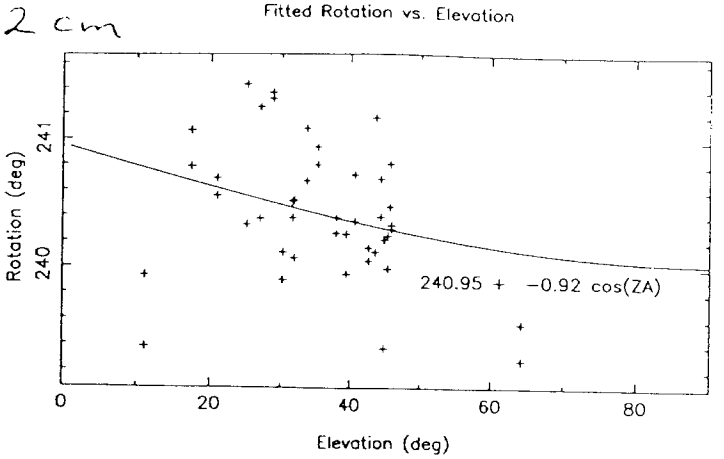
Station	Band	Old Focus	Old Var	Fit Focus	Fit Var	Old Rotation	Avg Rotation
SC:	2cm	103.0	---	97.5	7.4	241.6	240.4
SC:	1cm	98.3	6.0	97.9	6.6	301.8	296
FD:	2cm	93.0	---	86.4	7.3	218.5	220.3
FD:	1cm	87.5	6.8	87.4	7.0	278.3	276.2
LA:	2cm	88.1	---	84.0	6.6	201.1	201.2
LA:	1cm	83.8	6.7	84.5	6.0	260.7	259.4
KP:	2cm	87.4	---	82.8	6.9	207.4	208.0
KP:	1cm	83.2	8.1	83.5	6.6	262.9	260.9
OV:	2cm	82.4	---	76.1	5.7	185.5	184.9
OV:	1cm	75.1	5.6	76.8	5.6	245.2	243.6

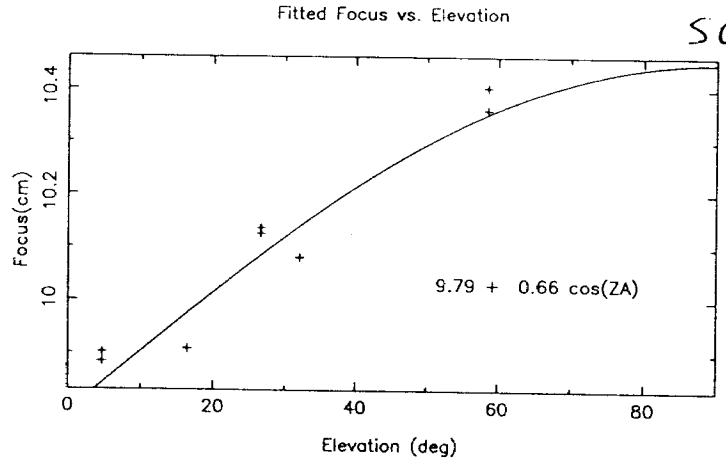
Figures 1 to 3 are the plots of the focus and rotation fits for the above stations.

A clear action item is to obtain good data of this sort for all antennas and for low zenith angles. Focus variations need to be determined and put in the FEPARM screens for 2 cm at all sites and the rotation values need to be fixed at some sites. The problem with SC at 1 cm needs to be understood.

