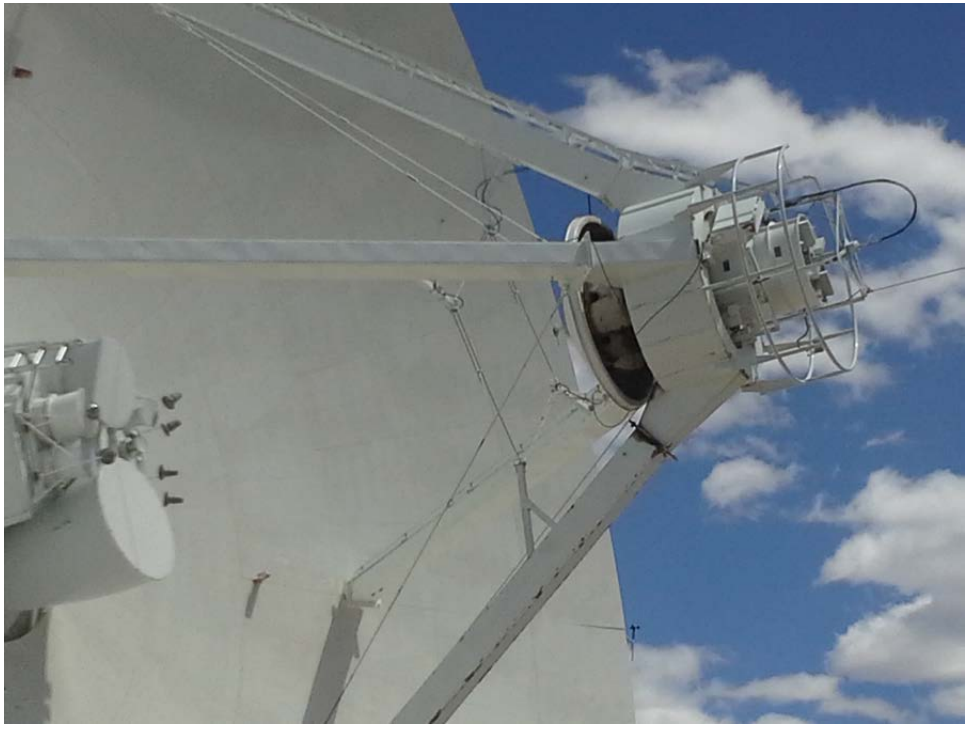
A New VHF (“4-Band”) Feed System for the Very Large Array

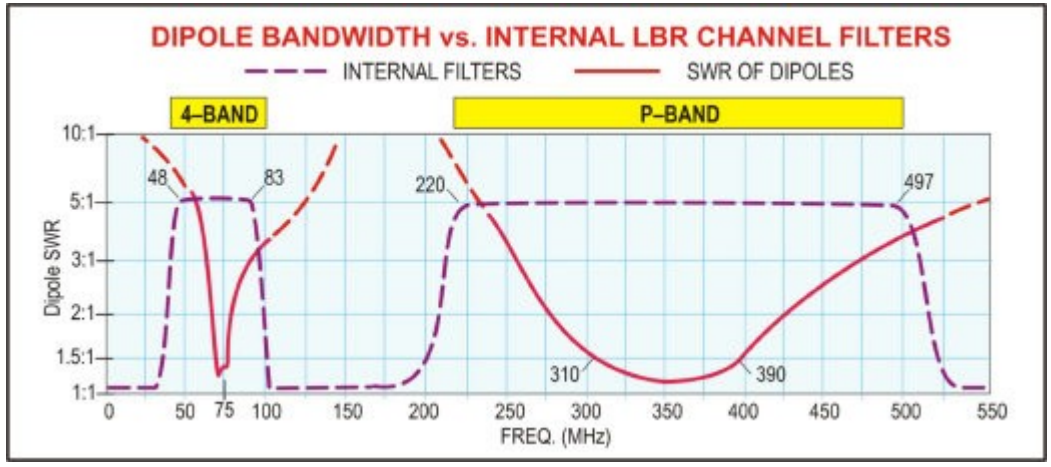
Steve Ellingson (VT)
Jan 6, 2016



Contributions from:
M. Harun (VT)
D. Mertley, S. Coffey, G. Doss,
H. Intema, F. Owen, S. Sturgis (NRAO)
R. Subrahmanyan (RRI)

VLA 4-Band Background

- Pre-EVLA (Erickson) system:
  - Thin dipole feeds
  - 1.6 MHz BW @ 74 MHz front end
  - ~7% sensitivity loss at L-band
  - Sagging introduces variability in L-band
  - So, only intermittently installed

