VLBA TEST MEMO 67

FOCUS on the VLBA

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Abstract

VLBA focus has been checked at all bands, in many cases for the first time in years. Some were far enough off to degrade data. The new measured values are given, many of which will be put in the system. A suggestion is made to add 2cm to the bands at which we adjust the focus with elevation. It is shown that the focus offsets between bands is very nearly the same at all sites. This may prove useful for operations for use as a consistency check or to provide a way of setting all bands even if measurements are only available at one.

1 Discussion

The focus for most receivers on the VLBA has been checked rarely, if at all, since they were installed. During April to July 2001, I made observations designed to check the focus at all bands above 2 GHz. I did not bother with 20, 50, and 90 cm because I was under the impression that those focus values were always against one or the other of the focus travel limits. It seems that there is some doubt about this and the 20 cm focus should be checked. The S/X focus at SC was found to be sufficiently far off to cause about 25% loss of sensitivity. I had that corrected immediately. Roughly 10% of the rest are sufficiently poor to cause amplitude losses of more than 5%. These poor values are mainly at high frequencies (2cm and up) although SC has problems at lower frequencies that suggest it might have suffered a 1 cm focus shift in the past that has only been corrected at some bands. With this memo, I suggest new focus values for use in operations. Where significant gain changes will result, we will need different station gains (in `vlba_gains.key`) before and after the change is made.

Table 1 gives some summary information for each band that should help understand the measured data. The columns are 1.) the band name, 2.) the typical focus pattern full-width-half-maximum, and 3.) the focus error that would cause a 1% amplitude loss. Column 4 is the average from the current data, across all stations, of the offset between the 7mm focus position and the measured focus position at the indicated band. To derive this offset, all focus values are adjusted to 40° elevation using the equation $F(El) = F(0) + F_{var} sin(El)$. The value used for F_{var} is that currently in use at the antenna (measured at some time in the past) if not zero. Otherwise it is 0.65 cm, which is a reasonable average of the previously measured values.

The offsets from the 7mm focus are included in Table 1 because they proved to be very consistent from antenna to antenna as will be apparent in the main data table below. This is a

TABLE 1
Band Dependent Focus Parameters

Band	Width cm	1% Loss Offset cm	Offset from 7mm cm at 40° El.
7mm	1.15	0.07	0.0
1cm	2.10	0.12	−0.05
2cm	2.85	0.17	−0.34
4cm	5.4	0.32	−0.40
4cmsx	5.5	0.33	−0.18 [1]
6cm	9.1	0.55	−0.82
13cm	21.5	1.3	−2.08

[1] Set 0.3 cm lower (-0.48 cm) for joint optimization with 13cmsx.

fact that can be utilized in various ways. When focus values are measured, the standard offsets can serve as a consistency check. If a new receiver is put up, they can be used to derive a very good first-guess focus. If something happens to the FRM to change the focus, they can be used to fix all bands quickly after measurement of only one. It is difficult to tell from the current data if the deviations from these averages represent measurement errors or real physical differences. If they are measurement errors, then the best way to set the focus values for an antenna might be to measure the focus at 7mm and apply the offsets for the other bands. Regardless, that method would produce much better focus values than we have been using so far in many cases.

The current data are not adequate in many cases to fit for new values for the focus variation with elevation (F_{var}). Therefore I have have retained the values already in use at the antennas. Those values are only non-zero for high frequencies where focus observations have been made frequently in the past. Where there are sufficient points for a fit using the current data, including at all stations at 7mm, the results agree well with the older values so there is no need for a change.

The focus variation is very similar at most sites. Using $F_{var} = 0.65$ would probably be acceptable for all cases. However there are variations that appear to be real so I am not advocating that we change to a common value (which I had seriously considered). Note that the most discrepant value is for 7mm at BR where there is a large astigmatism confusing the situation.

The focus variation has been non-zero for 1cm, 7mm, and 3mm in the past. It is also non-zero for 2cm at MK only. Without a focus variation, the focus error can be on the order of 0.3 cm at extreme elevations. This is well above the 1% loss point for 2cm observations, but not for 4 cm. Therefore I advocate that we add 2cm to the bands at which we are using the focus variation at all stations. The new suggested focus values assume that this is done.

Note that the focus value used at the station is the value at the horizon while the measurements that constrain it are mainly from high elevations. Therefore, the focus and focus variation have to be treated as a matched pair of numbers — they should not be adjusted independently.

