EVLA Memo 172
The Modified J-Pole Antenna

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This memo describes the "modified J-pole" (MJP), a broadband end-fed dipole-like antenna that was developed at Virginia Tech and NRAO/Socorro during the spring and summer of 2013, as part of an effort to upgrade the existing 4-meter observing system of the VLA. The MJP is shown in Figure 1. The principal characteristics are as follows:

Pattern	Dipole-like
Bandwidth	54–80 MHz for $\lvert s_{11} \rvert \leq -10$ dB
Directivity	+1.6 dBi (−0.5 dBd) @ 68 MHz
Gain	+0.5 dBi (includes 1.2 dB balun loss) @ 68 MHz
Interface	50 Ω coaxial, from end

Electromechanical design: The MJP consists of two parallel conductors of lengths 203.4 cm and 92.8 cm, spaced 5 cm apart. The conductors are 1/2-in diameter aluminum alloy (6061) tubing. The conductors are held in place by a clear polycarbonate spacer, shown in detail in Figure 2, as well as a balun unit, visible at the far right end in Figure 1 and shown in greater detail in Figure 3. The balun is a Mini-Circuits Laboratories Model TC1-1-13MG2+ 1:1 transformer installed in a DC-coupled ("Guanella") configuration.

Principle of operation: This design is adapted from a well-known type of antenna known as a "J-pole", which is clever scheme for getting a dipole-type pattern with reasonable impedance from an end-fed antenna.[1] In a classical J-pole, the long conductor is $3\lambda/4$ long and the short conductor is $\lambda/4$ long. Feeding this arrangement from the end results in equivalent radiating currents consisting of 3/4 cycles of a sinusoid on the long conductor, and 1/4 cycles on the short conductor. The quarter-cycle currents adjacent to each other on the long and short conductors are opposite in phase, and due to their proximity their contributions cancel in the far field of the antenna. This leaves the half-cycle on the longer conductor remaining, as one would obtain from a center-fed half-wavelength dipole. The modification which leads to the MJP is to shorten the longer conductor while increasing the relative length of the shorter conductor. This gives rise to two resonances: One corresponding to the length of the longer conductor (in this case, about 74 MHz since the longer conductor is about 2 meters long), and another which is about 25% lower in frequency. These resonances are spaced in such a way as to achieve a wide contiguous region of low reflection coefficient, as shown in Figure 4. The shortening spoils the canceling of currents that allows a true J-Pole to "spoof" a dipole, but the resulting loss of directivity turns out to be relatively small; just −0.5 dB as determined by measurements (as described below). As far as we are able to tell, this concept has not previously

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[1]Although very well-known, there appears to be no authoritative or seminal description of the J-pole in the engineering literature. A web search for the term "J-pole" will yield plenty of information however.

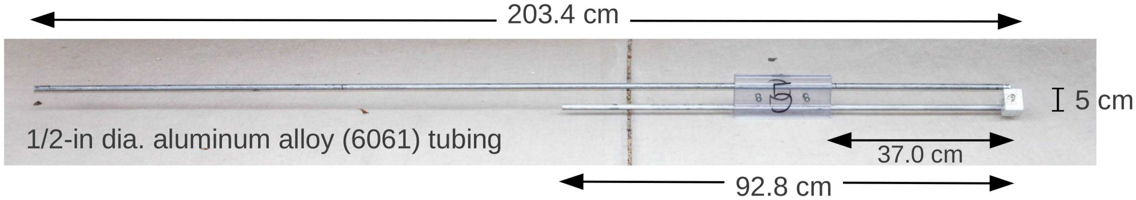

Figure 1: An MJP antenna designed for use in a proposed upgrade to the VLA 4-meter observing system.

been described in the relevant engineering literature.

