EVLA Memo 173
Strut-Straddling Arrays for the VLA 4-meter Observing System

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This memo describes several prototype "strut straddling" array feed systems that have been developed by Virginia Tech and NRAO as part of an effort to upgrade the existing 4-meter observing system of the VLA. The existing/legacy 4-meter system uses a pair of crossed dipoles which are suspended 1 m (i.e., $\lambda/4$ at 74 MHz) in front of the fully-retracted subreflector [1]. Interference with the reflector optics measurably degrades sensitivity and polarization characteristics at L-band [2], and therefore this system is only intermittently installed. The primary objective of the new feed system is to avoid the interference problem while delivering sensitivity comparable to that of the legacy system. A secondary objective is to increase the usable bandwidth of the 4-meter system so as to take advantage of the new and recently-installed 4/P ("low-band") front end, which expands the 4-band passband from 1.6 MHz around 74 MHz to approximately 54–86 MHz. This memo provides some background and describes the specific designs that have been evaluated. A subsequent memo will report test results for these designs.

An introduction to the concept of strut-straddling feed arrays is provided in [3], and a concise summary pertaining specifically to "4-band" on the VLA in given in [4]. The essential idea is to use four dipole-type elements arranged in a ring in front of the subreflector, as shown in Figure 1. The four elements are combined to obtain nominally linear "X" and "Y" polarizations using the combining scheme shown in Figures 2 and 3. This scheme uses 2 Marrimac PDM-20-500 2-way 0° combiners, and one M/A-COM H-183-4 4-way 0/180° hybrid combiner.

Four array designs have been installed and tested. These designs are summarized in Table 1. All designs used precisely the same polarization combining network described above. In each case there is 25 feet (±3.23 cm) of RG-8 coaxial cable between each antenna element and the polarization combiner, and 10 feet of 1/4-in heliax cable between the polarization combiner and the EVLA 4/P front end. The designs differ in the antenna element used and the specific geometry in which the antenna elements were mounted.

Two antenna elements were considered: the sleeve dipole and the modified J-pole (MJP). The sleeve dipole is a well-known classical design for an end-fed half-wave dipole. A sleeve dipole is formed from coaxial cable by separating the shield from the center conductor, "folding" the shield back on to itself to form one arm of the dipole, and extending the center conductor to form the other arm of the dipole. In our implementation, the outer shield layer is implemented using copper pipe, to which the shield is connected at the center of the dipole. The coaxial surfaces form a quarter-wavelength coaxial waveguide which serves as a balun. The result is an end-fed dipole with very low loss at the nominal design frequency (74 MHz, in this case). Unfortunately, the bandwidth

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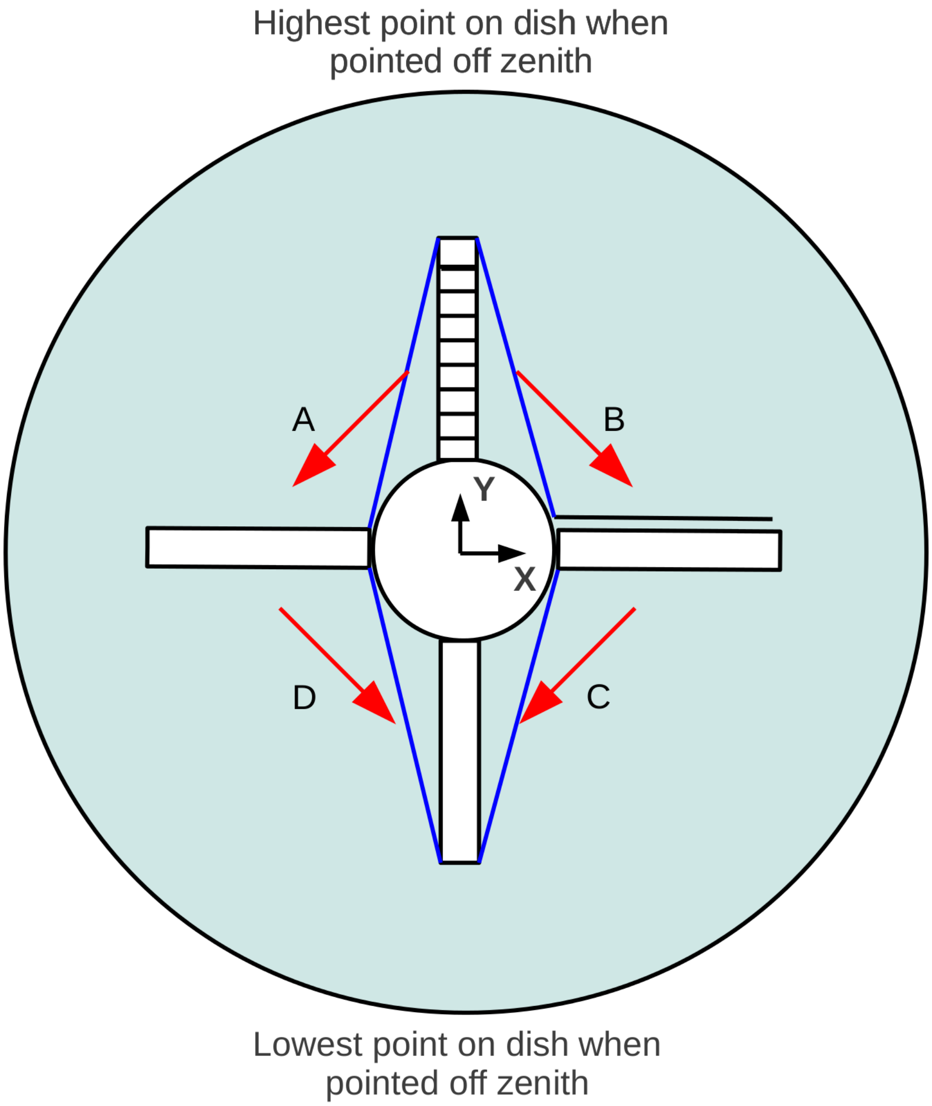