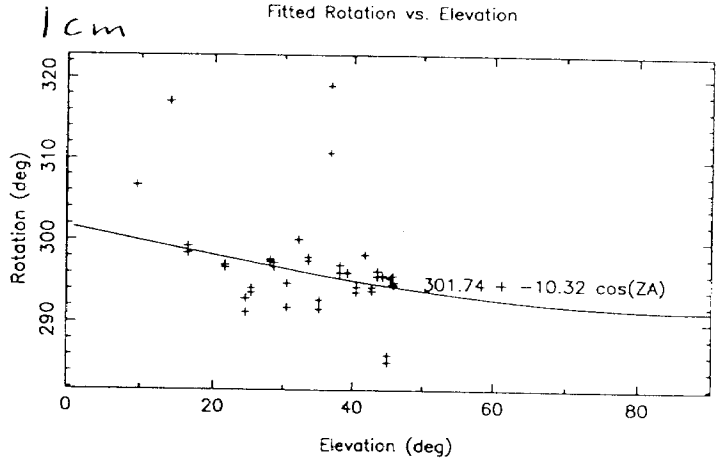


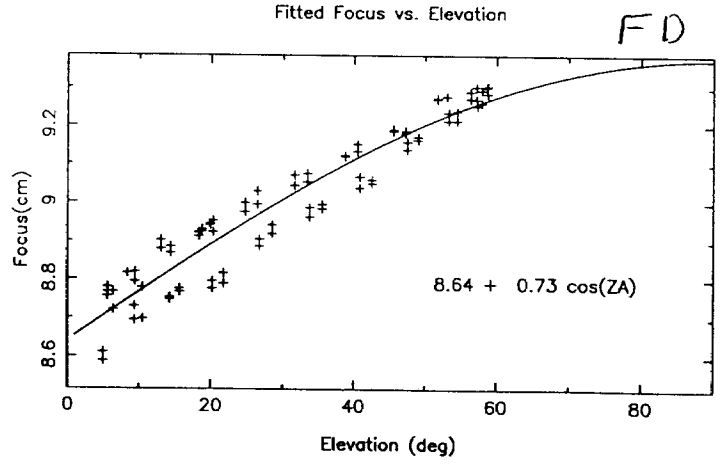
SC 2 cm



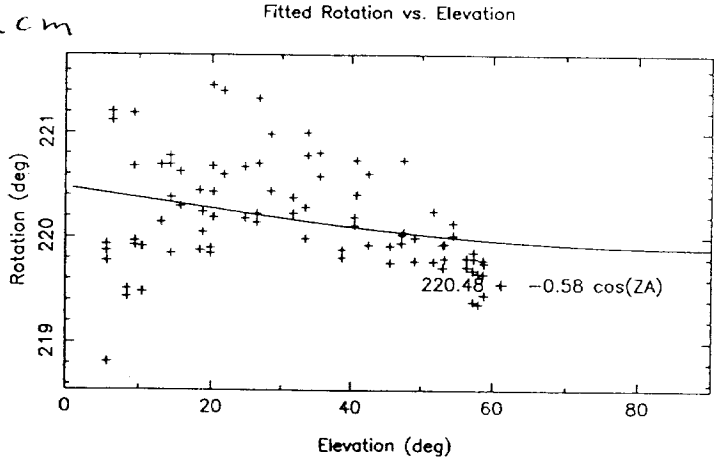


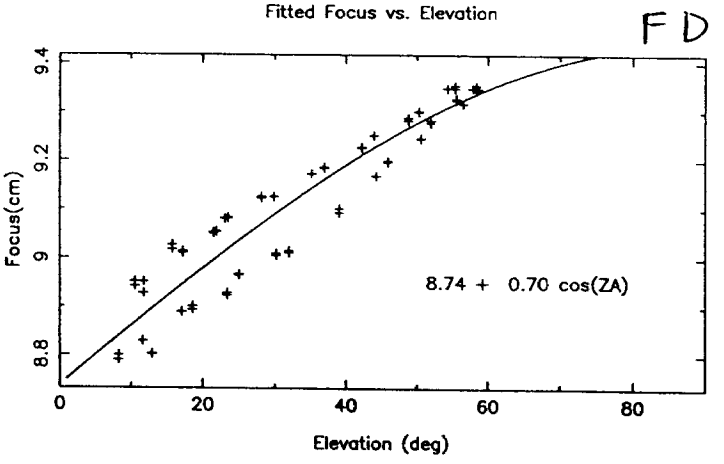