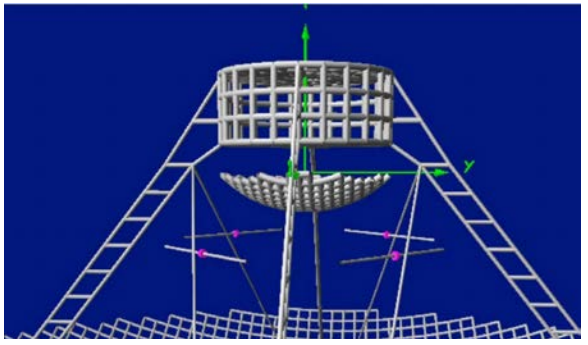


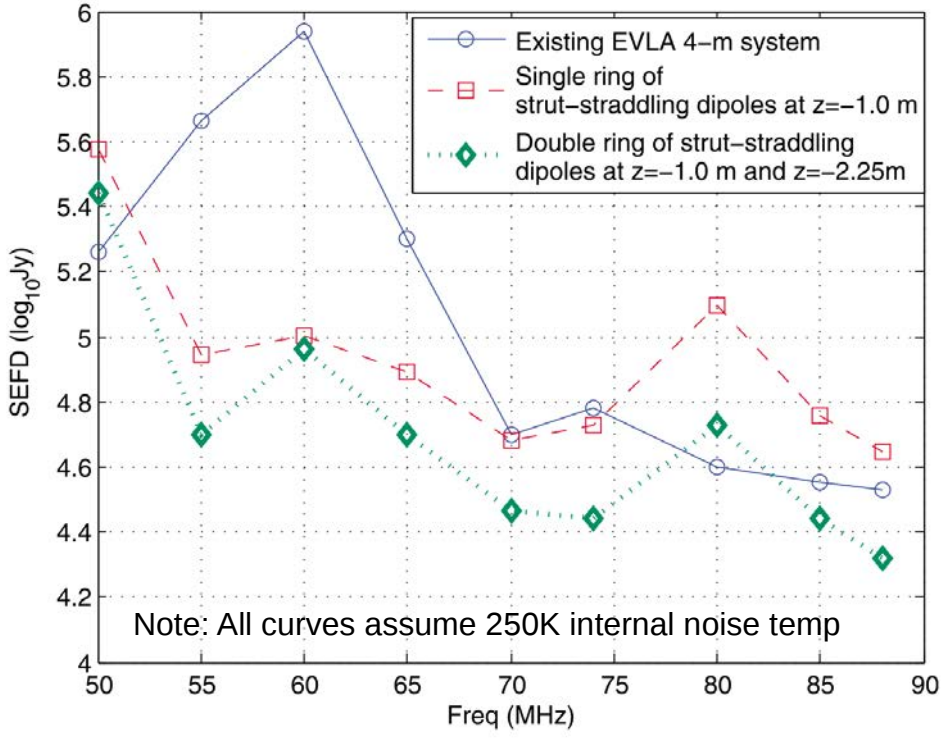
Graphics: P. Harden

- New receivers (added after EVLA upgrade) have much greater bandwidth
- Objectives for new feeds:
  - [*constraint*] Insignificant blocking to higher freqs; can be permanently installed
  - [*goal*] Best possible sensitivity at 74 MHz
  - [*goal*] Best possible use of new front end bandwidth

M. Harun (VT) Ph.D. Work (2011)

- Developed EM modeling techniques suitable for VLA 4- & P- band system analysis
- Studied “strut straddling” scheme to mitigate blockage
  - Showed that sensitivity could be competitive with Erickson scheme
  - Showed that L-band sensitivity reduction should be < 2.3%





Harun & Ellingson (2011), *Radio Sci.*, 46, RS0M04

Harun Dissertation: http://scholar.lib.vt.edu/theses/available/etd-11042011-103540/

Why “Strut Straddling” Works

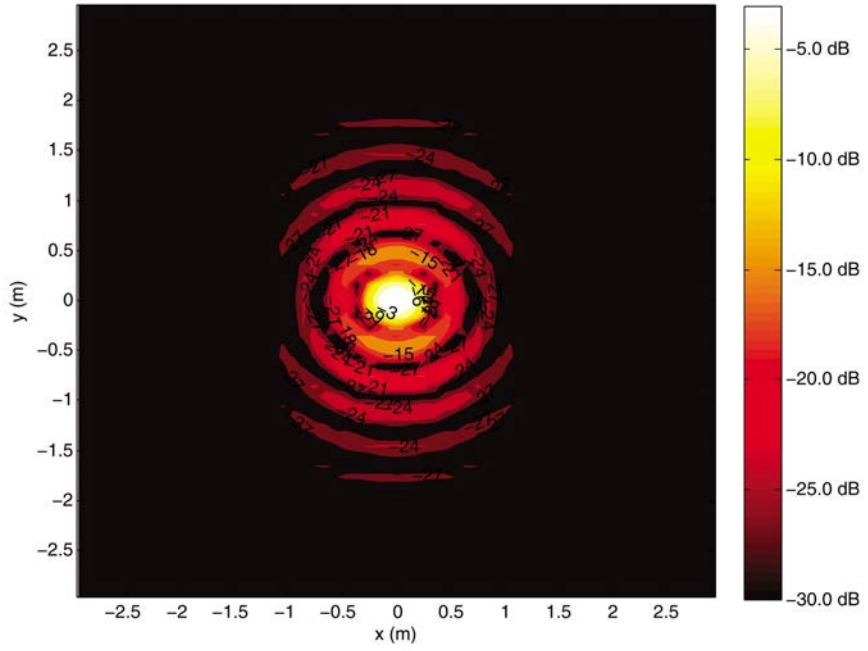


Figure 2. Distribution of power density in the focal plane of a reflecting paraboloid (D = 25 m, f/D = 0.36) relative to the power density at the focus at 500 MHz.

