EVLA Memo 174

Relative Sensitivity of Erickson and MPJ dipole feeds

Frazer Owen
National Radio Astronomy Observatory

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Abstract

Tests are described comparing the sensitivity of the Erickson dipole feeds with the new strut-straddling Modified J-Pole (MJP) feeds using the new VLA Lowband receivers in the 54-86 MHz window. These tests show that the sensitivity of the MJP feeds for the "B" mounting position is comparable to the Erickson dipoles. For the "C" mounting position the MJP sensitivity is a factor of two worse than for the "B" position.

1 Introduction

The new Lowband receiver system provides two frequency windows of 54-86 MHz and 230-470 MHz. Combined with the WIDAR correlator this system allows a much wider bandwidth leading to more sensitive observations at these low frequencies and the potential for spectral line and polarization observations in these bands.

However, the old "Erickson" feeds for the lower frequency range have proven to interfere with the observations in the 1-4 GHz range both by reducing effective collecting area in these bands and producing variable instrumental polarization. These drawbacks of the Erickson feeds means that they can only be mounted on the antennas for limited periods of time when they do not interfere with higher frequency science programs. The Erickson feeds must be manually mounted on the telescope by pulling on ropes. This activity is expensive in personnel time for mounting the dipoles and the maintenance costs due to the ware-and-tear on the dipoles and ropes.

A solution was proposed in the PhD thesis of M. Harun [1] and his adviser, Steven Ellingson at Virgina Tech [2]. The idea was, unlike the Erickson dipole feeds which are located on axis in the main optical path of the antenna, to mount dipoles around the perimeter of defined by the the antenna feed-legs or struts. Simulations using a realistic numerical model of a VLA antenna showed the such an arrangement should produce sensitivity comparable to the on-axis Erickson dipoles but with little blockage. The simulation showed that there a couple of favored mounting points, including location "C" below.

Mounting point "A" was used for initial testing which is at the same distance down from the sub-reflector that the Erickson dipoles are mounted but the dipoles are arranged in a box straddling the feed legs. The strut-straddling mounting point preferred by the Harun thesis, called "C" is located higher up, closer to the sub-reflector/best-fit prime focus. During preliminary testing, Steve Ellingson, suggested a third mounting location which place a somewhat smaller box slightly interior to mounting point "A". This mounting point is called "B". See Ellingson et al, EVLA memo 173 for details of mounting points "A", "B" and "C".

2 On-the-sky testing

A series of on-the-sky tests were carried out from November 2012 through July 2013 to compare various designs for strut-straddling dipoles and mounting point to the performance of on-axis Erickson dipoles. An original design for a narrow-band strut-straddling dipole by Ravi Subrahmanyan showed that the sources could be detected by such a feed system. Because of uncertainties in relative amplitudes for the WIDAR-generated amplitudes, Ravi used the Allan variance of the observed phases as a proxy for signal-to-noise (S/N). Using the Allan variance he showed that the peak sensitivity of the narrow-band strut-straddling dipoles mounted at position "A" was three to four times worse than the Erickson dipoles (Subrahmanyan, private communication). This result was disappointing.

In response to this result, Steve Ellingson designed a wider band dipole feed (a modified J-Pole,"MJP", see Ellingson, Coffey and Mertley, EVLA memo 172 for details). Steve also pointed out that the mounting point used for the tests of the narrow-band dipoles was about 40cm lower than the one favored by the Harun thesis and thus the results of the tests were consistent with the Harun simulation. He also proposed location "B" at this time.

During July and August 2013 tests were carried out using three Erickson dipoles, mounted on ea03, ea06 and ea09, and two MJP dipole feeds, installed on ea12 and ea27, located at mounting point "B" or "C". The VLA was in the C-configuration. Observations were made of a band from 54-86 MHz. Cygnus A was used for these tests, which is was not resolved by the baselines used. After the first set of tests were completed the MJP dipoles were moved to mounting location "C" and the tests were repeated.

3 Results

On 8-21-2013 we tested the performance of the MJP dipoles in comparison with the Erickson dipoles at mounting position "C" looking at Cygnus A. On 8-23-2013 we did a similar test with the MJP dipoles at position "B". The older narrow-band strut-straddling dipoles were also active for the tests but not analyzed. The observations covered the full band from 54 to 86 MHz using 1024 channels. This setup gave a channel width of 3.125 KHz. 0.5 second integration times were used. The pointing position used was the optimum one for the Erickson dipoles.