With the new data, I correct a situation that has always existed, namely that the focus value used for SX (4/13cm) dual band observations has been the one measured at 4cm with no effort to err in the direction to improve 13cm. The optimum focus positions for the two bands are different by about 1.8 cm. The losses would be about equal at the two bands with a 0.4 cm shift. But, because the 4cm band is more sensitive to any focus errors that might develop, including the uncompensated focus variation with elevation, and because usually the 4cm data are more important (for example, for geodesy), I have opted to give the 4cm a slight advantage. The values suggested below for dual band observing are at a position 0.3 cm lower than the 4cm peak.

The results of my measurements are given in Table 2. The columns are 1.) the station code, 2.) the band, 3.) the apriori focus at 0° elevation used by the system (F^0), 4.) the apriori focus variation (F^0_{var}), 5.) focus at 40° elevation implied by the apriori values (F^0_{40}), 6.) the best fit value for F_{40} assuming either the apriori F_{var}, if non-zero, or $F_{var} = 0.65$, 7.) the focus error at 40° ($F_{40} - F_{40}^0$), 8.) the implied percentage amplitude loss due to that error, 9.) the offset of the best fit F_{40} from the 7mm F_{40} at this site, 10.) the same as column 9 but with the average over stations for the band removed, 11.) the suggested new value of focus (F^0) to use at the site. The suggested new focus values assume we do not change the current values of F_{var} except to use $F_{var} = 0.65$ for 2cm at stations that were not already using a non-zero value at that band. For 4cmsx the focus values are set 0.3 cm below the fit value. Only those in bold numbers actually need to be changed. The rest are close enough.

The focus at FD was changed between 2001 Aug 26 and 31 by about a half cm as the result of a somewhat ill conceived test. Therefore, the suggested new focus values in Table 2 need to be adjusted upward. On 2001 Sept 07, the 1cm and 7mm focus values were measured at all stations, although with a lot less data than contributed to the main results in this memo. The measured values are given as suggested new values in Table 2. At other bands, the new focus should be the value implied by the Apr-July measurements plus 0.46 cm, the average of the 1cm and 7mm changes. More extensive observations should be made to firm up the new values. As for the other sites, the measurements were within about 0.01 cm of those reported here at most. At three sites, there were changes of 0.07 to 0.16 cm with good consistency between the 1 cm and 7mm bands, so these appear to be real changes.

In various observations, it has been noticed that the focus can vary significantly from the expected values. For example, changes over the course of a night of a couple of millimeters were seen recently at one station, causing the focus vs elevation curve to look significantly different during source rise and set. Variations of this magnitude could cause significant problems at 3mm. At the moment, such changes are not fully understood. Temperature variations could cause changes of that magnitude, but the temperature was constant during the incident mentioned above. This is clearly an area for future study.

I suggest that the 7mm or 1cm focus be checked on a regular basis, perhaps at startup, to catch quickly any shift in focus. The data presented here show that such a shift probably happened some time in the past at SC while the recent FD incident shows that it can happen now. We might be able to build such a check into startup pointing, or it might be a separate test.

Note — all focus positions in this memo are in cm as they are reported by *FIT*, the program that derives the pointing pattern results and provides the data for the focus analysis program. But *SARA* reports focus values in mm, and that is what is needed when putting values in through the FEPARM screens.

2 Summary of Recommendations.

- Adjust many of the focus values (those in bold font in Table 2). Set the focus variation to 0.65 cm for 2cm at all except MK which should retain its current value. For FD and for all antennas at 7mm, more recent measurements may supersede those in Table 1.
- Put a break in the gain values for all receivers for which the focus is changed.
- Offset the 4cmsx focus by -0.3 cm from peak to help 13cmsx (this change is included in the recommended new values).
- Check the focus values at the 20 cm band.
- Use the average offsets from 7mm in the future for focus checks and emergency setting.
- Check focus at 7mm or 1cm regularily.
- Occasionally double check that the focus in use follows the expected pattern between bands.
- Once all changes are done, do an all bands check at all stations.

