NATIONAL RADIO ASTRONOMY OBSERVATORY

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VLA Test Memorandum No. 111

A ROUGH MEASUREMENT OF THE POLARIZATION PROPERTIES OF THE VLA ANTENNA

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It has been noted that the VLA antenna has a small divergence between the left and right circularly polarized beams. This may also be considered to be an antisymmetric pair of circularly polarized sidelobes. As such, it is informative to consider them in the context of the other polarization sidelobes. Although no measurements have been directed toward this subject, a rough measurement can come from analysis of the standard pointing observations. This requires the injection of a strong note of caution: The standard pointing utilizes offsets only in the principal directions, horizontal and vertical; for the classical deep dish prime fed paraboloid, these directions are lines of nulls between polarization sidelobes.

For an equatorially mounted paraboloid the cross polarized sidelobes may simply be subtracted from the final map. For an az-el antenna, the situation is more complicated. Several maps may be made, each covering a narrow range of paralactic angle. Each map may then be corrected for cross polarization and then the ensemble combined for the final map. More computationally tractable, one may smear the polarization sidelobe map according to the time spent at each paralactic angle, and subtract this correction from the final map.

This memorandum is based on ten minutes observation made on May 25. The radio source was 3C147, which for the purpose of examining polarization sidelobes, may be considered quite unpolarized. The frequency was 4750MHz, bandwidth 25MHz. The source was observed with antenna two tracking the source, and antenna one moving successively to the on-source position and then to the 3db points on the beam in elevation and in azimuth. I shall present the analysis in great detail, as it is an unfamiliar one for me, and somewhat susceptible to factor-of-two errors, which I shall trust my lynx-eyed readers to immediately inform me of. The raw observations, amplitude and phase, are given in Table I. Amplitudes are in arbitrary units; they may be multiplied by a factor of about 5 to convert to Janskys.

RMS noise amounts to about 4 units in the last place.

Clearly, if we had been better organized, we would have rotated LO phases to get zero phase on the parallel hands, and we would have adjusted effective gains to get equal amplitudes in the RR and LL hands. This is done in Table II. The phases were rotated by assuming that the phase rotation was done in antenna one and the gain adjustments were chosen to make the on-source amplitudes equal to unity.

Also, if we had been better organized, we would have subtracted an appropriate beam center cross polarization. This is done in Table III under the assumption that all the cross polarization arises in antenna one. (This assumption does not affect the conclusions.) The beam center linear polarization ($.021\angle{-43^{o}}$ for RL, $.030\ \angle{20^{o}}$ for LR) is multiplied by the appropriate parallel hand correlator (RR for RL and LL for LR) and subtracted from the measured linear polarization vector.

What we are really interested in is not the properties of a single antenna (using the other as a reference) but what happens to a source at the edge of the field of view. Therefore, we want to calculate what the result would have been if we had observed the source with two antennas, both displaced relative to the source, both identical to antenna one. This is done in Table IV. The RR and LL visibilities are multiplied by their complex conjugates. The RL coefficient is multiplied by the LL visibility (to reduce its power due to the reduction of source power in the 2L IF as antenna two moves off source), and is added to the complex conjugate of the LR component similarly treated (the cross polarization induced in antenna two by moving off source). LR is not shown in the table since LR must be the Hermitian conjugate of RL for identical antennas and an unpolarized point source.

These numbers are converted into the usual percentage polarization in Table V. The column headed I/2 is (RR + LL)/2. The circular polarization is (RR - LL)/(RR + LL). The linear polarization is RL/(I/2). The direction of the linear polarization depends on the relative phases of the right and left IF signals. It must be calibrated by observing a strongly polarized source at known direction of polarization. For present purposes it is completely unknown.

We may reach the following conclusions. 1) With the existing, prototype, system the VLA is not useful for the measurement of circular polarization at wavelengths shorter than 18 cm. At 6 cm for instance, a 20" pointing error (quite within the bounds of expectation) introduces an apparent 1% circular polarization. 2) The linear polarization is large and annoying. After the more straight forward corrections, I would expect errors of 1½-2% in the percentage polarization at 21 cm and 6 cm and 2-3% at the higher frequencies. The instrument is still well suited to linear polarization measurements, especially since linear polarizations are frequently quite high on a small scale, but a reduction of a factor of about two in the polarized sidelobes is highly desirable.

Postscript: The measurements were repeated on July 6-7 using the source 3C273. The new 6 cm feed was used, and the antenna was allowed to dwell at each position for 3 minutes, rather than the 20 seconds in the observations above. Otherwise, the observations and reductions were identical, with the results shown in Table VI. These generally confirm the remarks about circular polarization above. However, the new 6cm feed is a factor of 3 better in linearly polarized sidelobes, making this aspect entirely satisfactory.

TABLE I
OBSERVED QUANTITIES

	RR		LL		RL		LR	
On	2.12	70	2.05	-151	.063	90	.045	156
+El	1.30	72	1.44	-148	.044	-116	.065	101
-El	1.50	64	1.24	-161	.072	99	.123	115
+Az	1.37	54	1.44	-164	.068	44	.094	-177
-Az	1.44	65	1.25	-156	.052	103	.042	154

TABLE II
CORRECTION FOR PHASES AT BEAM CENTER - NORMALIZED

	RR		LL		RL		LR	
On	1.000	0	1.000	0	.030	160	.021	5
+El	.613	2	.702	3	.021	-46	.031	-50
-El	.708	-6	.605	-10	.059	-175	.034	-52
+Az	.646	-16	.702	-13	.032	114	.045	32
-Az	.679	-5	.610	-5	.025	173	.020	3

TABLE III
CORRECTION FOR BEAM CENTER LINEAR POLARIZATION

	RR		LL		RL		LR	
On	1.000	0	1.000	0	.000		.000	
+El	.613	2	.702	3	.039	-34	.025	-76
-El	.708	-6	.605	-10	.042	-164	.029	-76
+Az	.646	-16	.702	-13	.023	77	.033	44
-Az	.679	-5	.610	-5	.008	-144	.606	0

TABLE IV
EQUIVALENT QUANTITIES FOR IDENTICAL ANTENNAS

	RR		LL		RL	
On	1.000	0	1.000	0	.000	
+El	.376	0	.493	0	.025	4
-El	.501	0	.366	0	.024	154
+Az	.417	0	.493	0	.019	-1
-Az	.461	0	.372	0	.003	-90

TABLE V
QUANTITIES CONVERTED TO PERCENTAGE POLARIZATIONS

	I/2	Circular	Linear
On	1.000	0	0
+El	.434	-13.5%	5.8%
-El	.434	15.6	5.5
+Az	.455	-8.4	4.2
-Az	.416	10.7	0.7

TABLE VI

Direction of Offset		I/2	Circular Polarization	Linear Polarization
0^{o}	(+El)	.519	-2.4%	0.9%
45^{o}		.506	-7.2	2.1
90^{o}	(+Az)	.427	-7.2	0.7
135^{o}		.387	-2.6	0.7
180^{o}	(-El)	.364	5.2	0.5
-135^{o}		.405	9.9	2.2
-90^{o}	(-Az)	.457	9.4	1.5
-45^{o}		.532	4.0	0.7