VLBA TEST MEMO 64

Checking VLBA Polarization Using the Squint

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1. Background.

It is possible to check almost all of the equipment at a VLBA site using available status information, pointing, readback tests, gps, lock tests, and the pulse cal system. Basically, if all of these tests give good results, about the only things that can still be wrong are the receiver polarization and and just possibly something in the maser. In practical experience, the polarization is the main item that has been wrong. I'm not sure of the statistics, but something like 10% of receivers end up being mounted with the polarization crossed. In the past, it was thought that the only way to check this was with real time fringe tests or with actual recorded observations. But the real time fringe tests have been very unsatisfactory for reasons that are not fully understood and anything involving recording takes days to complete.

A few months ago, I realized that we do indeed have a simple test for polarization available in data that we are already collecting. With the offset feed geometry used on both the VLA and VLBA, there is an offset between the pointing positions of the RCP and LCP beams. This offset is called the squint. It amounts to about 5% of the beam full width, half maximum (FWHM) and is easily seen in the pointing observations. In fact, one of the first steps that the pointing analysis program, *PTANAL*, does is to measure the squint and correct all data points to correspond to the desired pointing position half way between the beams. The squint is in the direction of the position of the feed on the feed ring. The test for polarization is to check the squint direction. If the system is cross polarized, the squint direction will be reversed.

A recent incident, where crossed polarization at MK at 7mm was not detected for over 4 months, has prompted me to first investigate the use of squint to detect polarization problems, and to implement a check in *PTANAL*. We are also considering changes to the sniffer to help catch crossed polarizations faster using any programs correlated with full polarization products.

It turns out that the squint can even be used at 50/90 cm to detect polarization. While the prime focus feed system does not have the full offset geometry of the other bands, the asymmetric subreflector empirically gives a systematic squint. The direction of the squint agrees well with that seen at 20 cm which is not surprising because the rotation position for 50/90 cm is the same as 20 cm to allow for multi-band observations. There is one current exception at BR where the squint is low in magnitude and deviates from the expected angle by more than 90 degrees at 50cm. Sniffer tests indicate that this system is not crossed, so I have built this exception into *PTANAL*. Of course, this means that a code change will be required if the situation at BR is altered.

2. Some Sample Data

Here I have extracted data from one of the big pointing equation analysis runs. Several pointing runs over a couple of months were combined to form a data set containing a minimum of 71 data points at any frequency/band (over 130 at the vast majority) with over 300 at 1cm and 600 at 7mm at each station. This is a fairly typical data set of the sort I use to check pointing equations. I have not included 3mm, but a quick look at a few stations shows no surprises.

Squint data from *PTANAL* from the "End2000" data set (arc minutes):