Focal Plane Power Density @ 500 MHz

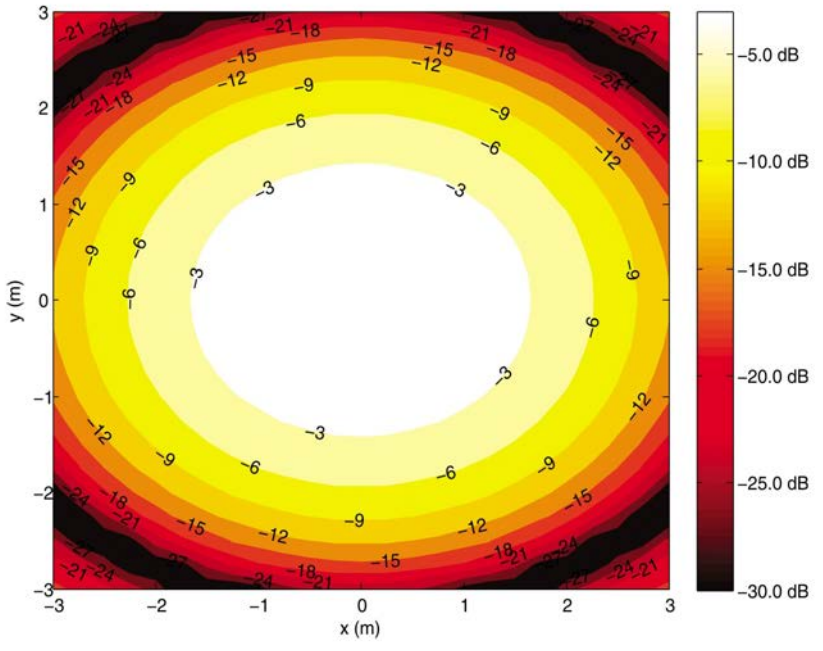
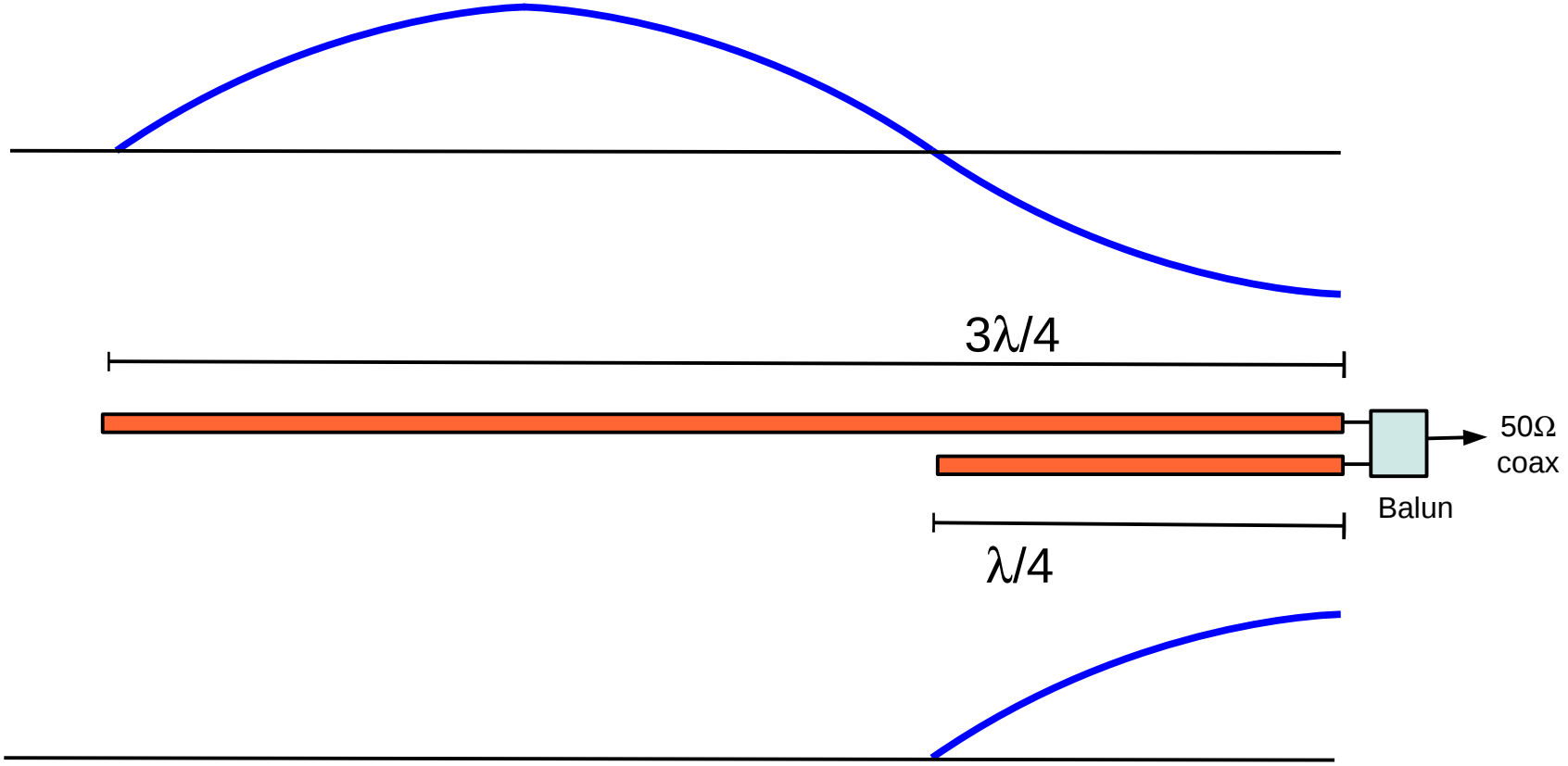


Figure 3. Distribution of power density in the focal plane of a reflecting paraboloid (D = 25 m, f/D = 0.36) relative to the power density at the focus at 50 MHz.

