An Experimental Permanently-Installed Broadband VHF-Low Feed System for the VLA

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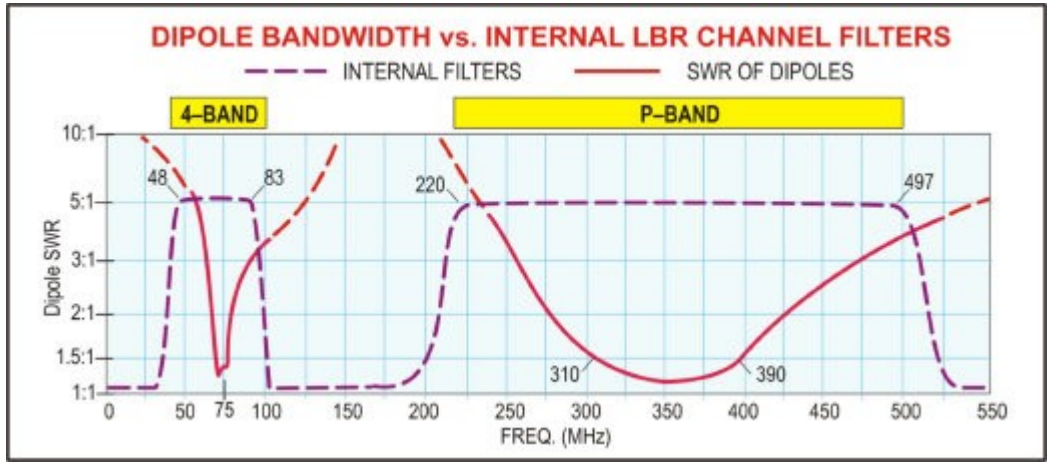
VLA 4-Band Background

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



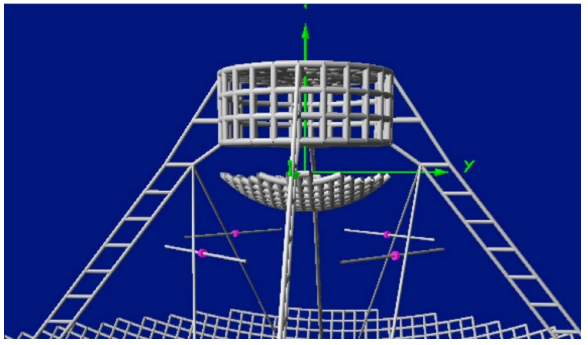
- New receivers have increased BW: 55-82 MHz

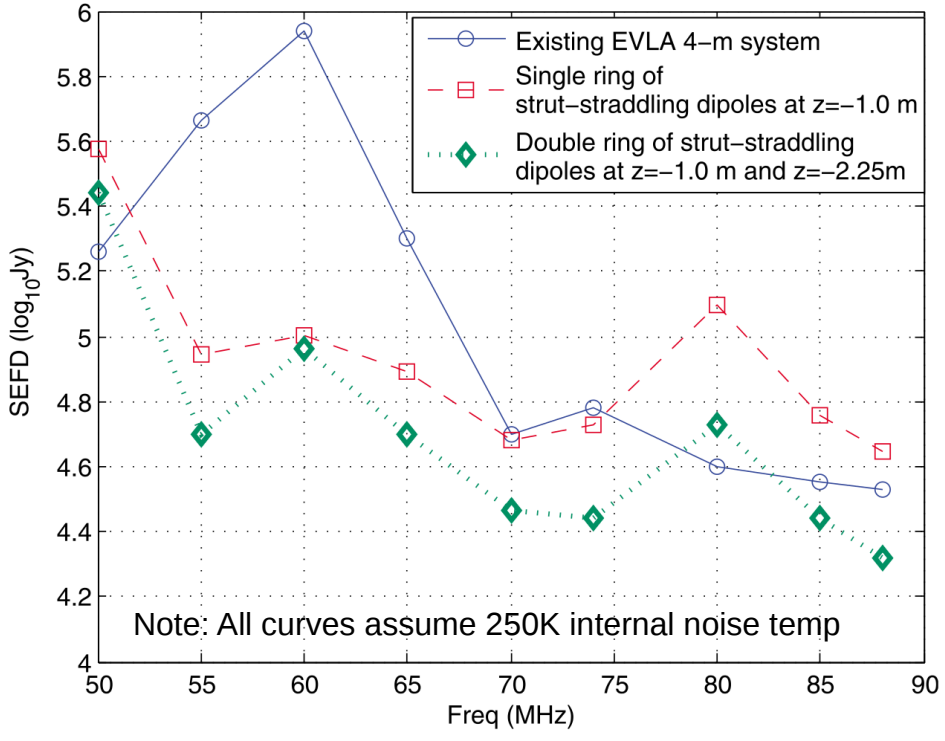
- Objectives for new feeds:
  - [*constraint*] Insignificant blocking to higher freqs; can be permanently installed
  - [*goal*] Best possible sensitivity at 74 MHz
  - [*goal*] Best possible use of new front end bandwidth