		90cm	50cm	21cm	18cm	13cm	13cmsx	6cm	4cm	4cmsx	2cm	1cm	7mm
SC	Az:	-0.19	-0.94	-1.46	-1.43	0.51	0.50	0.40	-0.17	-0.64	0.11	0.10	0.01
SC	El:	-0.76	-0.47	-0.56	-0.53	0.83	0.77	-0.12	0.21	0.23	-0.11	0.04	-0.05
HN	Az:	-2.27	-1.40	-1.27	-1.44	0.32	0.30	0.48	-0.16	-0.57	0.15	0.06	0.02
HN	El:	-0.33	-0.61	-0.68	-0.56	0.89	0.86	-0.14	0.22	0.21	-0.10	0.02	-0.05
NL	Az:	-0.25	-1.49	-1.66	-1.60	0.43	0.42	0.48	-0.17	-0.47	0.11	0.07	0.01
NL	El:	-2.76	-1.28	-0.66	-0.49	1.03	0.96	-0.13	0.22	0.23	-0.09	0.03	-0.04
FD	Az:	-1.53	-2.72	-1.55	-1.32	0.33	0.36	0.49	-0.16	-0.45	0.09	0.10	0.02
FD	El:	-0.77	0.48	-0.55	-0.55	0.86	0.81	-0.14	0.21	0.20	-0.10	0.04	-0.05
LA	Az:	-1.55	-3.30	-1.56	-1.34	0.62	0.49	0.48	-0.17	-0.48	0.10	0.11	0.02
LA	El:	-1.47	-2.07	-0.72	-0.61	0.89	0.83	-0.14	0.23	0.19	-0.08	0.01	-0.04
PT	Az:	-1.28	-1.50	-1.64	-1.30	0.63	0.55	0.47	-0.19	-0.42	0.06	0.10	0.01
PT	El:	-2.15	-1.67	-0.59	-0.41	0.89	0.92	-0.15	0.23	0.18	-0.08	0.04	-0.05
KP	Az:	-1.10	-4.39	-1.60	-1.68	0.79	0.79	0.51	-0.17	-0.51	0.11	0.09	0.01
KP	El:	-1.60	1.88	-0.60	-0.47	0.84	0.97	-0.05	0.21	0.21	-0.11	0.04	-0.04
OV	Az:	-1.74	-1.38	-1.74	-1.35	0.52	0.49	0.50	-0.18	-0.46	0.12	0.09	0.12
OV	El:	-1.27	-2.05	-1.03	-0.97	0.98	0.92	-0.10	0.23	0.16	-0.11	0.03	-0.14
BR	Az:	-0.74	0.50	-1.69	-1.41	0.45	0.45	0.48	-0.16	-0.48	0.13	0.03	0.02
BR	El:	-0.69	-0.19	-0.62	-0.56	0.81	0.77	-0.12	0.21	0.19	-0.14	0.03	-0.05
MK	Az:	-1.68	0.42	-1.57	-1.33	0.54	0.50	0.49	-0.17	-0.44	0.11	0.07	0.02
MK	El:	-0.26	-3.41	-0.69	-0.50	0.90	0.85	-0.12	0.21	0.18	-0.11	0.03	-0.05

Below are the same data but converted to amplitude (arc minutes) and angle. The angle is in counterclockwise degrees measured from the elevation axis. These are to be compared with the angles on the feed cone drawings but do not confuse them with the FRM encoder angles set at the antenna or put in the monitor data. The FRM encoder angles have a different zero at each antenna.

		90cm	50cm	21cm	18cm	13cm	13cmsx	6cm	4cm	4cmsx	2cm	1cm	7mm
SC	Amp:	0.78	1.05	1.56	1.53	0.97	0.92	0.42	0.27	0.68	0.16	0.11	0.05
SC	Ang:	-166.	-117.	-111.	-110.	32.	33.	107.	-39.	-70.	135.	68.	169.
HN	Amp:	2.29	1.53	1.44	1.55	0.95	0.91	0.50	0.27	0.61	0.18	0.06	0.05
HN	Ang:	-98.	-114.	-118.	-111.	20.	19.	106.	-36.	-70.	124.	72.	158.
NL	Amp:	2.77	1.96	1.79	1.67	1.12	1.05	0.50	0.28	0.52	0.14	0.08	0.04
NL	Ang:	-175.	-131.	-112.	-107.	23.	24.	105.	-38.	-64.	129.	67.	166.

FD	Amp:	1.71	2.76	1.64	1.43	0.92	0.89	0.51	0.26	0.49	0.13	0.11	0.05
FD	Ang:	-117.	-80.	-110.	-113.	21.	24.	106.	-37.	-66.	138.	68.	158.
LA	Amp:	2.14	3.90	1.72	1.47	1.08	0.96	0.50	0.29	0.52	0.13	0.11	0.04
LA	Ang:	-133.	-122.	-115.	-114.	35.	31.	106.	-36.	-68.	129.	85.	153.
PT	Amp:	2.50	2.24	1.74	1.36	1.09	1.07	0.49	0.30	0.46	0.10	0.11	0.05
PT	Ang:	-149.	-138.	-110.	-108.	35.	31.	108.	-40.	-67.	143.	68.	169.
KP	Amp:	1.94	4.78	1.71	1.74	1.15	1.25	0.51	0.27	0.55	0.16	0.10	0.04
KP	Ang:	-145.	-67.	-111.	-106.	43.	39.	96.	-39.	-68.	135.	66.	166.
OV	Amp:	2.15	2.47	2.02	1.66	1.11	1.04	0.51	0.29	0.49	0.16	0.09	0.18
OV	Ang:	-126.	-146.	-121.	-126.	28.	28.	101.	-38.	-71.	133.	72.	139.
BR	Amp:	1.01	0.53	1.80	1.52	0.93	0.89	0.49	0.26	0.52	0.19	0.04	0.05
BR	Ang:	-133.	111.	-110.	-112.	29.	30.	104.	-37.	-68.	137.	45.	158.
MK	Amp:	1.70	3.44	1.71	1.42	1.05	0.99	0.50	0.27	0.48	0.16	0.08	0.05
MK	Ang:	-99.	173.	-114.	-111.	31.	30.	104.	-39.	-68.	135.	67.	158.