SC 1 cm





FD 2 cm





FD 1 cm

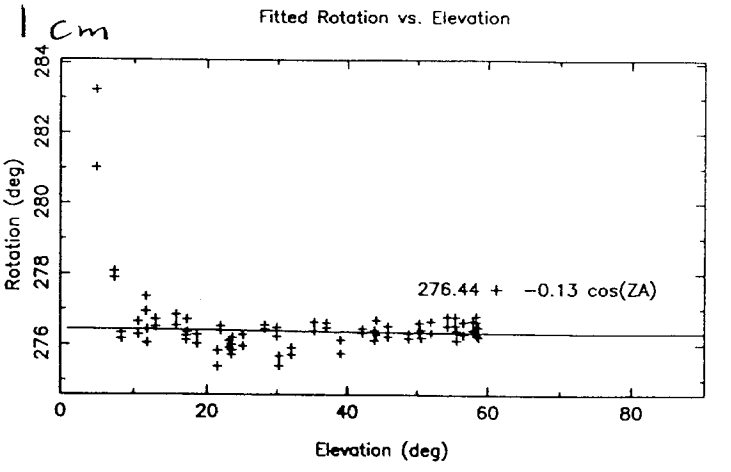
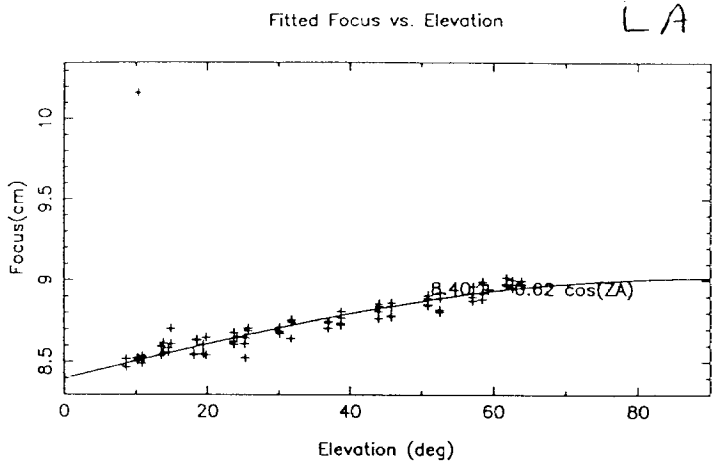
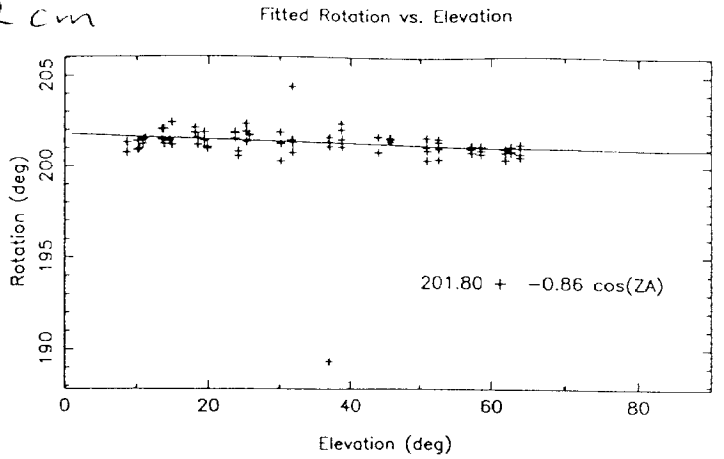