Since there is some question about how to interpret the observed amplitudes, it was decided to use the Allan variance of the observed phase as a proxy for S/N. A new AIPS task, ALVAR, was kindly written on short notice by Eric Greisen for this purpose. After Hanning smoothing, the Allan phase variance was calculated for each of the three Erickson dipole baselines, 3-6, 3-9, 6-9, and the one MJP baseline, 12-27. The variance was calculated with a time averaging window of 1 second for the YY and XX cross-correlations (RR and LL as shown by the AIPS header). The total observing time was 90 seconds. Eleven frequency channels, separated by 62.5 kHz (2 channels) centered on 74.5 MHz were analyzed. The highest and lowest variance channels of the 11 frequencies were dropped from the analysis of each polarization/baseline pair. An average Allan variance was then calculated for each polarization/baseline pair and the results for the three Erickson baselines were averaged together.

The ratios of the square root of the phase variances of the Erickson dipoles to the MJP dipoles was used as the proxy for the relative sensitivity at 74.5 MHz. The results for the "B" mounting position were YY: 2.04(0.18) and XX: 1.33(0.10), where the error in the mean is given in parenthesis. Thus the narrow-band sensitivity near the designed frequency of the Erickson dipoles is significantly better than the MPJ dipoles.

However, the MJP dipoles have a wider, flatter frequency response than the Erickson dipoles, so the wideband sensitivity is relatively better for the MJP dipoles than the monochromatic results indicate. Given the changing source spectra and sky temperatures, it is not straight-forward to calculate the true relative wide-band sensitivity. What was done to give some sort of a wide-band relative sensitivity was to numerically integrate the observed amplitudes normalized at 74.5 MHz for the Erickson and MJP dipoles over the full observed bandwidth and calculate the ratio of the normalized bandwidths between the the types of dipoles to yield a normalized bandwidth ratio. Dividing the monochromatic S/N by the square root of the normalized bandwidth ratio gives a relative observed wide-band S/N. The results after this correction was a ratio Erickson/MJP of YY: 1.53 and XX: 1.33. Given the uncertainty in the numerical integration I would estimate an error in these last quantities of $\sim 20\%$. Thus for wide-band operation, the sensitivity of the MJP dipoles is slightly worse, $\sim 70\%$ of the Erickson dipoles.

The same analysis was repeated for the "C" position. For this case the relative wide-band sensitivity for the Erickson/MJP dipoles is YY: 2.90 and XX: 2.50, or about a factor of two worse than for the "B" mounting position.

4 Conclusions

Thus for the "B" mounting position, given the errors, the Erickson and MJP dipoles have comparable wide-band sensitivity at the optimum pointing position for the Erickson dipoles. For the "C" mounting position, the sensitivity for the MJP's is about a factor of two worse. So the "B" position is favored. Tests of the MJP pointing relative to the Erickson dipoles so far has been inconclusive; thus if the MJPs have a different optimum pointing position then the MJPs sensitivity might improve relative to the Erickson result. On the other hand the Erickson dipoles are have more gain toward the upper part of the 54-86 MHz band than the MJP's; thus since the sky background is lower in the upper part of the band, the sensitivity might be somewhat relatively better for the Erickson dipoles. Of course, the MJPs produce a lower mean frequency and a flatter response, so they are better for spectral studies. Thus which feeds are better is dependent on the science goal of a given experiment. So the conclusion of these tests is that the MJP dipole feeds mounted at the "B" position appear to be at least comparable in wide-band sensitivity to the Erickson dipoles.

5 References

[1] M. Harun 2011, "Modification of Large Reflector Antennas for Low Frequency Operation", Ph.D Dissertation, available online:
http://scholar.lib.vt.edu/theses/available/etf-11042011-103540/.

[2] M. Harun and S. W. Ellingson 2011, "Design and Analysis of Low Frequency Strut-Straddling Feed Arrays for EVLA Reflector Antennas", *Radio Sc.*, RM0M04, DOI:10.1029/2011RS004710. Preprint version:
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