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EVLA MEMO 190

IMAGING TESTING OF THE 4BAND MJP DIPOLE FEEDS

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ABSTRACT

Imaging testing of six production MJP 4band feeds is described. The new mounts appear to be robust and the impact of the system on higher frequencies is undetectable. The optimally usable range of frequencies for most VLA science is 72-84 MHz, although the 54-72 MHz range is useful for some experiments. At 74 MHz, the MJP feeds appear to be of similar efficiency to the old Erickson dipoles and the net sensitivity of a fully MJP-equipped VLA projects to be at least 2-4X better than the old VLA.

1. INTRODUCTION

In EVLA memo 174, testing of two prototype MJP (modified-J-Pol) feeds covering the 54-86 MHz window, i.e. 4band, is documented. These feeds were mounted in a strut-straddling configuration as described in EVLA memo 173. EVLA memo 172 documents the MJP design itself. The goal of the work described in these memos is to produce an alternative feel design for 4band to cover the wider bandwidths available due to the dramatically reduced TV interference and the wider bandwidths available using WIDAR, without the negative impact of the on-axis Erickson feeds on higher frequency observations. The novel ideas of Steve Ellingson were shown to be practical and to meet the requirements of the EVLA electronics and dynamic operation.

Memo 174 shows that the MJP feeds have a sensitivity per unit bandwidth comparable to the on-axis, mounted Erickson dipole feeds, using an Allen phase variance technique, originally invented by Ravi Subrahmanyan. Nonetheless, for a production system appropriate for permanent use on the entire array, more work was needed. The mounting system was for demonstration and not intended to survive on the antenna for very long. Also the prototype system had shown a number of 4band receiver failures during testing, apparently due to transient power surges. Furthermore, it seemed important demonstrate the feed performance by imaging the sky and measuring the noise on the resulting images.

In order to move the demonstration experiment into a permanent system, it was decided in September 2013 to build six new dipole feeds using a robust mounting system designed by a mechanical engineer, to add a surge protector to the 4band receiver, and perform imaging tests of the resulting system to demonstrate its viability for long term scientific use on the VLA.

The project was delayed by the government shutdown and various budget woes. The new mounts (designed by Silver Sturgis), feeds (using the Ellingson design), and the surge protector (designed by Paul Harden) were installed on six antennas, by Dan Mertely and Co., by the end of August, 2014. However, the array was then in D-configuration, too small for imaging, so those tests were delayed until 2015. Various practical issues with the array and the WIDAR correlator delayed imaging testing until April 2015. However, two successful imaging tests were run, one on April 14th for Virgo A and a second on April 28th on a relatively blank field, A2256.

2. GENERAL RESULTS

All non-imaging tests/goals have been successful. The six new mounts survived the winter of 2014/2015 and appear to be robust. The surge protectors appear to have stopped the 4band receiver failures. The impact of the the MJP feeds on higher frequency bands, as tested most completely by Rick Perley during his flux density calibration runs, is too small to be measured. There was very strong, internally generated interference on antenna 14, at 55.3 MHz which resulted from the new ACU installation. It was identified as being due to an unshielded component associated with the fiber optic serial port converter box up at the apex. This was fixed and the interference vanished. Thus the new system has passed all the non-imaging tests.

3. IMAGING RESULTS

Both fields were observed and the initial calibration was done in the same way with the same antenna configuration. All calibration was done in AIPS and all imaging was performed in CASA using the MSMFS algorithm and the W-projection. Three of the six MJP antennas were located at the ends of the arms (E36, W36 and N36), while the other 3 MJPs were at E08, W16 and N20. The WIDAR correlator was configured to observe eight subbands between 54 and 86 MHz, each with a bandwidth of 4 MHz and 256 channels. Cygnus A was used as the bandpass and flux density calibrator. Before observing the target source and again just before observing Cygnus A, the requantizers were calibrated. This step is key to get the full sensitivity from WIDAR. In figure 1, we show a typical bandpass solution derived from Cygnus A, assuming a 74 MHz model for that source and a spectral index of -0.6 over the 54 to 86 MHz. spectral range.