Graphics: P. Harden

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

- Developed EM modeling techniques suitable for 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 It Works

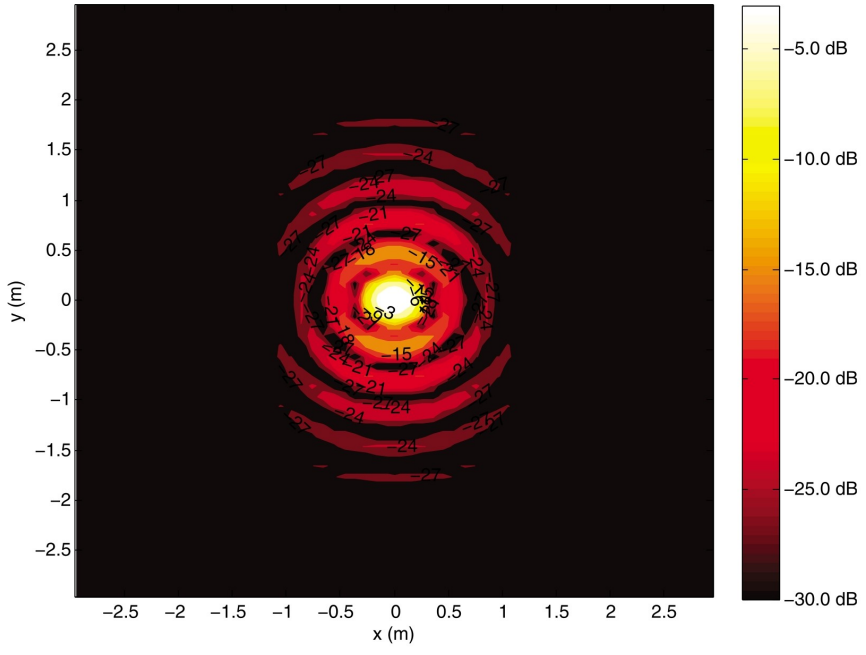


Figure 2. Distribution of power density in the focal plane of a reflecting paraboloid (D = 25 m, f/D = 0.36) relative to the power density at the focus at 500 MHz.