Figure 1: Strut-straddling feed geometry, common to all configurations considered in this report. The direction of the arrows is significant; for sleeves and MJPs, they point *from* the "fed" end.

Design	**Sleeve-A**	**MJP-A**	**MJP-B**	**MJP-C**
Element	Sleeve dipole	MJP	MJP	MJP
Geometry	A	A	B	C
Mounting Plane	Same as legacy	Same as legacy	Same as legacy	Closer to subreflector
d_1 (see Fig 4)	1.541 m	1.541 m	1.541 m	1.000 m
d_2 (see Fig 4)	1.016 m	1.016 m	1.016 m	0.475 m
Illustrations	Fig. 5 (left)	Fig. 5 (right)	Figs. 6 & 7	Fig. 8
Remarks			"shrunken box"	as proposed in [4]

Table 1: A summary of array designs tested. They are shown from left to right in the order in which they were installed and tested.

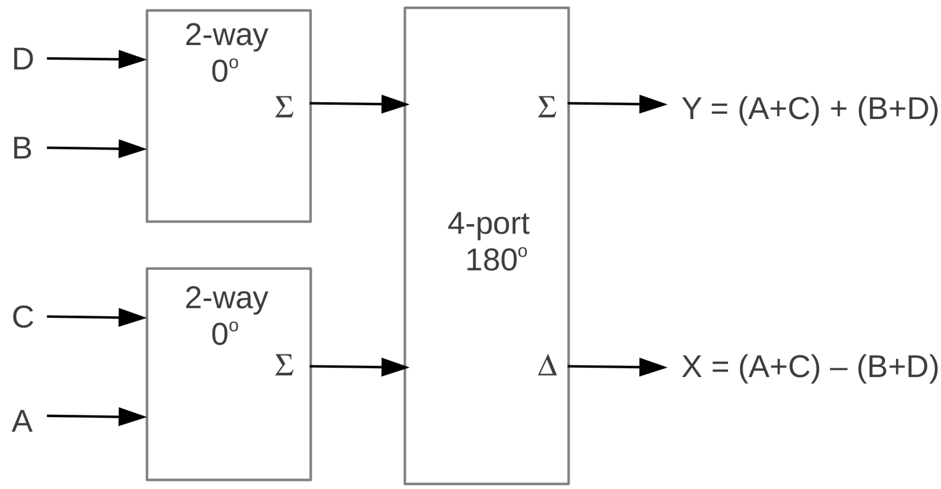

Figure 2: Polarization combining scheme.

Figure 3: Polarization combining, as implemented.