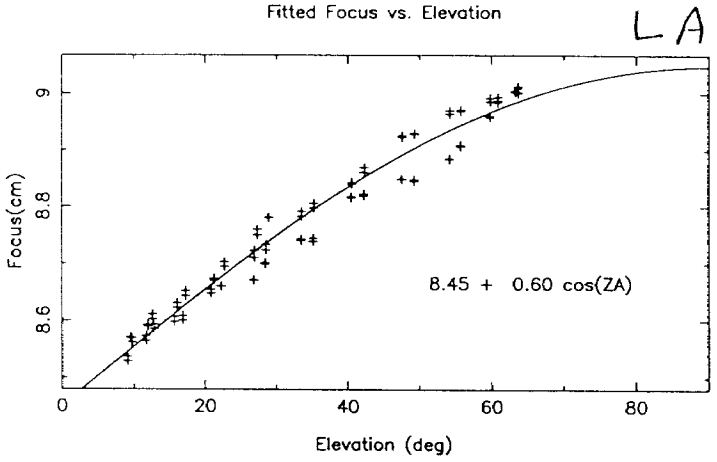
Fig 1

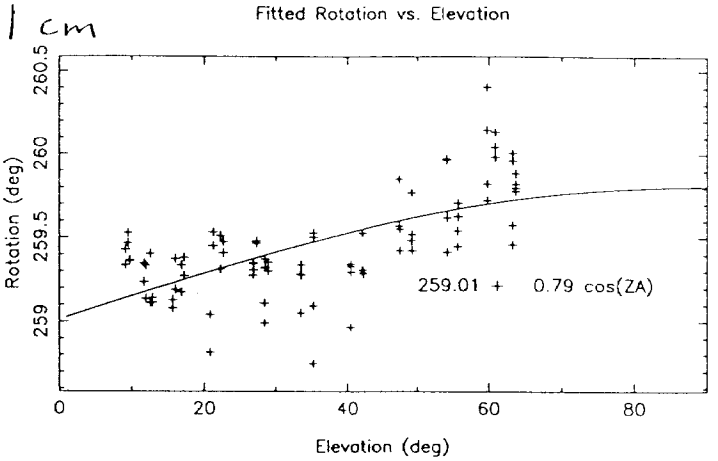
LA 2cm



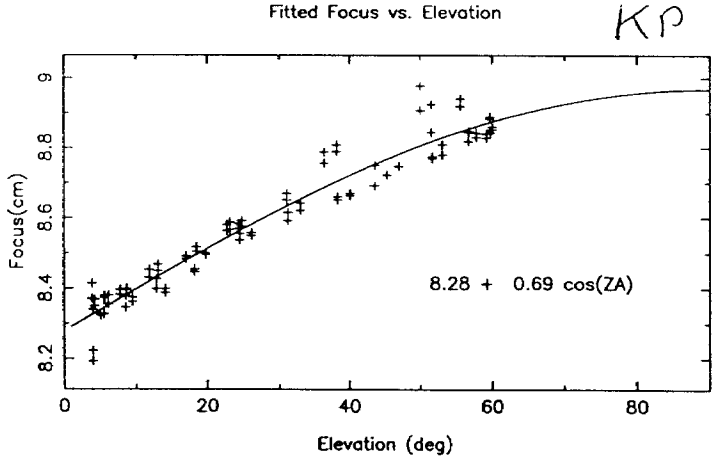


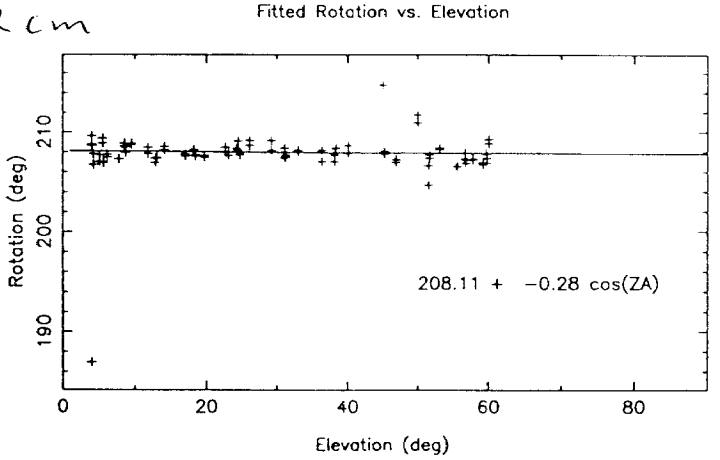
LA 1cm



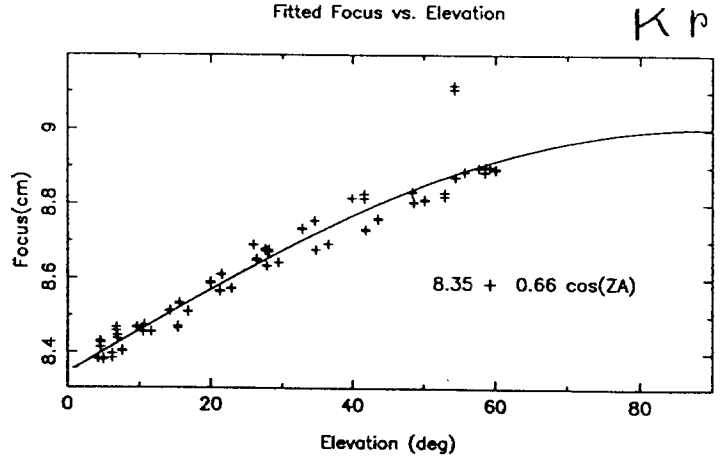


KP 2cm





KP 1cm



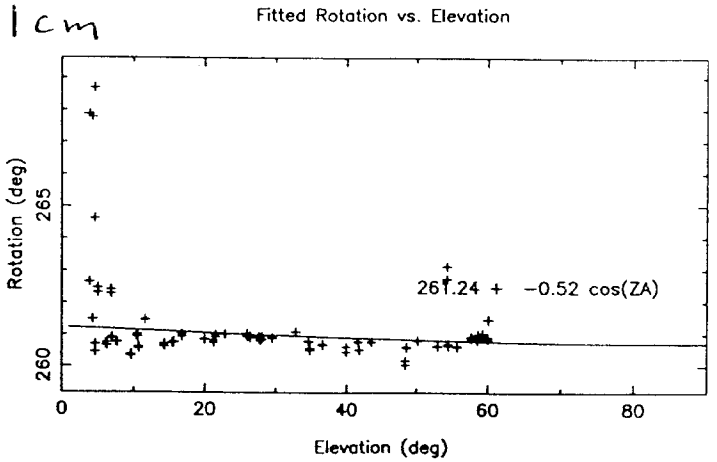


Fig 2

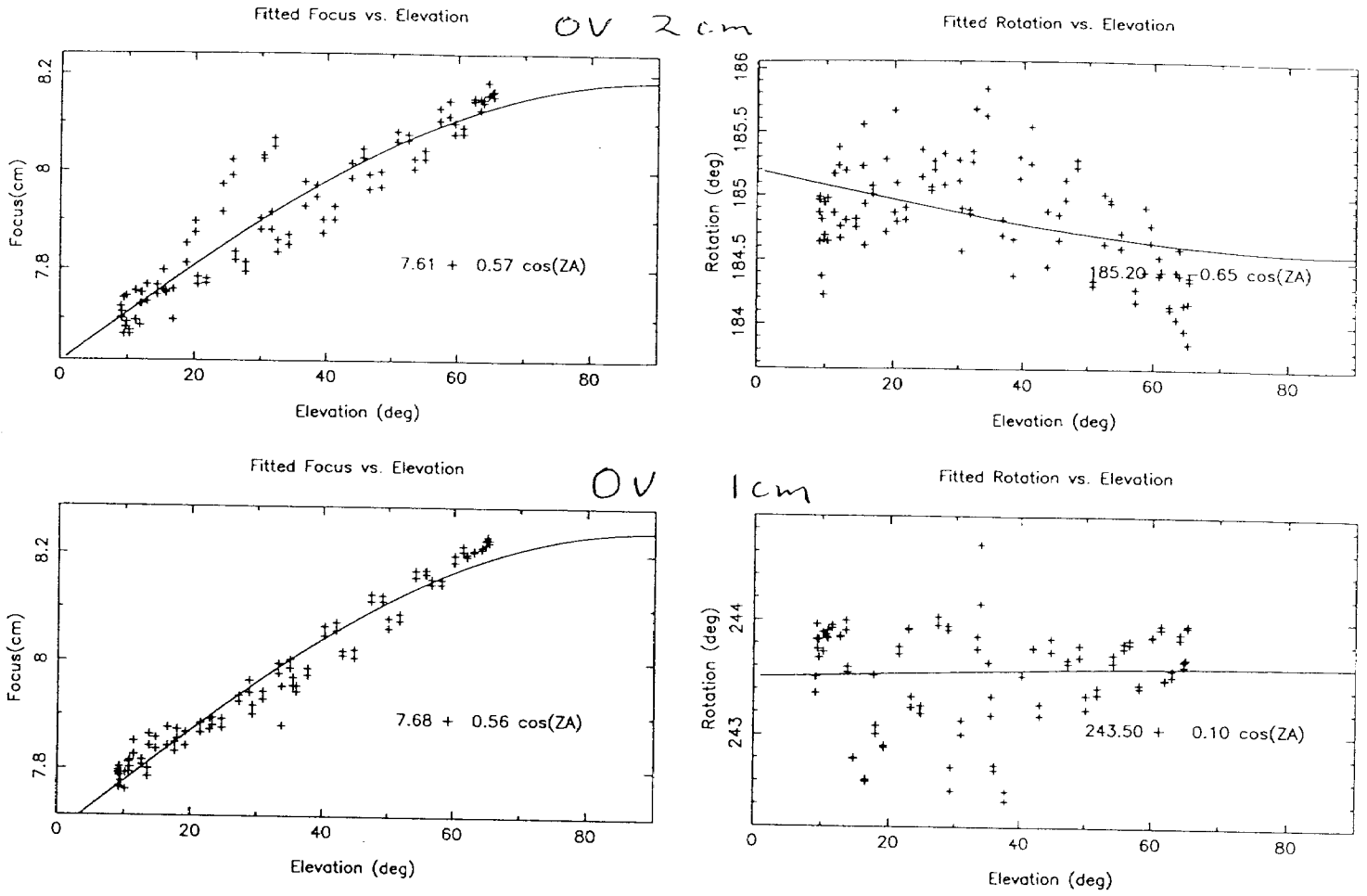

Fitted Focus vs. Elevation
0V 2cm
Focus(cm)
8.2
8
7.8
7.61 + 0.57 cos(ZA)
0
20
40
60
80
Elevation (deg)
Fitted Rotation vs. Elevation
Rotation (deg)
186
185.5
185
184.5
184
185.20 + 0.65 cos(ZA)
0
20
40
60
80
Elevation (deg)
Fitted Focus vs. Elevation
0V 1cm
Focus(cm)
8.2
8
7.8
7.68 + 0.56 cos(ZA)
0
20
40
60
80
Elevation (deg)
Fitted Rotation vs. Elevation
Rotation (deg)
244
243
243.50 + 0.10 cos(ZA)
0
20
40
60
80
Elevation (deg)

Fig 3

FRM VALUES IN USE:

In an effort to check for any possible problems with the focus and rotation values in use, I tabulated the values from the FEPARM screens. I used a spreadsheet to do some comparisons between