However, due to the shape of the bandpass for the MJP feed, plus the rapidly increasing sky temperature as frequency decreases, the band from 72-84 MHz was found to be optimum for imaging. Taking into account the sensitivity drop at each end of this frequency range,

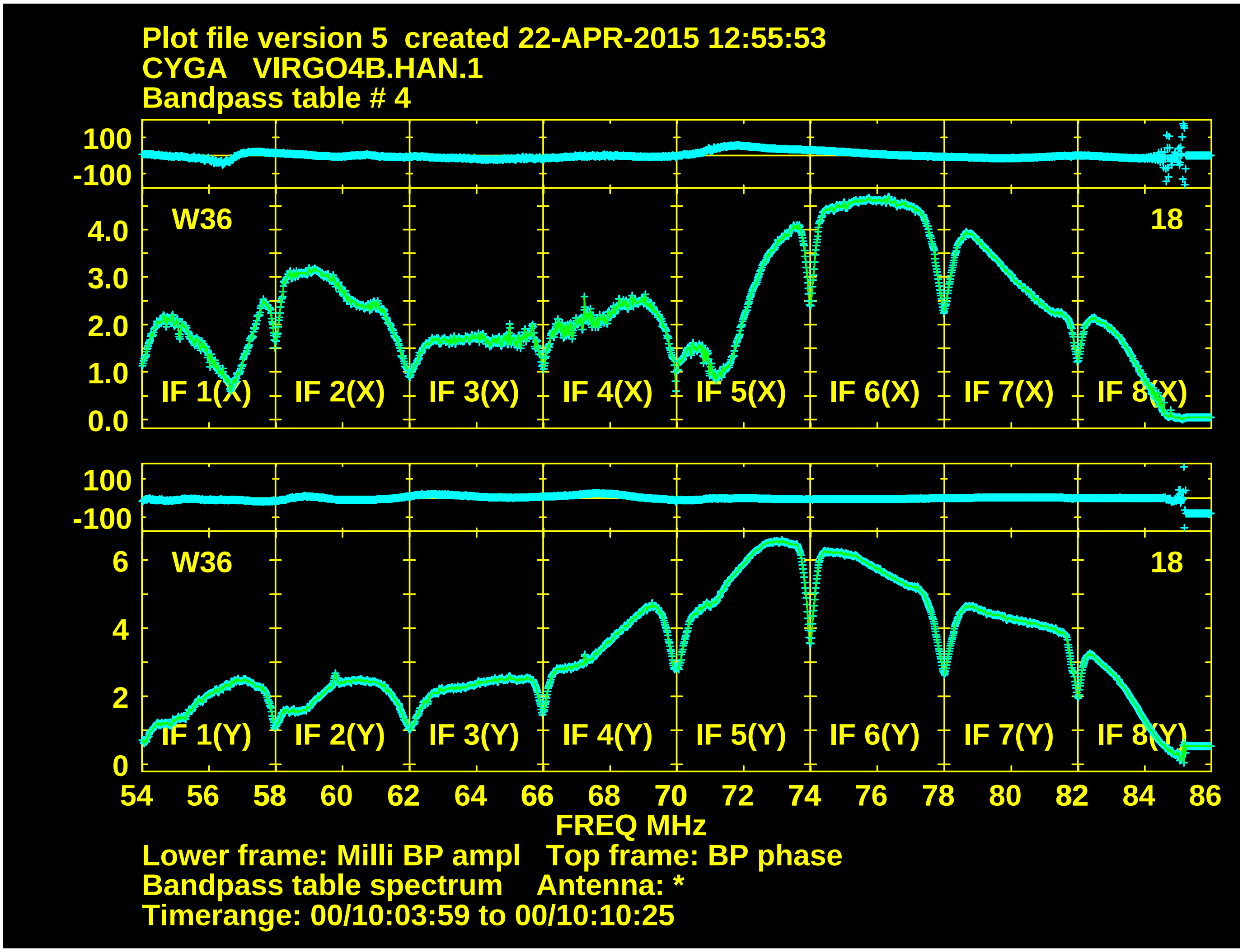

Figure 1. Typical amplitude and phase bandpasses for X and Y polarizations.

this band represents an equivalent bandwidth of about 8 MHz. Comparing this band with the 1.5 MHz of the old system, the increase is effective bandwidth is $\sim 5\times$. Thus all other things being equal, with six antennas we expect the our sensitivity per unit time to be about $2\times$ worse than the old 27 antenna system, if Gain/T_{sys} is about the same for the old and new systems.