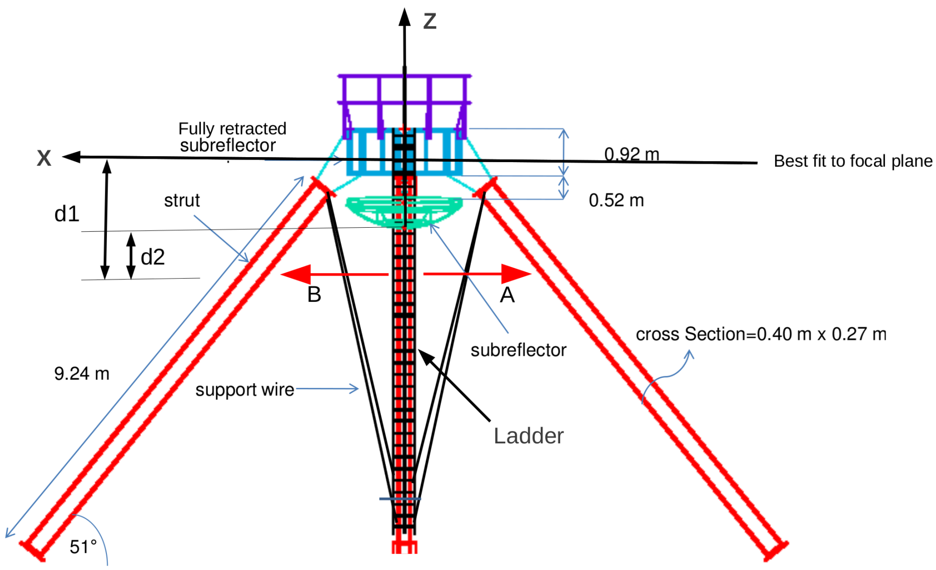

Figure 4: Side view of antenna mounting geometry.

Figure 5: Antennas mounted in the "A" geometry. *Left*: Sleeve dipoles. *Right*: MJPs.

of this dipole is very narrow, due to the nature of the quarter-wave balun. In fact, the sleeve dipole has nearly the minimum possible theoretical impedance bandwidth for a half-wave dipole; even the legacy dipoles (which use transformer baluns) have significantly greater bandwidth.

The MJP design and specifications are documented in EVLA Memo 172 [5]. MJPs are end-fed and have approximately the same length as the sleeve dipoles and the legacy dipoles, but have much greater bandwidth. The principal disadvantage of the MJPs is their relative bulk, since they use two parallel conductors, each of 1/2-in diameter. Also, compared to the sleeve dipoles, they have relatively high internal loss (about 1.2 dB).

The designators "A", "B", and "C" refer to schemes for mounting the dipoles. In geometries A and B, the dipoles are mounted in the same plane as the legacy dipoles. The difference is that in the A geometry the dipoles lie along a line that intersects the mounting points on the struts (AKA the "quadropod legs"); whereas in the B geometry the dipole "box" dimensions are considerably smaller. The C geometry is the mounting scheme advocated in [4], in which mounting plane is about one-half meter closer to the subreflector. Details and illustrations documenting geometries A, B, and C are provided in Figures 4–8.

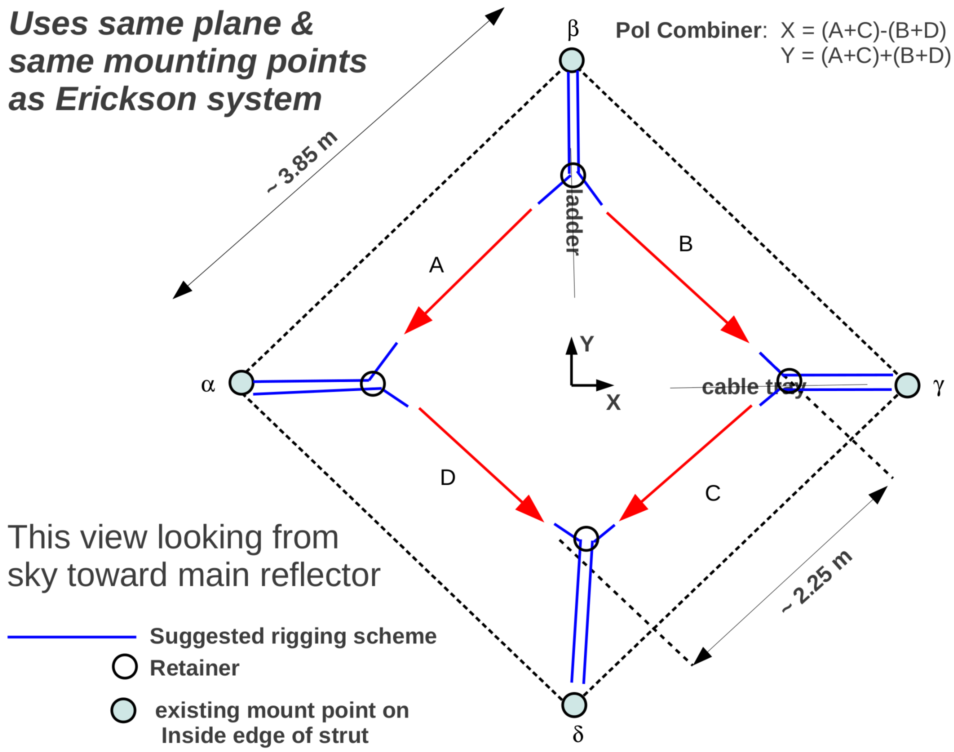

Figure 6: "B" Geometry. ("Erickson system" refers to the legacy/existing "crossed dipoles" system.)