sites and with design values. The resulting tables are attached. The table for each antenna gives the rotation angle for each band according to the figure in the Project Book, the band name, the current focus value in the FEPARM screen (in mm), the current value for the rotation (in deg), the value for the focus variation with elevation (in mm), the deviation of the rotation from the Project Book value after removing an offset that sets the deviation for 1.3 cm to zero and after accounting for the opposite sign convention, and the offset of the focus from the 1.3 cm value. The "Rotation Offset" for each antenna is the rotation that had to be removed to set the deviation at 1.3 cm to zero (not counting n X 360 deg). The final two columns are collected on the summary sheet for easy examination.

Note that an offset from the optimum value of rotation by about 1.7 deg will have an effect at 1.3 cm of on the order of 2% based on results earlier in this memo. Most antennas have values for rotation that are consistent with the Project Book to within less than a degree. Pie Town and Kitt Peak have a few exceptions. This is the result of the use of a special tool to align feeds at all other sites but not at PT and KP. Also, all of the 7 mm receivers are offset from the Project Book nominal position. This is the result of a need to move the nominal position in order to fit the receiver in the feed cone. From these data, I expect that none of the rotation values that we are using are seriously in error, although it would be good to understand the PT and LA data. This analysis, of course, is only sensitive to the apriori values in use. Problems such as that identified at SC above would not show up here.

The focus offsets from 1.3 cm are quite consistent from antenna to antenna. The main exceptions are BR at 2cm (where we have an efficiency problem and where the value was obtained with snow in the dish), and SC at 13 and 6 cm. I have asked operations to check these values.