TABLE 2
Results of Focus Observations

Sta.	Band	F^0	F^0_{var}	F^0_{40}	F_{40}	$F_{40} - F^0_{40}$	Gain loss	$F^0_{40} - F^{7mm}_{40}$	F_{40} - F^{7mm}_{40adj}	New F^0
		cm	cm	cm	cm	cm	%	cm	cm	cm
SC	7mm	8.15	0.70	8.60	8.72	0.12	3.0	0.00	0.00	**8.27**
HN	7mm	9.45	0.75	9.93	9.88	-0.05	0.5	0.00	0.00	9.40
NL	7mm	6.15	0.72	6.61	6.52	-0.10	2.1	0.00	0.00	**6.05**
FD	7mm	8.80	0.65	9.22	9.40	0.19	7.8	0.00	0.00	8.99 (**9.42**)[1]
LA	7mm	9.61	0.65	10.03	10.20	0.17	6.4	0.00	0.00	**9.78**
PT	7mm	8.35	0.89	8.92	9.10	0.18	6.9	0.00	0.00	**8.53**
KP	7mm	8.40	0.68	8.84	8.99	0.15	4.7	0.00	0.00	**8.55**
OV	7mm	7.94	0.68	8.38	8.38	0.00	0.0	0.00	0.00	7.94
BR	7mm	10.76	0.20	10.89	11.04	0.15	3.6	0.00	0.00	**10.91**
MK	7mm	8.75	0.75	9.23	9.17	-0.07	1.0	0.00	0.00	**8.68**
SC	1cm	8.40	0.60	8.79	8.61	-0.18	2.0	-0.11	-0.07	**8.22**
HN	1cm	9.20	0.60	9.59	9.79	0.21	3.0	-0.09	-0.05	**9.41**
NL	1cm	6.20	0.62	6.60	6.46	-0.14	1.2	-0.06	-0.02	**6.06**
FD	1cm	8.75	0.68	9.19	9.36	0.17	1.9	-0.04	0.00	8.92 (**9.44**)[1]
LA	1cm	9.60	0.67	10.03	10.19	0.16	1.6	-0.01	0.03	**9.76**
PT	1cm	8.54	0.83	9.07	9.13	0.05	0.2	0.03	0.07	8.59
KP	1cm	8.32	0.81	8.84	8.98	0.14	1.3	-0.01	0.03	**8.46**
OV	1cm	7.95	0.56	8.31	8.37	0.06	0.2	-0.01	0.03	8.01
BR	1cm	10.50	0.69	10.94	10.83	-0.11	0.7	-0.21	-0.17	**10.39**
MK	1cm	8.65	0.60	9.04	9.16	0.13	1.0	-0.01	0.03	**8.78**
SC	2cm	8.40	0.00	8.40	8.43	0.03	0.0	-0.29	0.05	**8.01**[2]
HN	2cm	9.56	0.00	9.56	9.59	0.03	0.0	-0.29	0.05	**9.17**[2]
NL	2cm	6.70	0.00	6.70	6.25	-0.45	6.9	-0.27	0.07	**5.83**[2]
FD	2cm	9.30	0.00	9.30	9.01	-0.29	2.8	-0.39	-0.05	8.60 (**9.06**)[1, 2]
LA	2cm	10.10	0.00	10.10	9.71	-0.39	5.6	-0.49	-0.15	**9.29**[2]
PT	2cm	8.92	0.00	8.92	8.81	-0.11	0.4	-0.29	0.05	**8.39**[2]
KP	2cm	8.74	0.00	8.74	8.59	-0.15	0.8	-0.40	-0.06	**8.17**[2]
OV	2cm	8.24	0.00	8.24	7.97	-0.27	2.5	-0.41	-0.07	**7.55**[2]
BR	2cm	11.00	0.00	11.00	10.80	-0.20	1.2	-0.24	0.10	**10.39**[2]
MK	2cm	8.83	0.60	9.22	8.80	-0.41	6.2	-0.37	-0.03	**8.42**
SC	4cm	9.13	0.00	9.13	8.26	-0.87	7.3	-0.46	-0.07	**8.26**
HN	4cm	9.55	0.00	9.55	9.49	-0.06	0.0	-0.39	0.00	9.49
NL	4cm	6.20	0.00	6.20	6.18	-0.02	0.0	-0.34	0.05	6.18
FD	4cm	8.78	0.00	8.78	9.01	0.23	0.5	-0.39	0.00	9.01 (**9.47**)[1]
LA	4cm	9.80	0.00	9.80	9.80	0.00	0.0	-0.40	-0.01	9.80
PT	4cm	8.61	0.00	8.61	8.81	0.20	0.4	-0.29	0.10	8.81
KP	4cm	8.49	0.00	8.49	8.65	0.16	0.2	-0.34	0.05	8.65
OV	4cm	7.65	0.00	7.65	7.92	0.27	0.7	-0.46	-0.07	**7.92**
BR	4cm	10.65	0.00	10.65	10.50	-0.15	0.2	-0.54	-0.15	10.50
MK	4cm	8.88	0.00	8.88	8.77	-0.11	0.1	-0.40	-0.01	8.77

[1] For FD, values in parentheses are adjusted for a recent change.
[2] Use 0.65 for the focus variation at 2cm except MK.