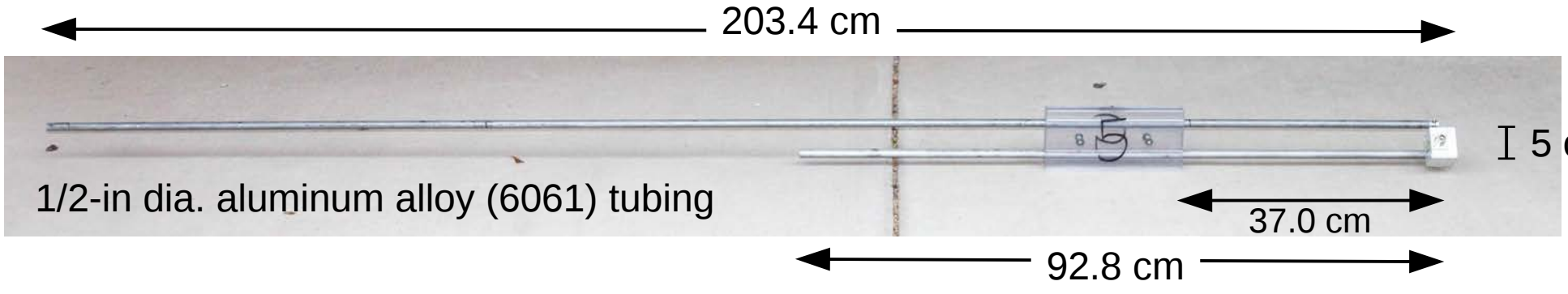
Focal Plane Power Density @ 50 MHz

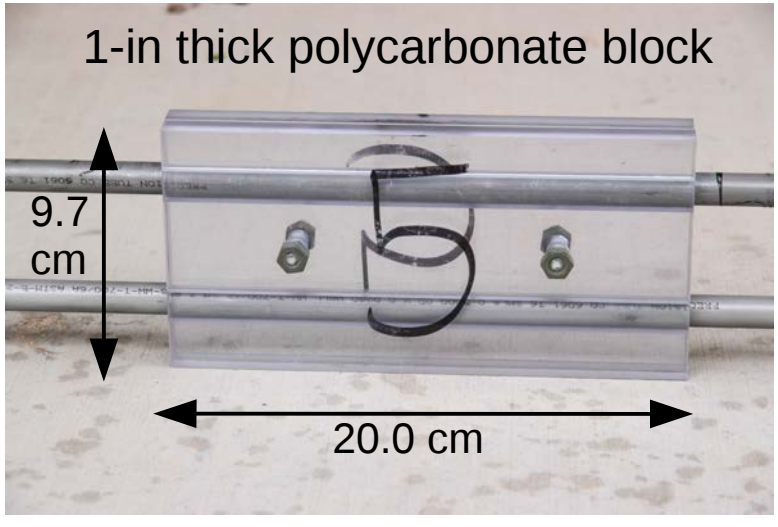
“J-Pole” Antenna

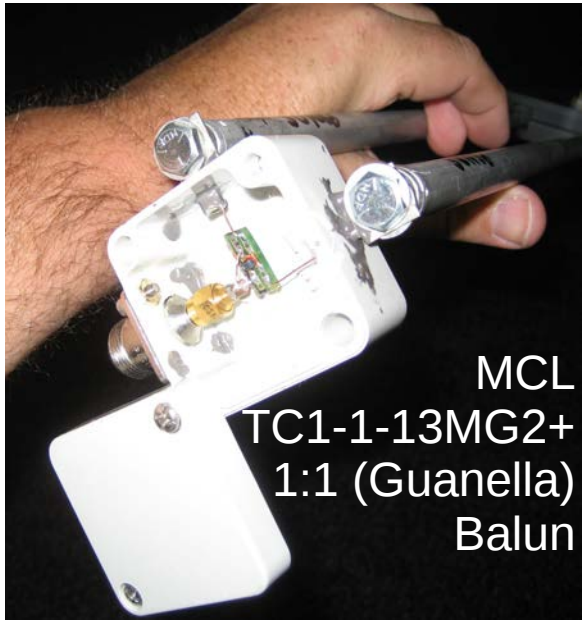


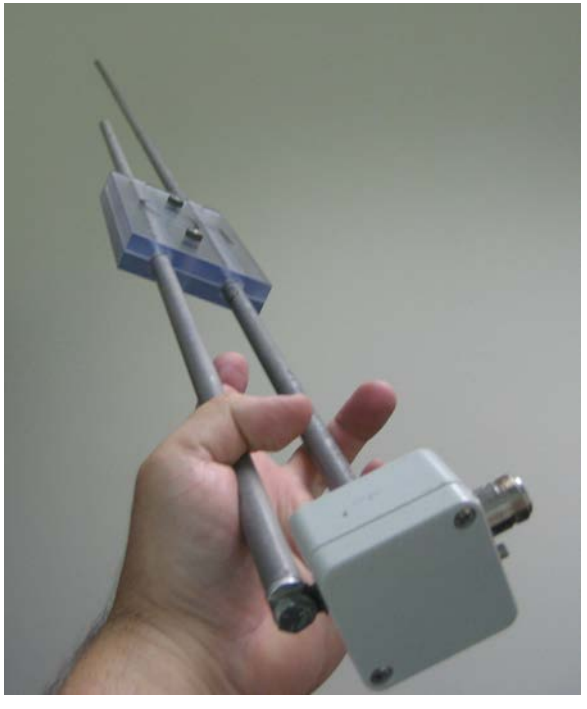
Simple trick to get a half-wave dipole current distribution from an end-fed antenna.
(Can also do this with a sleeve dipole, but those are <u>very</u> narrowband.)

Modified J-Pole (MJP)