FOCUS and ROTATION VALUES at PT

Rotation offset 35.2

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	314.2		-1.0	589.1
251.0	20cm	28.4	141.4		-2.8	-62.2
32.0	13cm	65.0	363.5		0.3	-25.6
108.0	6cm	83.0	288.7		1.5	-7.6
323.0	4cm	86.1	70.1		-2.1	-4.5
32.0	4cmsx	85.5	363.5		0.3	-5.1
347.0	3cm	87.5	47.7		-0.5	-3.1
138.0	2cm	89.2	260.8		3.6	-1.4
78.0	1cm	86.0	317.2	7.7	0.0	0.0
155.0	7mm	88.0	233.4	8.4	-6.8	2.4

FOCUS and ROTATION VALUES at KP

Rotation offset -19.1

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	88.8		-172.1	591.6
251.0	20cm	28.4	88.8		-1.1	-59.7
32.0	13cm	68.0	308.0		-0.9	-20.1
108.0	6cm	82.8	236.0		3.1	-5.3
323.0	4cm	84.9	17.8		-0.1	-3.2
32.0	4cmsx	86.4	308.0		-0.9	-1.7
347.0	3cm					
138.0	2cm	87.4	207.4		4.5	-0.7
78.0	1cm	83.2	262.9	8.1	0.0	0.0
155.0	7mm	83.2	179.0	7.6	-6.9	-0.3

FOCUS and ROTATION VALUES at LA

Rotation offset -21.3

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	87.8		-170.9	591.9
251.0	20cm	28.4	87.8		0.1	-59.4
32.0	13cm	63.7	306.4		-0.3	-24.1
108.0	6cm	79.3	231.1		0.4	-8.5
323.0	4cm	86.7	375.4		-0.3	-1.1
32.0	4cmsx	87.8	306.4		-0.3	0.0
347.0	3cm					
138.0	2cm	88.1	201.1		0.4	0.3
78.0	1cm	83.8	260.7	6.7	0.0	0.0
155.0	7mm	84.9	179.3	6.5	-4.4	1.0

FOCUS and ROTATION VALUES at FD

Rotation offset -3.7

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	105.7		-170.6	588.1
251.0	20cm	28.4	105.7		0.4	-63.2
32.0	13cm	70.8	324.4		0.1	-20.8
108.0	6cm	85.0	248.6		0.3	-6.6
323.0	4cm	87.8	393.0		-0.3	-3.8
32.0	4cmsx	89.7	324.4		0.1	-1.9
347.0	3cm					
138.0	2cm	93.0	218.5		0.2	1.4
78.0	1cm	87.5	278.3	6.8	0.0	0.0
155.0	7mm	86.2	196.7	8.1	-4.6	-0.5

FOCUS and ROTATION VALUES at NL

Rotation offset 17.1

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	126.3		-170.8	605.8
251.0	20cm	28.4	126.3		0.2	-45.5
32.0	13cm	51.0	344.7		-0.4	-22.9
108.0	6cm	68.0	269.7		0.6	-5.9
323.0	4cm	73.6	53.9		-0.2	-0.3
32.0	4cmsx	75.5	344.7		-0.4	1.6
347.0	3cm					
138.0	2cm	76.7	239.6		0.5	2.8
78.0	1cm	70.2	299.1	6.2	0.0	0.0
155.0	7mm	71.2	217.7	6.0	-4.4	0.9

FOCUS and ROTATION VALUES at OV

Rotation offset -36.8

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	314.2		71.0	601.2
251.0	20cm	28.4	72.3		0.1	-50.1
32.0	13cm	61.0	290.7		-0.5	-17.5
108.0	6cm	73.6	215.6		0.4	-4.9
323.0	4cm	76.5	359.7		-0.5	-2.0
32.0	4cmsx	82.5	290.7		-0.5	4.0
347.0	3cm					
138.0	2cm	82.4	185.5		0.3	3.9
78.0	1cm	75.1	245.2	5.6	0.0	0.0
155.0	7mm	76.0	162.5	6.4	-5.7	1.4

FOCUS and ROTATION VALUES at BR

Rotation offset 128.5

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	237.8		-170.7	579.6
251.0	20cm	28.4	237.8		0.3	-71.7
32.0	13cm	81.0	96.5		0.0	-19.1
108.0	6cm	94.5	381.1		0.6	-5.6
323.0	4cm	100.7	165.1		-0.4	0.6
32.0	4cmsx	101.0	96.5		0.0	0.9
347.0	3cm					
138.0	2cm	82.0	351.0		0.5	-18.1
78.0	1cm	96.0	50.5	6.9	0.0	0.0
155.0	7mm	96.1	327.2	6.9	-6.3	0.1