Focal Plane Power Density @ 500 MHz

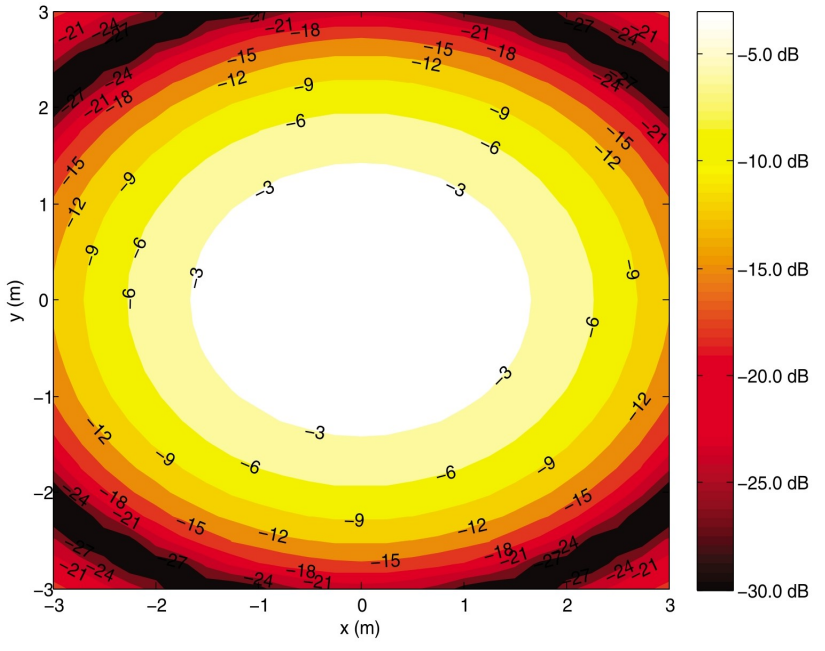
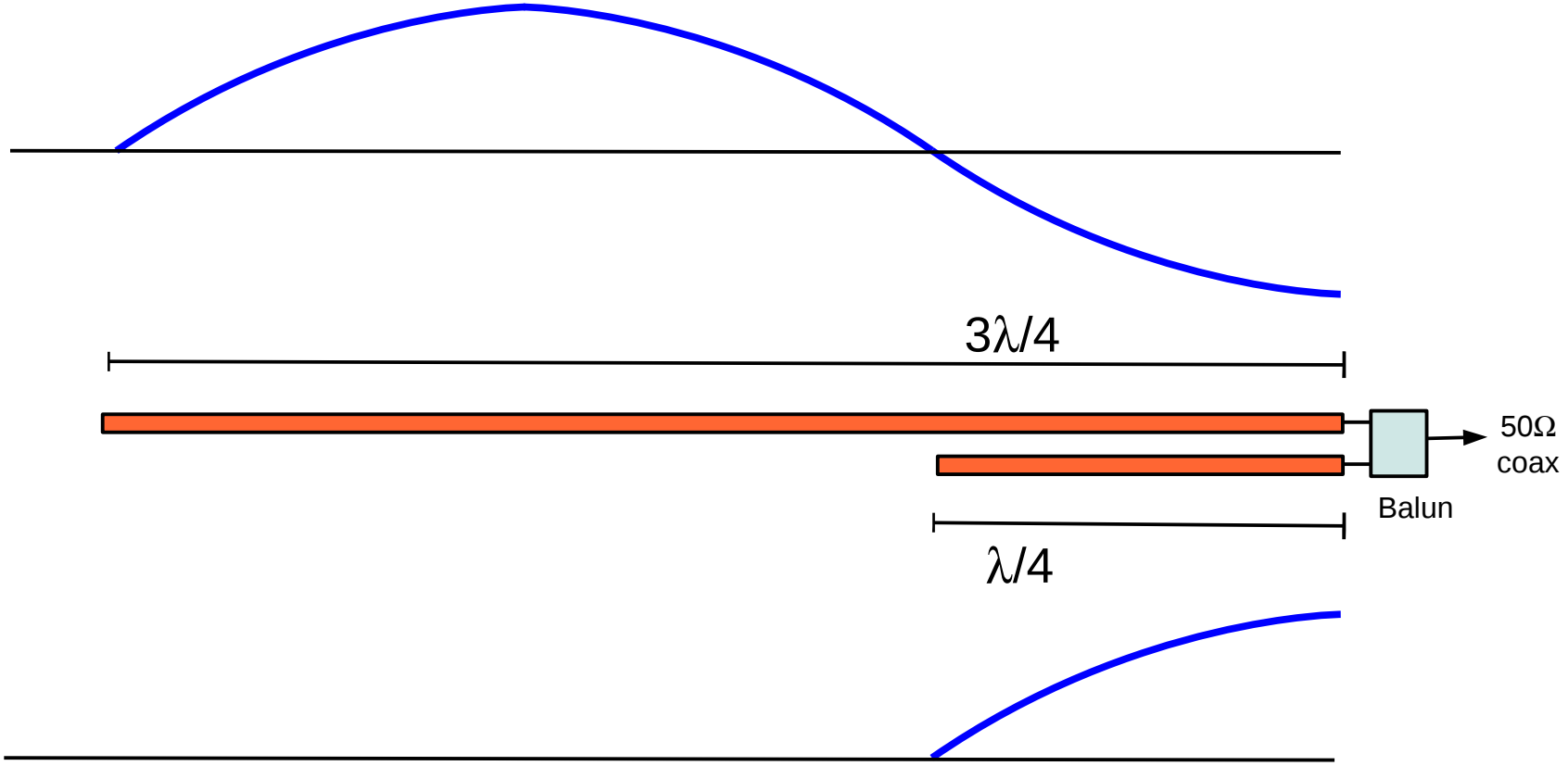