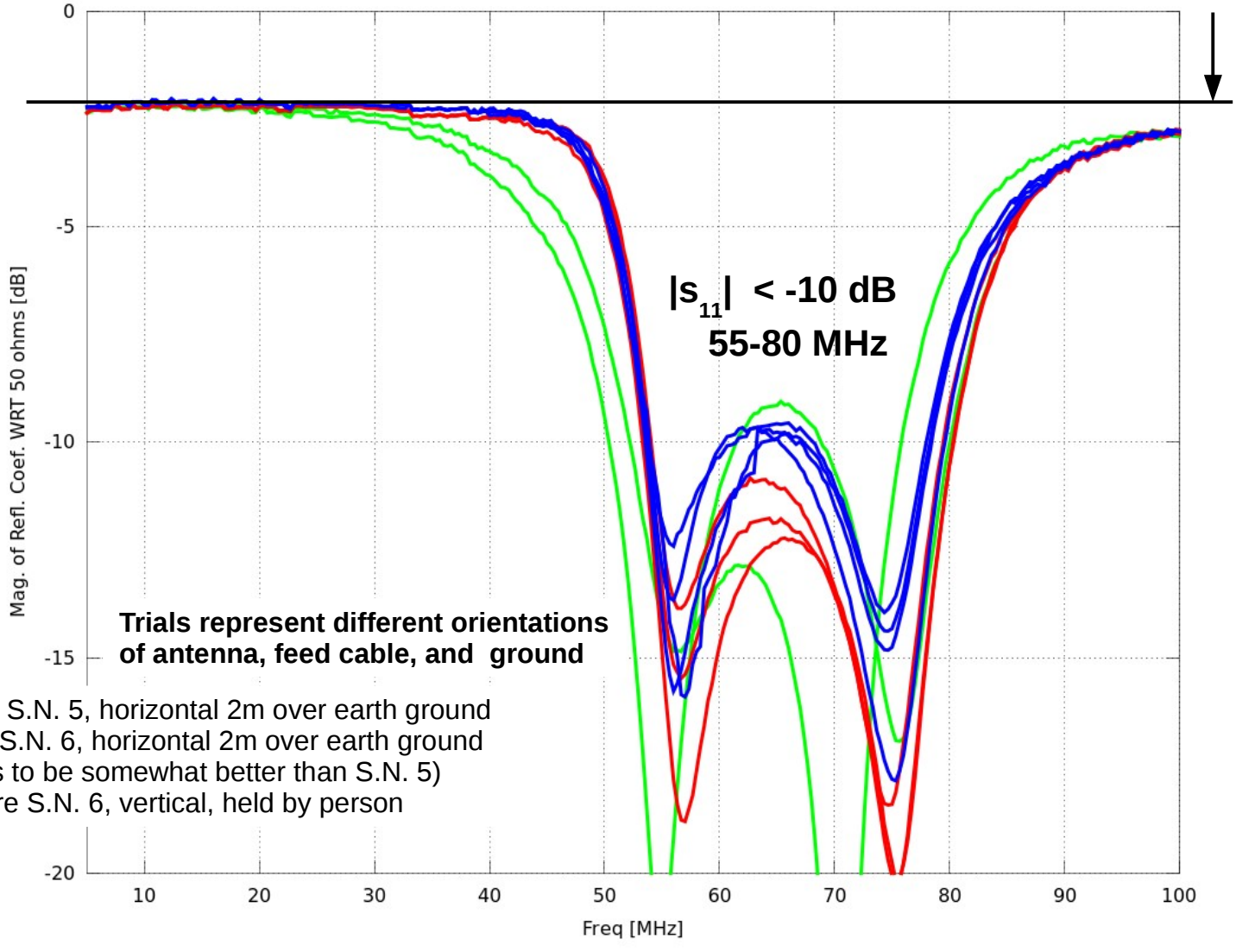






Ellingson, Coffey & Mertley (2013), EVLA Memo 172

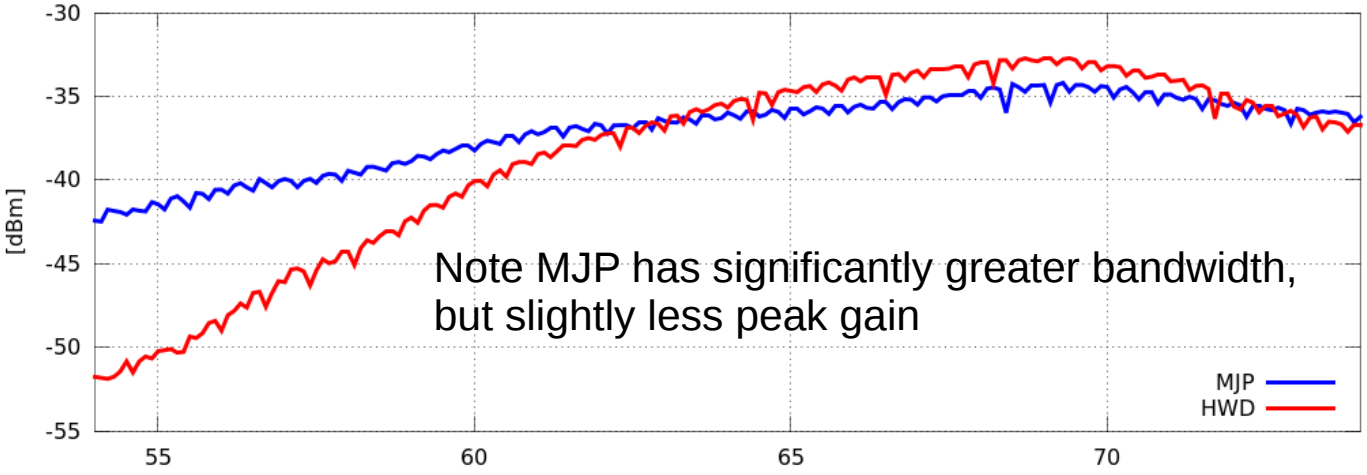
MJP Impedance Match to 50Ω & Loss *(meas.)*



Blue curves are S.N. 5, horizontal 2m over earth ground
Red curves are S.N. 6, horizontal 2m over earth ground
(note: appears to be somewhat better than S.N. 5)
Green curves are S.N. 6, vertical, held by person