FOCUS and ROTATION VALUES at HN

Rotation offset -1.7

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	107.4		-170.9	584.1
251.0	20cm	28.4	107.4		0.1	-67.2
32.0	13cm	72.0	326.1		-0.2	-23.6
108.0	6cm	92.3	250.7		0.4	-3.3
323.0	4cm	96.0	35.0		-0.3	0.4
32.0	4cmsx	101.0	326.1		-0.2	5.4
347.0	3cm					
138.0	2cm	96.6	220.3		0.0	1.0
78.0	1cm	92.0	280.3	6.0	0.0	0.0
155.0	7mm	96.2	197.4	6.0	-5.9	4.2

FOCUS and ROTATION VALUES at SC

Rotation offset 19.8

Std Rot	Band	Focus (mm)	Rotat. (deg)	Foc Var (mm)	Rotat. Diff.	Foc-1cm
80.0	90cm	679.7	128.5		-171.3	577.8
251.0	20cm	28.4	128.5		-0.3	-73.5
32.0	13cm	95.0	347.1		-0.7	-6.9
108.0	6cm	89.4	271.9		0.1	-12.5
323.0	4cm	102.1	55.9		-0.9	0.2
32.0	4cmsx	103.5	347.1		-0.7	1.6
347.0	3cm					
138.0	2cm	103.0	241.6		-0.2	1.1
78.0	1cm	98.3	301.8	6.0	0.0	0.0
155.0	7mm	0.0	217.7	0.0	-7.1	-101.9

SUMMARY

Rotation difference from blueprint

Band	PT	KP	LA	FD	NL	OV	BR	HN	SC	MK
Offset	35.2	-19.1	-21.3	-3.7	17.1	-36.8	128.5	-1.7	19.8	-19.1
90cm	-1.0	-172.1	-170.9	-170.6	-170.8	71.0	-170.7	-170.9	-171.3	-260.9
20cm	-2.8	-1.1	0.1	0.4	0.2	0.1	0.3	0.1	-0.3	-89.9
13cm	0.3	-0.9	-0.3	0.1	-0.4	-0.5	0.0	-0.2	-0.7	-308.9
6cm	1.5	3.1	0.4	0.3	0.6	0.4	0.6	0.4	0.1	-232.9
4cm	-2.1	-0.1	-0.3	-0.3	-0.2	-0.5	-0.4	-0.3	-0.9	-17.9
4cmsx	0.3	-0.9	-0.3	0.1	-0.4	-0.5	0.0	-0.2	-0.7	-308.9
3cm	-0.5									
2cm	3.6	4.5	0.4	0.2	0.5	0.3	0.5	0.0	-0.2	-202.9
1cm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-262.9
7mm	-6.8	-6.9	-4.4	-4.6	-4.4	-5.7	-6.3	-5.9	-7.1	-185.9

Focus difference from 1cm.

Band	PT	KP	LA	FD	NL	OV	BR	HN	SC	MK
90cm	589.1	591.6	591.9	588.1	605.8	601.2	579.6	584.1	577.8	0.0
20cm	-62.2	-59.7	-59.4	-63.2	-45.5	-50.1	-71.7	-67.2	-73.5	0.0
13cm	-25.6	-20.1	-24.1	-20.8	-22.9	-17.5	-19.1	-23.6	-6.9	0.0
6cm	-7.6	-5.3	-8.5	-6.6	-5.9	-4.9	-5.6	-3.3	-12.5	0.0
4cm	-4.5	-3.2	-1.1	-3.8	-0.3	-2.0	0.6	0.4	0.2	0.0
4cmsx	-5.1	-1.7	0.0	-1.9	1.6	4.0	0.9	5.4	1.6	0.0
3cm	-3.1									
2cm	-1.4	-0.7	0.3	1.4	2.8	3.9	-18.1	1.0	1.1	0.0
1cm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7mm	2.4	-0.3	1.0	-0.5	0.9	1.4	0.1	4.2	-101.9	0.0
1cm tru	86.0	83.2	83.8	87.5	70.2	75.1	96.0	92.0	98.3	0.0