Measurements of Reflection Coefficient: Reflection coefficient vs. frequency is shown in Figure 4. Note that the curve does not trend toward 0 dB but rather indicates an intrinsic 2.4-dB loss, implying one-way loss of 1.2 dB. This is much greater than the data sheet value of ≈ 0.2 dB indicated for the balun in this frequency range, and indicates about 1 dB of loss due to interconnects, with possibly some contribution from the polycarbonate spacer. This loss could probably be reduced, but is of little concern as the corresponding contribution to system temperature (just 92 K) is much less than the minimum antenna temperature in this frequency range.

Measurements of Gain (Directivity): Measurements of gain were performed using an improvised test range. The transmit antenna was a commercial "Buddipole" portable dipole antenna mounted horizontally about 2 m above an earth ground and tuned to resonate at 74 MHz by adjusting antenna length. This antenna uses a ferrite ring choke balun. The receive antenna was either the similarly-mounted MJP, or an identical Buddipole used as a reference antenna. The distance between antennas was roughly 20 m. Cable losses were measured separately and calibrated out. Note, however, that the intrinsic 1.2 dB loss of the MJP remains. Figure 5 shows the results (power received) for the MJP and the reference dipole. The bottom panel of Figure 5 indicates that the worst-case difference between the two antennas is about -1.7 dB (around 68 MHz); from this we infer that the directivity of the MJP is $-1.7 - (-1.2) = -0.5$ dBd, which is $+1.6$ dBi. At frequencies below about 62 MHz, the MJP significantly outperforms the reference dipole, presumably due to the superior impedance bandwidth.

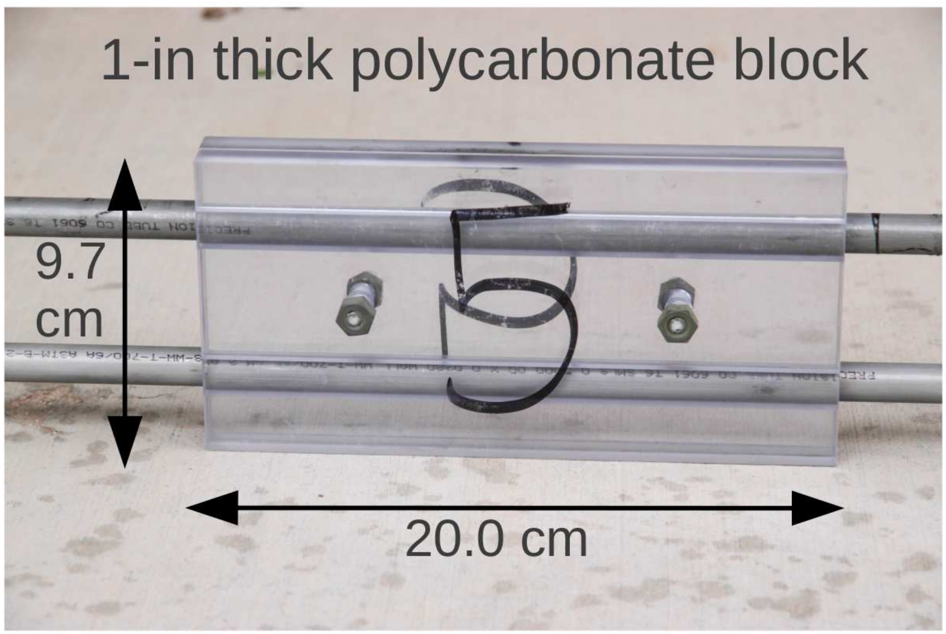

Figure 2: Detail of the spacer.