Based on the simulations of the performance of the two polarizations on VLA antennas, one expects the X polarization to be 2.5 times less sensitive than the Y polarization (Harun, 2011). This trend was, in fact, observed. Thus the two polarizations were imaged separately and the images optimally combined to produce a final image, based on the observed noise on each image.

The best comparison images are from the 74MHz VLSSr survey (Lane et al, 2012). These result from the full array in the B-configuration with at least 75 minutes of observations. VLSSr has a median rms of 95mJy. For our images and for the VLSSr field near Virgo A, the images are dynamic-range-limited, supposedly more of a problem for the much smaller number of MJP baselines and these poorer uv-coverage than VLSSr. The rms noise on the VLSSr and MJP images was determined using IMEAN in AIPS, which uses the peak in the pixel histogram to estimate and the underlying noise in the presence of detected sources in the field.

3.1. *Virgo A*

Virgo A was observed for 5.5 hours. The Virgo A observation was intended to provide a strong source so that we could calibration the delay changes in the center of the field as a function of time. This worked well and the total observed flux density agreed with the values in the literature to within 10%, although the fidelity was limited by the the small number of observed baselines and, in particular due to lack of short spacings. Thus with the requantizer calibration, flux density calibration transfer worked well from the much stronger Cygnus A to Virgo A. Since Virgo A only contributes modestly to T_{sys}, the results for this source should be similar to a blank field.

However, since Virgo A is relatively bright compared with random sources, it dominates the field and did not allow any other sources in the field to be used for direction dependent delay calibration with only six antennas. The ionosphere was fairly well behaved during these observations and allowed a large region around the field center to be imaged successfully. In Figure 2, we show images of a region near the field center. On the left we show the VLSSr image and on the right the MJP image.