Figure 3. Distribution of power density in the focal plane of a reflecting paraboloid (D = 25 m, f/D = 0.36) relative to the power density at the focus at 50 MHz.

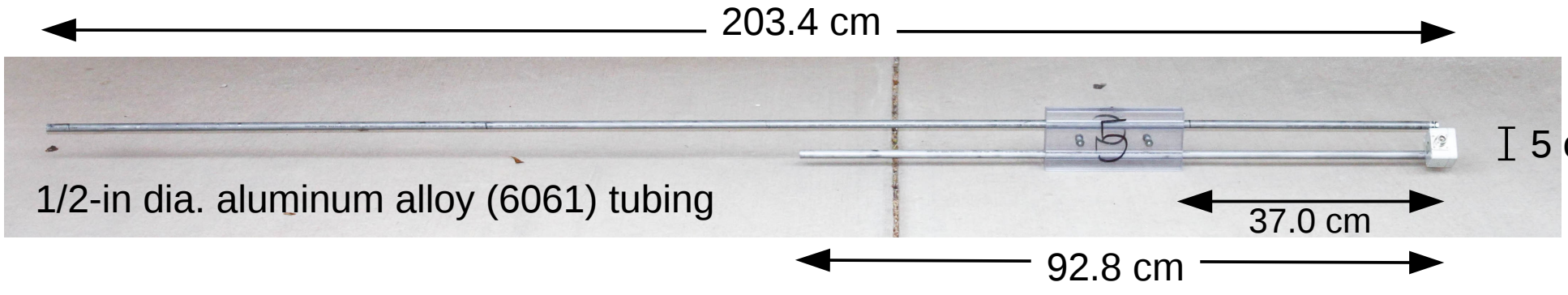
Focal Plane Power Density @ 50 MHz

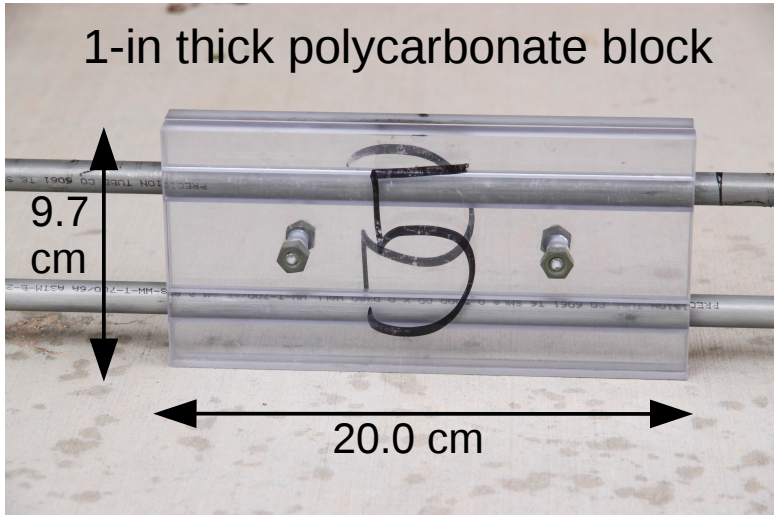