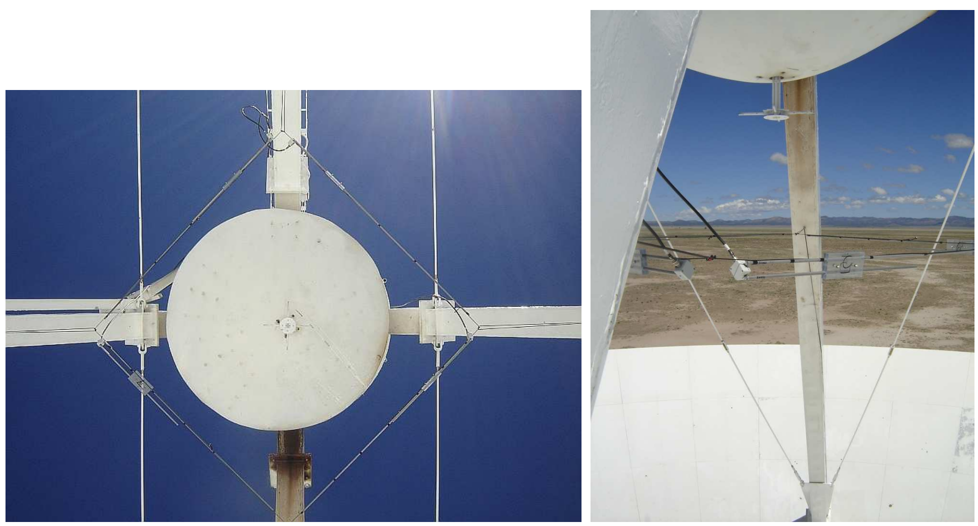

Figure 7: MJPs mounted in the "B" geometry.

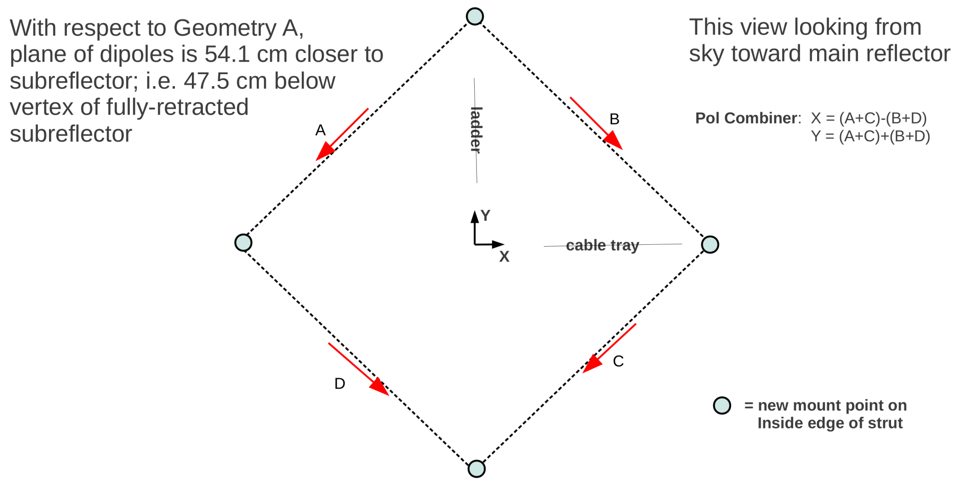

Figure 8: "C" Geometry.

All of the designs listed in Table 1 have been installed on several dishes and tested in some manner during the period January 2013 through August 2013. The results of these tests will be documented in a subsequent memo. However, each of these configurations has also been evaluated in simulation at 74 MHz, assuming generic thin half-wave dipoles as feed elements, using the same techniques described in [4]. These simulations indicated that the "C" geometry should have sensitivity roughly equal to the legacy system, "A" should be worse by a factor of about 4, and "B" should be significantly better than both "C" and the legacy system. "A" remains of interest primarily because it should offer the lowest level of interference to higher-frequency systems.

References

[1] N.E. Kassim *et al.* 2007, "The 74 MHz System on the Very Large Array," *ApJS*, 172, 686.

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[4] M. Harun and S.W. Ellingson 2011, "Design and Analysis of Low Frequency Strut-Straddling Feed Arrays for EVLA Reflector Antennas," *Radio Sci.*, 46, RS0M04, DOI:10.1029/2011RS004710. Preprint version: http://www.ece.vt.edu/swe/mypubs/1108_RS_Harun_Preprint.pdf.

[5] S. Ellingson, S. Coffey & D. Mertley 2013, "The Modified J-Pole Antenna," EVLA Memo 172.