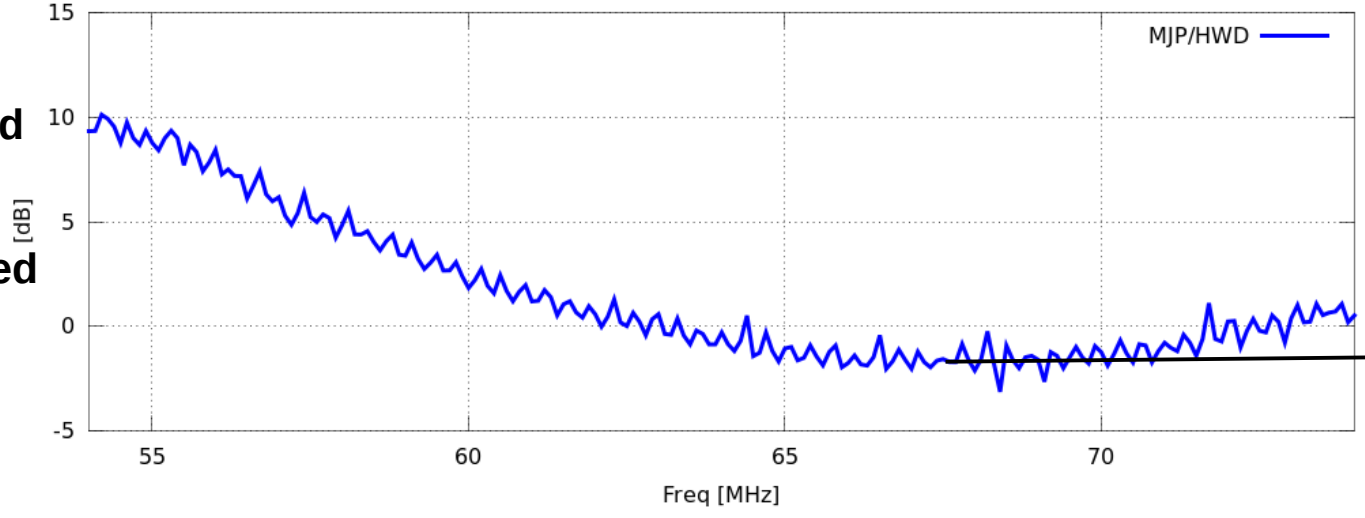
Gain: MJP vs. Half-Wave Dipole *(meas.)*

Absolute received power



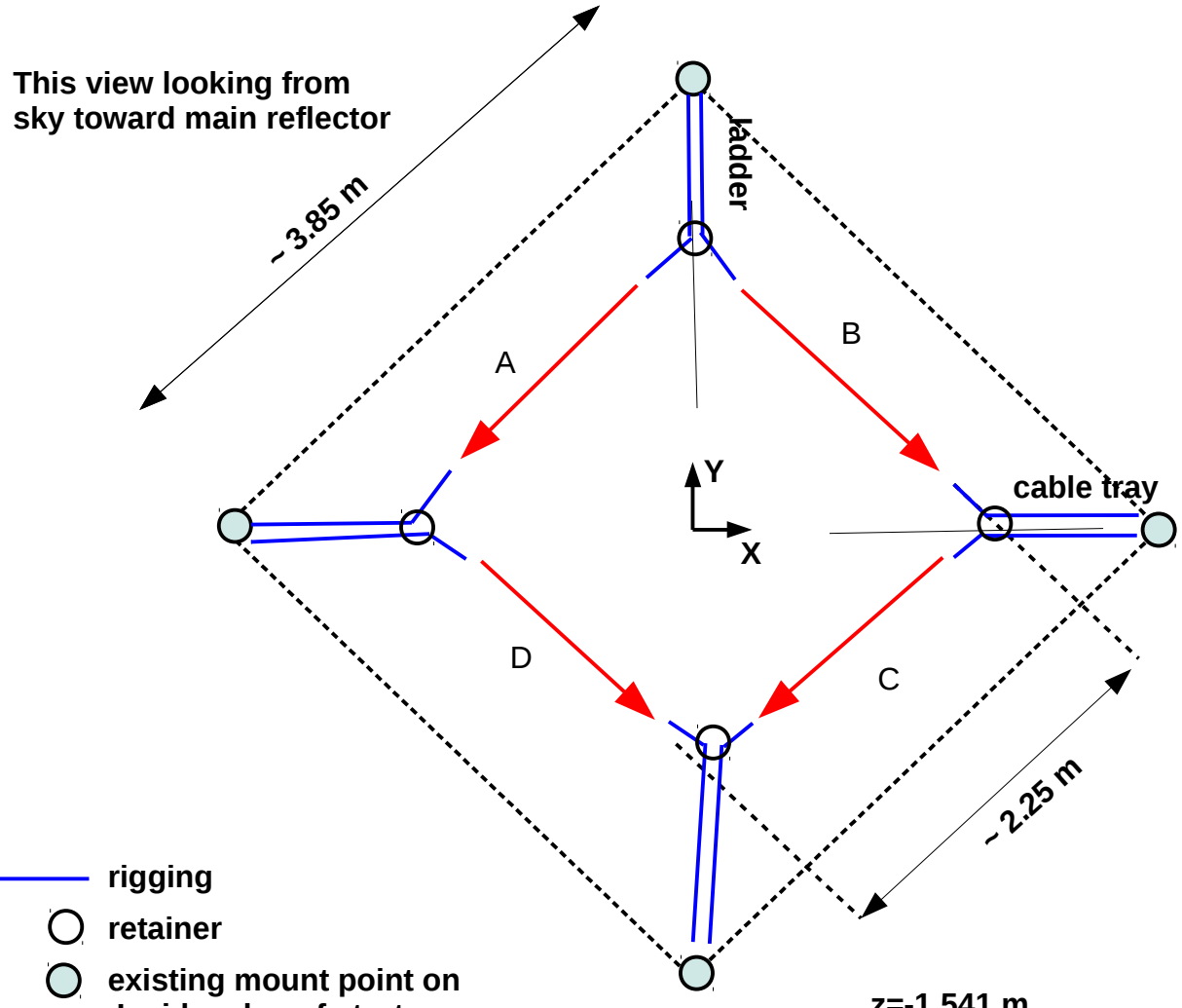
HWD =
Thin dipole,
Half-wavelength
@ 74 MHz

MJP-received power divided by HWD-received power



-1.7 dB
-(-1.2 dB)
-0.5 dB
directivity
relative to
HWD

“MJP-B” Feed Geometry



Original (Prototype) Rigging

Pol Combiner: X = (A+C)-(B+D)
Y = (A+C)+(B+D)

Initial Testing (2013-2014)

- **Testing extremely difficult & limited for various technical & administrative reasons.**
- **Metric: Visibility phase variance as an indirect measurement SEFD**