“J-Pole” Antenna

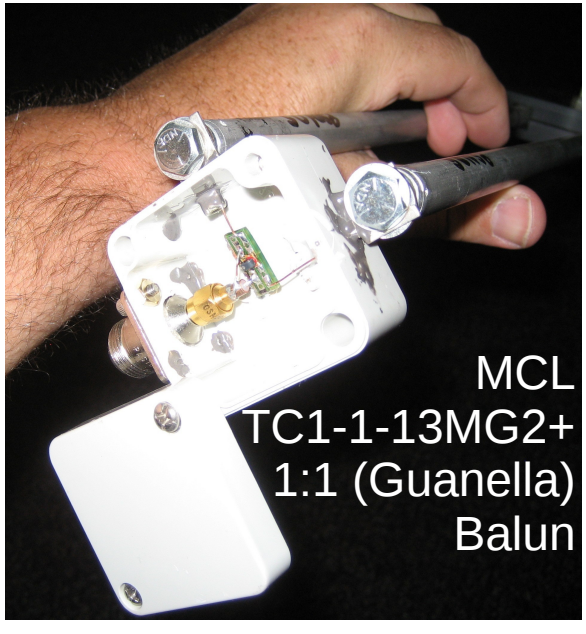


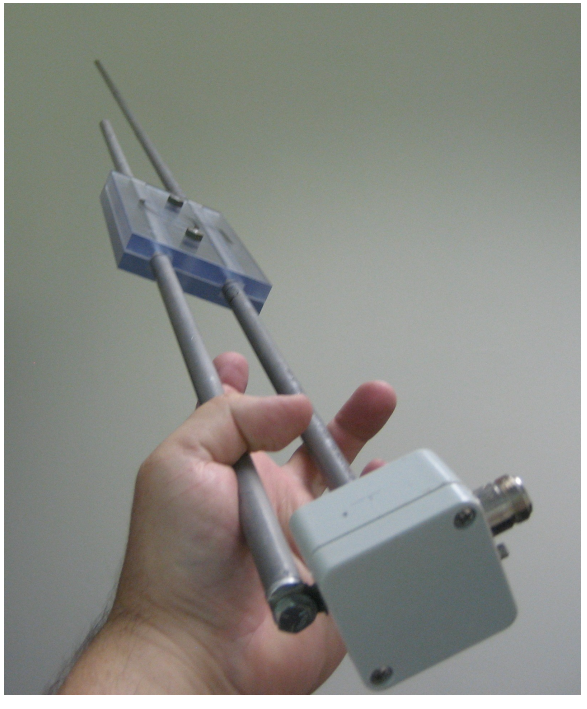
Simple trick to get a half-wave dipole current distribution from an end-fed antenna.
(Can also do this with a sleeve dipole, but those are very narrowband.)

Modified J-Pole (MJP)