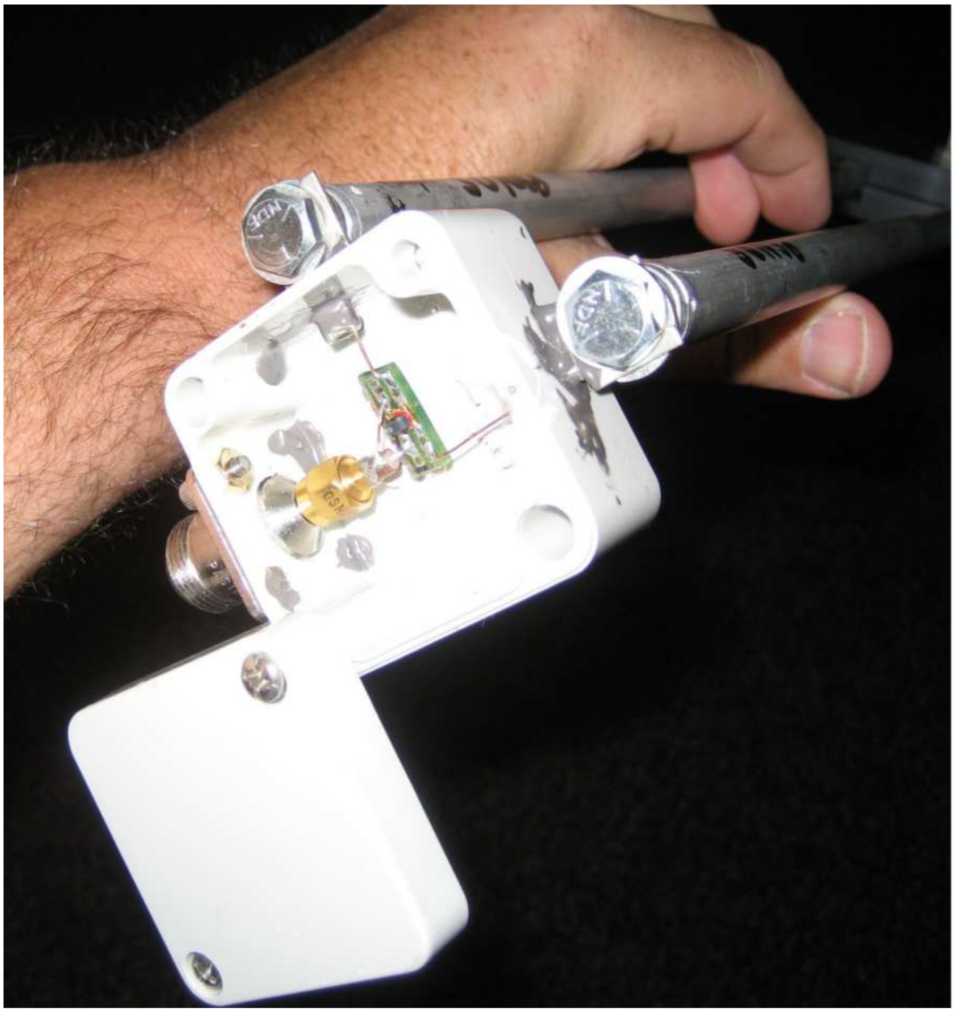

Figure 3: Balun unit; cover removed to show internal connections.