- **Measurements indicated:**
  - **Sensitivity comparable to the legacy (Erickson) system (confirming simulations)**
  - **L-band sensitivity impact < 1.5%, compared to 7% for Erickson system (consistent with simulations)**
  - **High cross-pol in uncalibrated linears (~40%), compared to ~10% for Erickson system (consistent with simulations)**
  - **Both systems have a roughly 2:1 polarization imbalance due to VLA feed support asymmetry**
- **Pattern: <u>Extremely</u> difficult to measure. Simulations suggest these are not nice. Perhaps irrelevant since imaging FOV (arcseconds) << beamwidth (10s of degrees).**

- **MJP-B systems installed on 6 dishes in preparation for imaging test**

April 2015 Imaging Test

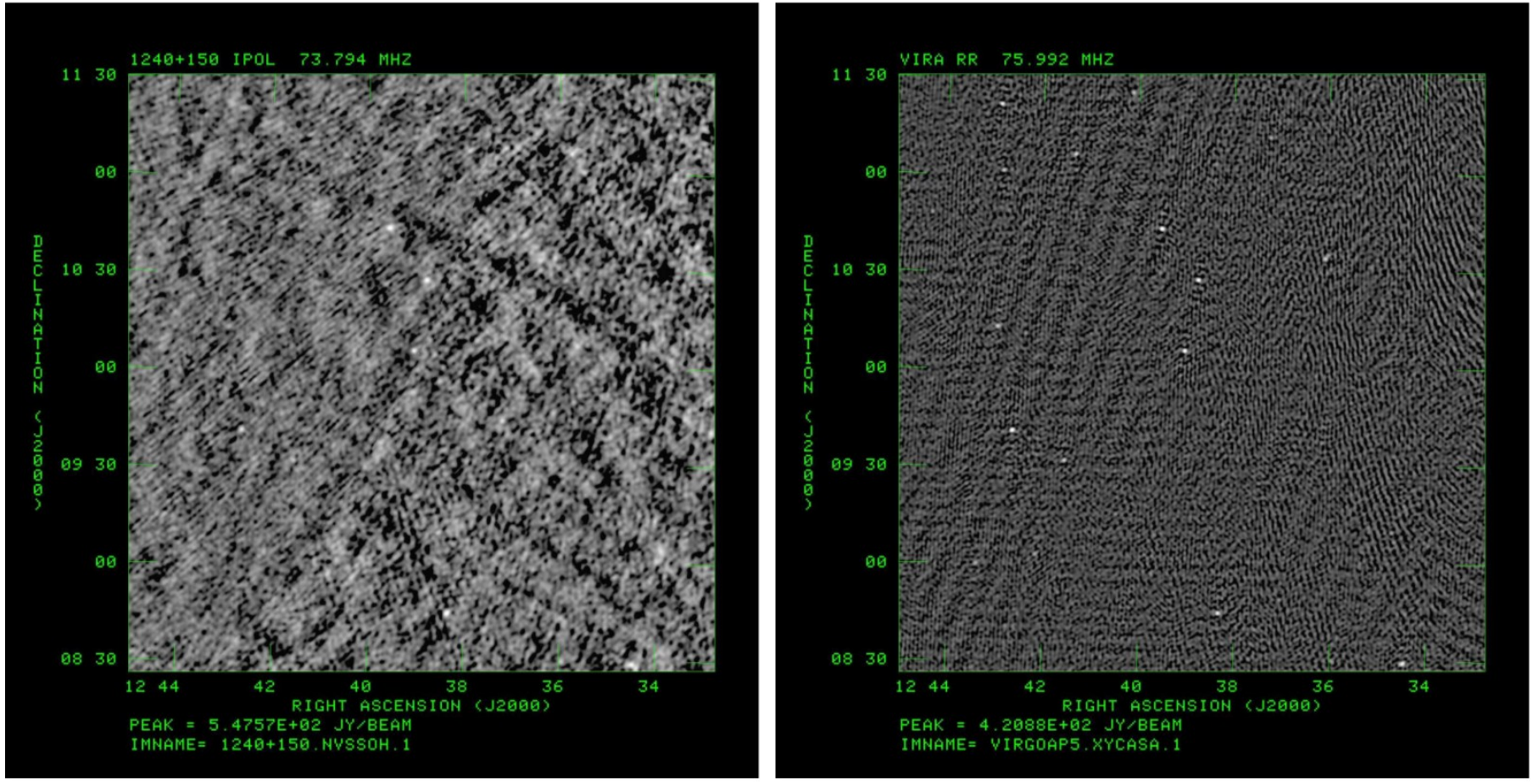
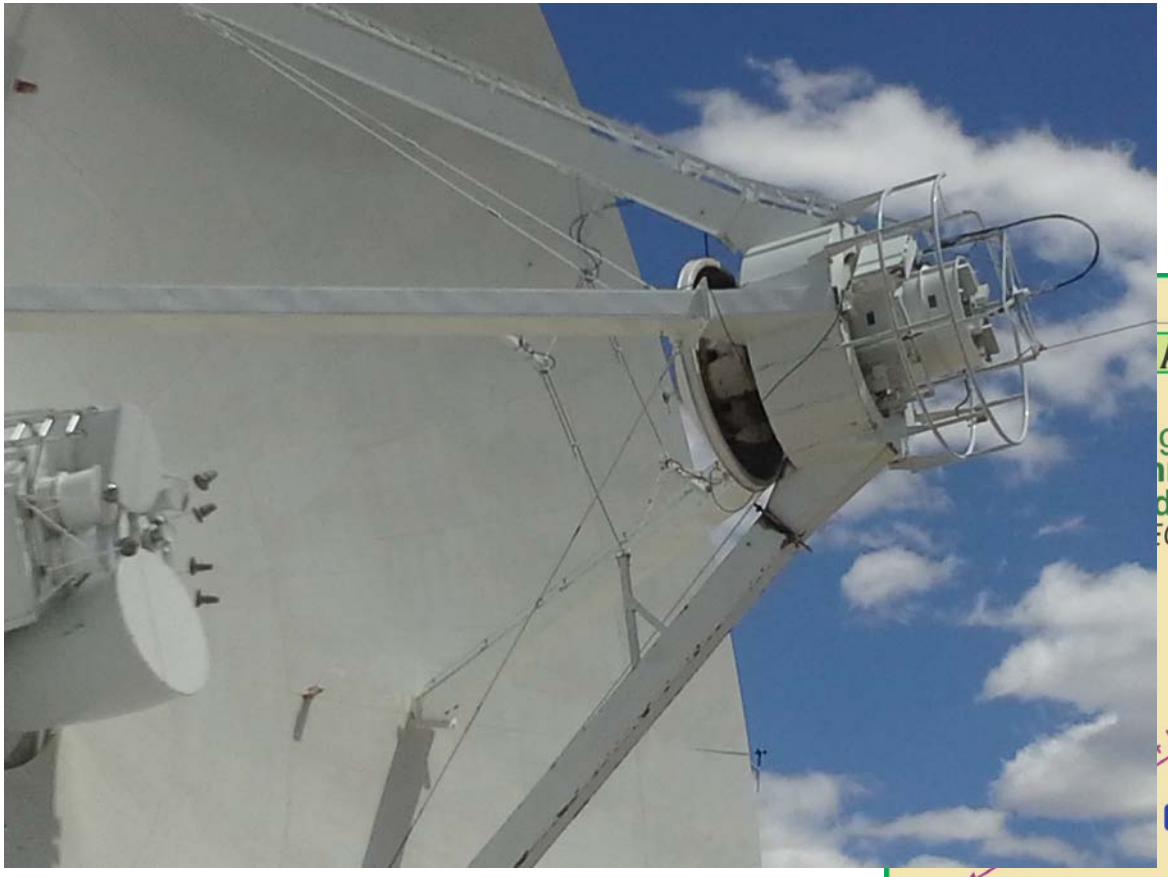
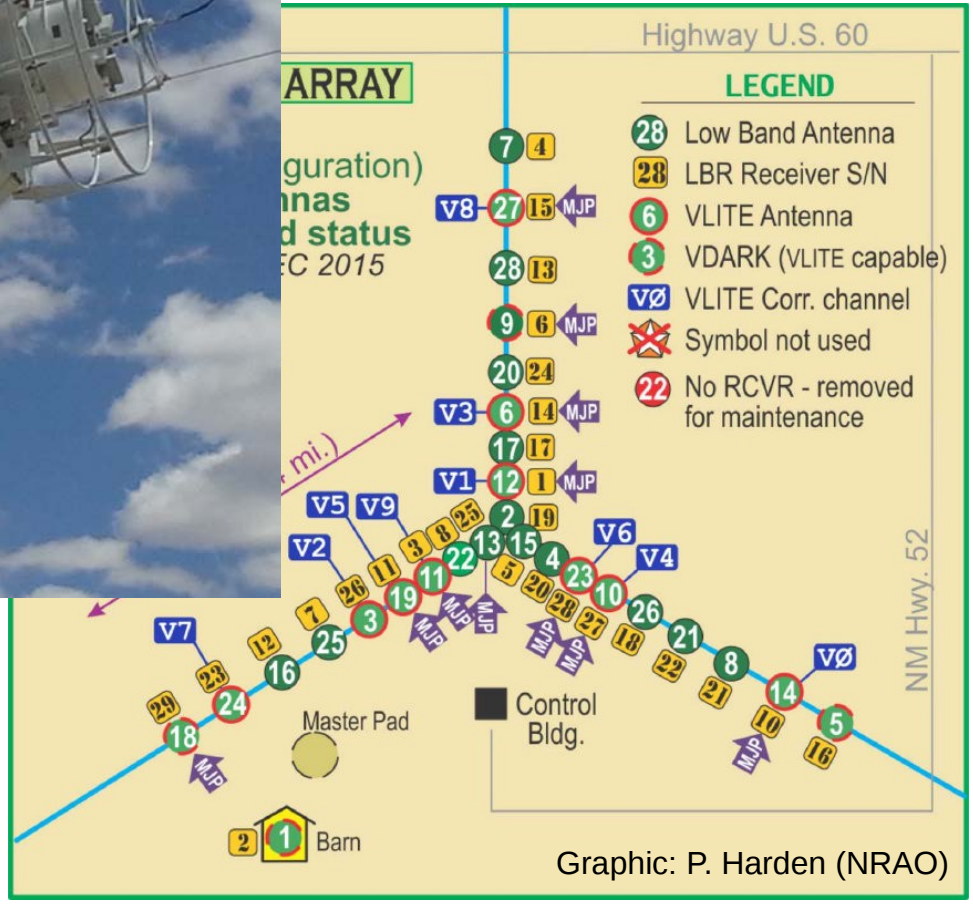


Figure 2. Comparison of regions near Virgo A. Left: VLSSr, Right: MJPs

F. Owen & H. Intema (2015), unpublished memo

Status as of December 2015





Production MJP-B systems currently installed on EA05, 06, 09, 10, 11, 12, 13, 14, 18, 19, 25, 27
Installation on two more dishes imminent
→ total 14 dishes

Concluding Remarks

- **54-86 MHz feed system permanently installed on 14 of the 28 dishes of the VLA**
- **A single MJP-B-equipped VLA dish has sensitivity comparable to (roughly ~1/2 order of magnitude less than) an LWA1 beam → "eLWA"**
- **Room for improvement:**
  - **Optimization of mounting geometry would be a good idea ("MJP-B" is merely the best-liked of 3 possibilities considered)**
  - **MJP combining scheme is a "best guess"; could be optimized to improve polarization balance, purity, pattern**
  - **Yagi-ization of MJPs to increase aperture efficiency**
  - **2nd ring of MJPs – Harun's 2011 work shows O(50%) improvement possible**