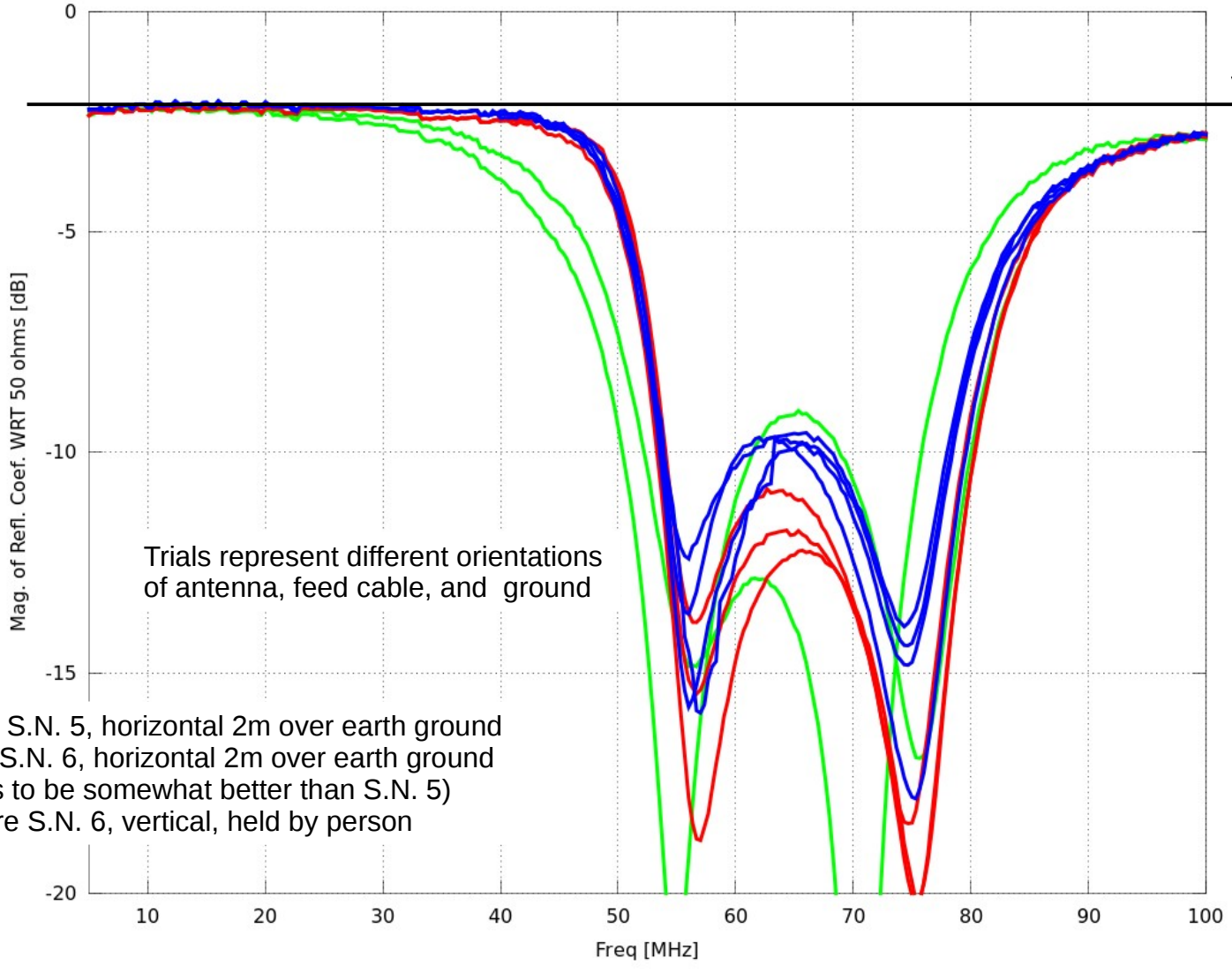






Ellingson, Coffey & Mertley (2013), EVLA Memo 172

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



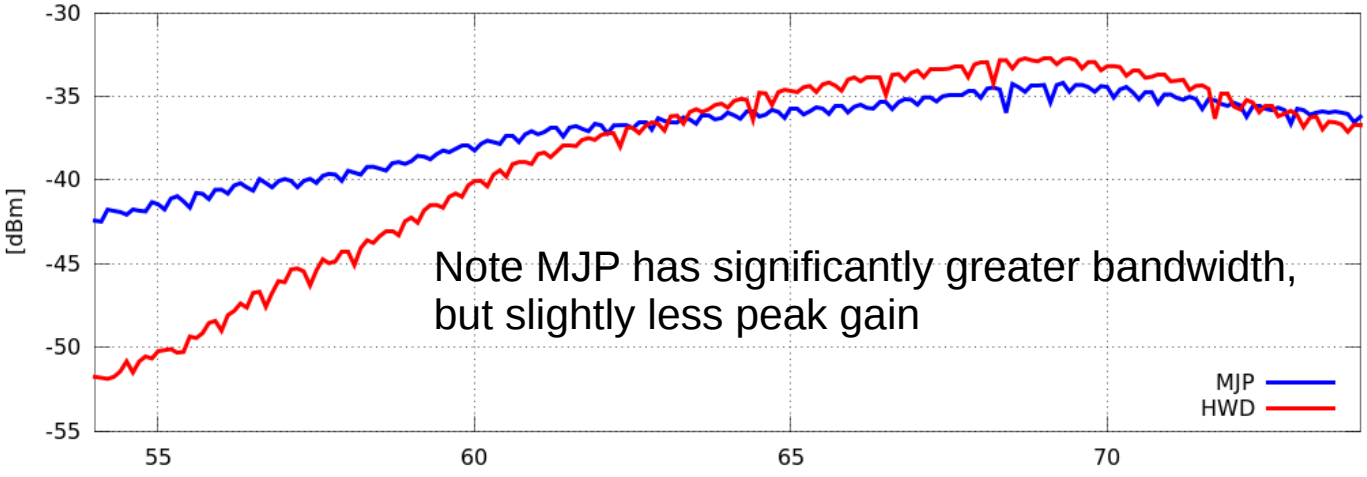