Below are the averages using all of the data from all stations. Also shown are the rms deviations from the averages. Columns 6 and 7 show the averages expressed as an amplutude and angle rather than as azimuth and elevation terms. The final column shows the position of the feed on the feed ring for most bands and the subreflector rotation setting used for observations in the case of the 50/90cm prime focus system.

BAND	AZavg	AZrms	ELavg	ELrms	AMP	Angle	Feed
90cm	-1.23	0.67	-1.21	0.81	1.72	226.	251.
50cm	-1.62	1.53	-0.94	1.50	1.87	240.	251.
21cm	-1.57	0.13	-0.67	0.14	1.71	247.	251.
18cm	-1.42	0.13	-0.56	0.15	1.53	248.	251.
13cm	0.51	0.14	0.89	0.07	1.03	30.	32.
13cmsx	0.48	0.13	0.87	0.07	0.99	29.	32.
6cm	0.48	0.03	-0.12	0.03	0.49	104.	108.
4cm	-0.17	0.01	0.22	0.01	0.28	322.	323.
4cmsx	-0.49	0.07	0.20	0.02	0.53	292.	32.
2cm	0.11	0.02	-0.10	0.02	0.15	133.	138.
1cm	0.08	0.02	0.03	0.01	0.09	69.	78.
7mm	0.03	0.03	-0.06	0.03	0.06	155.	155.

The next table is essentially the same as the last one except that the average was taken a second time rejecting any station that deviated by more than 1.5 sigma. The new final column shows the number of stations used for the average. Given that a few stations have deviant values, these edited averages are the best to use as the standards for comparison. Note the very good agreement between the feed position angle and the squint angle. In fact, the largest offsets other than 4cmsx are at the highest frequencies where the errors due to the fact that I am only working with ascii numbers with two places beyond the decimal can cause much of the error. The results for 4cmsx are not too surprising given that this signal has two additional offset reflections. The theoretical expectation for the ellipsoid/dichroic combination is not known to me.

BAND	AZavg	AZrms	ELavg	ELrms	AMP	Angle	Feed	NACC
90cm	-1.37	0.36	-1.17	0.64	1.81	230.	0.	7
50cm	-1.53	1.14	-0.98	0.93	1.82	237.	0.	8
21cm	-1.59	0.07	-0.62	0.06	1.71	249.	251.	8
18cm	-1.40	0.10	-0.53	0.06	1.49	249.	251.	8
13cm	0.49	0.12	0.88	0.05	1.01	29.	32.	8
13cmsx	0.45	0.08	0.85	0.07	0.97	28.	32.	9
6cm	0.48	0.01	-0.13	0.02	0.50	105.	108.	8
4cm	-0.17	0.01	0.22	0.01	0.27	322.	323.	9
4cmsx	-0.48	0.05	0.20	0.02	0.52	293.	32.	8
2cm	0.11	0.01	-0.10	0.01	0.15	133.	138.	7
1cm	0.09	0.02	0.03	0.01	0.09	68.	78.	8
7mm	0.02	0.01	-0.05	0.00	0.05	162.	155.	9

Finally I show the deviations from the edited averages of the individual station data. The comparison is done as a ratio of amplitudes and as a deviation of the angle. Any station/band that has more than a 20% amplitude offset or more than a 20 degree angle offset is flagged.