TABLE 1 (Continued)

Sta.	Band	F^0 cm	F^0_{var} cm	F^0_{40} cm	F_{40} cm	Error cm	Amp loss %	$F^0_{40} - F^{7mm}_{40}$ cm	F_{40} - F^{7mm}_{40adj} cm	New F^0 cm
SC	4cmsx	8.44	0.00	8.44	8.64	0.20	0.4	-0.08	0.09	**8.34**
HN	4cmsx	10.10	0.00	10.10	9.56	-0.54	2.7	-0.32	-0.15	**9.26**
NL	4cmsx	6.45	0.00	6.45	6.45	0.00	0.0	-0.07	0.10	**6.15**
FD	4cmsx	8.97	0.00	8.97	9.29	0.32	0.9	-0.11	0.06	8.99 (**9.45**)[1]
LA	4cmsx	10.00	0.00	10.00	9.91	-0.09	0.1	-0.29	-0.12	**9.61**
PT	4cmsx	8.55	0.00	8.55	8.95	0.40	1.5	-0.15	0.02	8.65
KP	4cmsx	8.64	0.00	8.64	8.87	0.23	0.4	-0.12	0.05	8.57
OV	4cmsx	8.25	0.00	8.25	8.16	-0.09	0.1	-0.22	-0.05	**7.86**
BR	4cmsx	10.10	0.00	10.10	10.77	0.67	3.9	-0.27	-0.10	**10.47**
MK	4cmsx	9.04	0.00	9.04	9.03	-0.01	0.0	-0.14	0.03	**8.73**
SC	6cm	9.16	0.00	9.16	7.90	-1.26	5.2	-0.82	-0.01	**7.90**
HN	6cm	9.23	0.00	9.23	9.06	-0.17	0.1	-0.82	-0.01	9.06
NL	6cm	5.75	0.00	5.75	5.67	-0.08	0.0	-0.85	-0.04	5.67
FD	6cm	8.50	0.00	8.50	8.62	0.12	0.0	-0.78	0.03	8.62 (**9.08**)[1]
LA	6cm	9.50	0.00	9.50	9.30	-0.20	0.1	-0.90	-0.09	9.30
PT	6cm	8.30	0.00	8.30	8.35	0.05	0.0	-0.75	0.06	8.35
KP	6cm	8.28	0.00	8.28	8.25	-0.03	0.0	-0.74	0.07	8.25
OV	6cm	7.36	0.00	7.36	7.50	0.14	0.1	-0.88	-0.07	7.50
BR	6cm	10.25	0.00	10.25	10.15	-0.10	0.0	-0.89	-0.08	10.15
MK	6cm	8.24	0.00	8.24	8.42	0.18	0.1	-0.75	0.06	8.42
SC	13cm	7.43	0.00	7.43	6.54	-0.89	0.5	-2.18	-0.18	6.54
HN	13cm	7.20	0.00	7.20	7.84	0.64	0.3	-2.04	-0.04	7.84
NL	13cm	4.00	0.00	4.00	4.54	0.54	0.2	-1.98	0.02	4.54
FD	13cm	7.08	0.00	7.08	7.43	0.35	0.1	-1.97	0.03	7.43 (**7.89**)[1]
LA	13cm	8.20	0.00	8.20	8.08	-0.12	0.0	-2.12	-0.12	8.08
PT	13cm	6.50	0.00	6.50	6.97	0.47	0.1	-2.13	-0.13	6.97
KP	13cm	6.80	0.00	6.80	6.92	0.12	0.0	-2.07	-0.07	6.92
OV	13cm	6.10	0.00	6.10	6.21	0.11	0.0	-2.17	-0.17	6.21
BR	13cm	10.35	0.00	10.35	9.07	-1.28	1.1	-1.97	0.03	**9.07**
MK	13cm	7.68	0.00	7.68	7.14	-0.54	0.2	-2.03	-0.03	7.14
SC	13cmsx	8.44	0.00	8.44	7.30	-1.14	1.1	-1.42	0.58	
HN	13cmsx	10.10	0.00	10.10	7.90	-2.20	3.3	-1.98	0.02	
NL	13cmsx	6.45	0.00	6.45	4.97	-1.48	1.5	-1.55	0.45	
FD	13cmsx	8.97	0.00	8.97	7.64	-1.33	1.2	-1.76	0.24	
LA	13cmsx	10.00	0.00	10.00	8.07	-1.93	2.3	-2.13	-0.13	
PT	13cmsx	8.55	0.00	8.55	7.42	-1.13	0.9	-1.68	0.32	
KP	13cmsx	8.64	0.00	8.64	7.02	-1.62	1.6	-1.97	0.03	
OV	13cmsx	8.25	0.00	8.25	6.04	-2.21	2.9	-2.34	-0.34	
BR	13cmsx	10.10	0.00	10.10	8.90	-1.20	0.9	-2.14	-0.14	
MK	13cmsx	9.04	0.00	9.04	7.37	-1.67	1.9	-1.80	0.20	

[1] For FD, values in parentheses are adjusted for recent change.

[2] Use 0.65 for the focus variation at 2cm except MK.