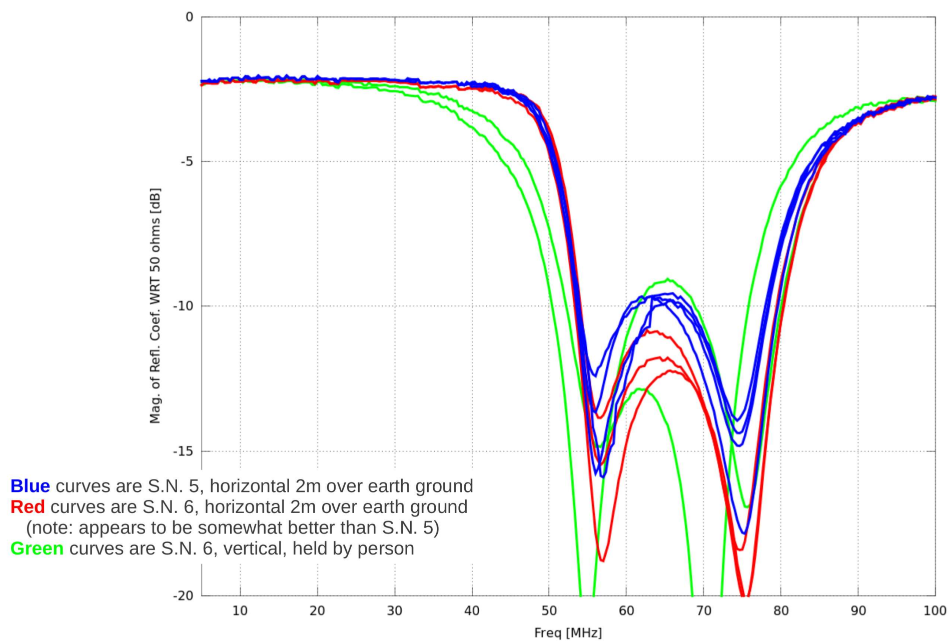

Figure 4: Reflection coefficient ($|s_{11}|$ for $Z_0 = 50\Omega$) looking into the N-connector. Note two identical models ("S.N. 5" and "S.N. 6") of the same antenna are examined in a variety of mounting configurations. Also note the frequency-independent loss of about 2.4 dB, which is attributed to the round-trip path through the balun (i.e., ≈ 1.2 dB one-way).

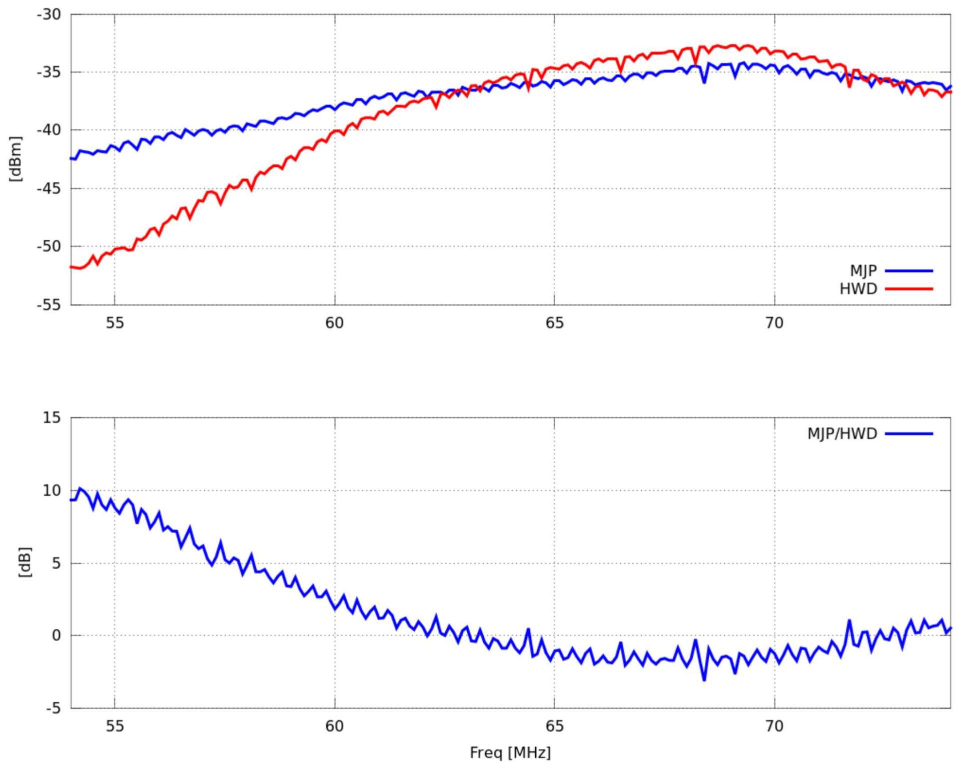

Figure 5: Measured gain and directivity of the MJP, compared to a commercial center-fed half-wave dipole. *Top:* Absolute values of receive power measured on the test range. *Bottom:* Ratio of the results in the top panel, providing an indication of MJP gain relative to that of the half-wave dipole. Note this result includes the 1.2 dB one-way loss inferred from Figure 4, whereas the associated loss for the half-wave dipole is presumably less.