	90cm	50cm	21cm	18cm	13cm	13cmsx	6cm	4cm	4cmsx	2cm	1cm	7mm
SC Amp ratio:	0.43	0.58	0.91	1.02	0.97	0.95	0.83	0.99	1.31	1.05	1.18	1.04
SC Angle diff:	-35.	6.	0.	0.	2.	5.	2.	-1.	-3.	2.	0.	7.
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HN Amp ratio:	1.27	0.84	0.84	1.04	0.94	0.94	1.00	0.99	1.17	1.22	0.69	1.09
HN Angle diff:	32.	9.	-7.	-1.	-9.	-9.	1.	2.	-2.	-10.	3.	-3.
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NL Amp ratio:	1.53	1.08	1.05	1.12	1.11	1.08	0.99	1.01	1.01	0.96	0.83	0.84
NL Angle diff:	-44.	-8.	0.	4.	-6.	-4.	0.	0.	3.	-4.	-2.	4.
FD Amp ratio:	0.95	1.52	0.96	0.96	0.91	0.92	1.02	0.96	0.95	0.91	1.18	1.09
FD Angle diff:	14.	43.	2.	-2.	-8.	-4.	1.	0.	1.	5.	0.	-3.
LA Amp ratio:	1.18	2.14	1.01	0.99	1.08	1.00	1.00	1.04	1.00	0.87	1.21	0.91
LA Angle diff:	-3.	1.	-3.	-4.	6.	3.	1.	1.	-1.	-5.	16.	-8.

PT Amp ratio:	1.38	1.24	1.02	0.91	1.08	1.11	0.98	1.09	0.88	0.68	1.18	1.04
PT Angle diff:	-19.	-15.	2.	3.	6.	3.	3.	-2.	1.	10.	0.	7.

KP Amp ratio:	1.07	2.63	1.00	1.17	1.14	1.29	1.02	0.99	1.07	1.05	1.08	0.84
KP Angle diff:	-15.	56.	1.	5.	14.	11.	-9.	-1.	0.	2.	-2.	4.

OV Amp ratio:	1.19	1.36	1.18	1.11	1.10	1.08	1.02	1.07	0.94	1.10	1.04	3.75
OV Angle diff:	4.	-23.	-9.	-15.	-1.	0.	-4.	0.	-3.	-1.	3.	-22.

BR Amp ratio:	0.56	0.29	1.05	1.02	0.92	0.92	0.99	0.96	1.00	1.29	0.46	1.09
BR Angle diff:	-3.	-126.	1.	-1.	0.	2.	-1.	0.	-1.	4.	-23.	-3.
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MK Amp ratio:	0.94	1.89	1.00	0.95	1.04	1.02	1.01	0.99	0.92	1.05	0.83	1.09
MK Angle diff:	32.	-64.	-2.	0.	2.	3.	-1.	-1.	0.	2.	-2.	-3.

The most deviant value in this table is at 7mm at OV where there is a squint of nearly 4 times the normal size. This probably indicates some problem with the optical alignment, but it is not yet clear what. The offsets at BR are probably not too surprising since that site is known to have a fairly serious astigmatism. HN also has surface problems, probably in panel adjustment, although it is not clear that they should affect the squint.

In any case, the largest angle deviation in this table from the average value is 23 degrees. The actual data were taken during the polarization problem at 7mm at MK and the actual squint values were of opposite sign to the ones shown above. I corrected the ones above to help get good averages. With the original signs, the angle offset for MK was close to 180 degrees demonstrating the ability to detect crossed polarization.

I have modified *PTANAL* to detect deviant squints. It will give a low level check message for amplitudes deviating from those expected by more than 60% and angles deviating by more than 30 degrees. The tolerances are higher at 50/90 cm. If the angle deviates by more than 90 degrees from the expected value, a high level check flag is written to the check file, tick marks are written below the squint in the summary file, and a messages appears on the screen while the program is running. The check message and screen message indicate a probable cross polarization. I hope this will help ensure that we catch polarization problems quickly in the future.