One sees that the brighter sources are seen in both

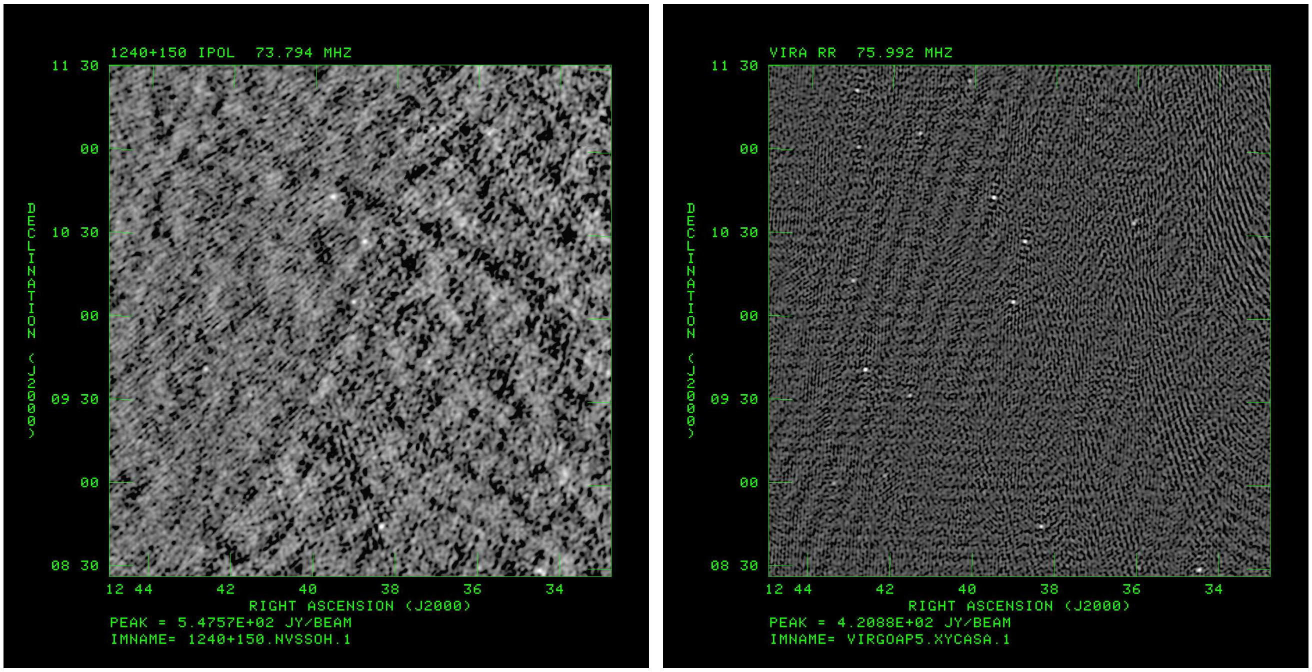

Figure 2. Comparison of regions near Virgo A. Left: VLSSr, Right: MJPs

images; however, in spite of the obvious dynamic range artifacts, the MJP image is clearly deeper, showing more sources. The reality of these additional sources is confirmed by reference to the 1.4 GHz NVSS survey. For the region displayed, the rms noise on the VLSSr image is 197 mJy and for the MJP image the rms noise is 87 mJy. Ignoring the dynamic range issues on each image, the MJP image is more than 2× deeper. Assuming the minimum VLSSr integration time and taking into account, the relative observing time, number of antennas, and bandwidth, one expects the noise to about the same.

3.2. *A2256*

The goal of the A2256 field was to observed a relatively blank field but one which was well understood at low frequencies. It was hoped that direction dependent delay calibration could be used to correct for the ionosphere. However, based on attempts to apply this calibration, it became clear that ionosphere was badly behaved during this observation. The combination of the small number of MJP antennas and the bad ionosphere made position dependent delay calibration impossible.

A2256 was observe for about 3 hours on source. About half this time was somewhat useful. After successful bandpass calibration using Cygnus A, a model of the A2256 region from VLSSr was used to correct the delay for the entire field as a function of time. This was partly successful and allowed an amplitude calibrated image to be produced, which allowed the brightest sources to be seen, although with clear dynamic range issues. The noise on this image is thus an upper limit to the noise the MJP feeds would produce under good conditions. The rms noise over a 10 degree field for the MJP image is 123mJy compared with 136mJy for the same region on VLSSr image. The VLSSr image does not appear to be dynamic range limited. Based on observing time, number of antennas, and bandwidth, one would expect the VLSSr image to be a factor of two lower in rms noise than the MJP image.

4. DISCUSSION

The imaging tests of the new MJP feeds, while never reaching thermal noise, appear to produce lower noise levels than one would guess extrapolating from the old VLA with its narrower bandwidth. The system seems to work at least a factor of two better than one would expect based on this extrapolation. Several things may contribute to this unexpected, apparent improvement. Although the sky temperature contributes a majority of the noise, the receivers are somewhat lower noise than the old system. Second, the tests done for memo 174 had a non-optimum setup for WIDAR and that likely increase the observed phase noise. Third, for the old VLA system since it was not understood that one polarization was much noisier than the other, the non-optimum combination of these signals likely increased the noise. Thus the new system, besides providing dipoles with similar efficiency to the old system, allows a better use of the resulting signals for astronomy.

5. CONCLUSIONS

The bottom line is that the new MJP feeds work well on VLA antennas using WIDAR. The efficiency of the feeds must be as least similar to the old Erickson feeds, as the simulations predict. if all the antennas in the array are equipped with MJPs, the wider bandwidth and the possibility of imaging the two linear polarizations separately before combining to make a final image, can be expected to yield a factor of 3-4 better net sensitivity. The small number of MJP feeds (6) available for these tests and the ionospheric conditions during the tests, did not allow the full suite of direction dependent calibration to be used. Thus we do not yet have a full determination of the eventual floor to the noise we can expect from this system but these results are very encouraging. More feeds will allow even better testing.

The robustness of the new system, evaluated over about one year, seems to be high. The impact of the MJP feeds on other higher frequency bands so far appears to be below any measurable level.

The optimum band for most science with the feeds appears to be 72-84 MHz. The lower frequency is range 54-72 MHz is usable for some science, e.g strong sources, transients, combination with LWA, but much less sensitive than the 72-84 MHz band due to a combination of the MJP feed performance and the increasing sky temperature.

6. REFERENCES

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