One-way loss of 1.2 dB (92K) due to balun

$|s_{11}|$ < -10 dB 55-80 MHz

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

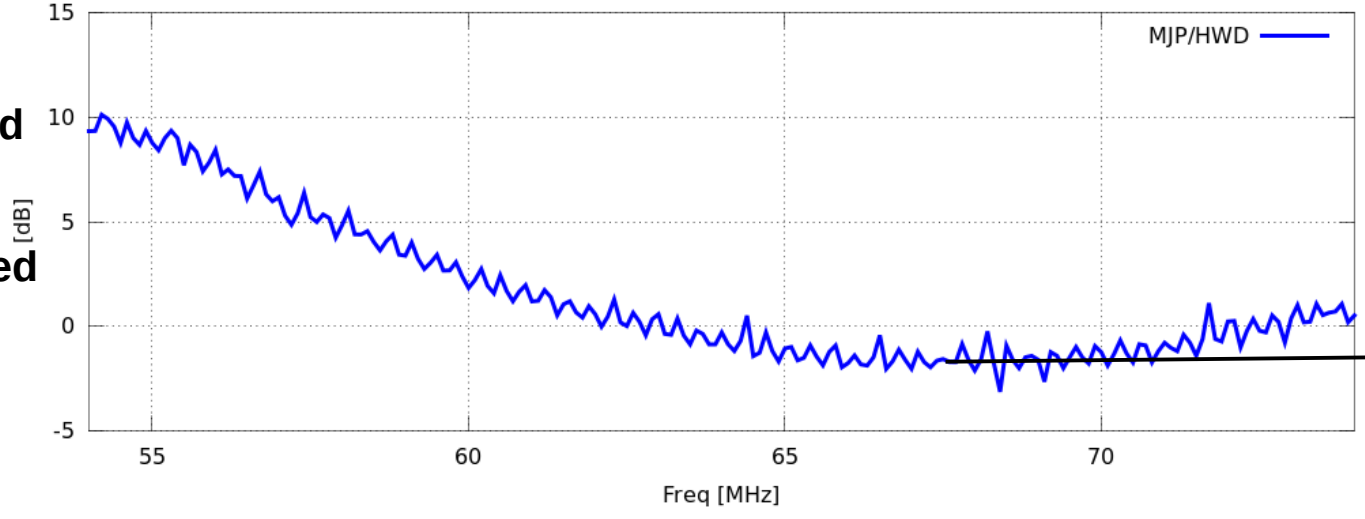
Gain: MJP vs. Half-Wave Dipole *(meas.)*

Absolute received power



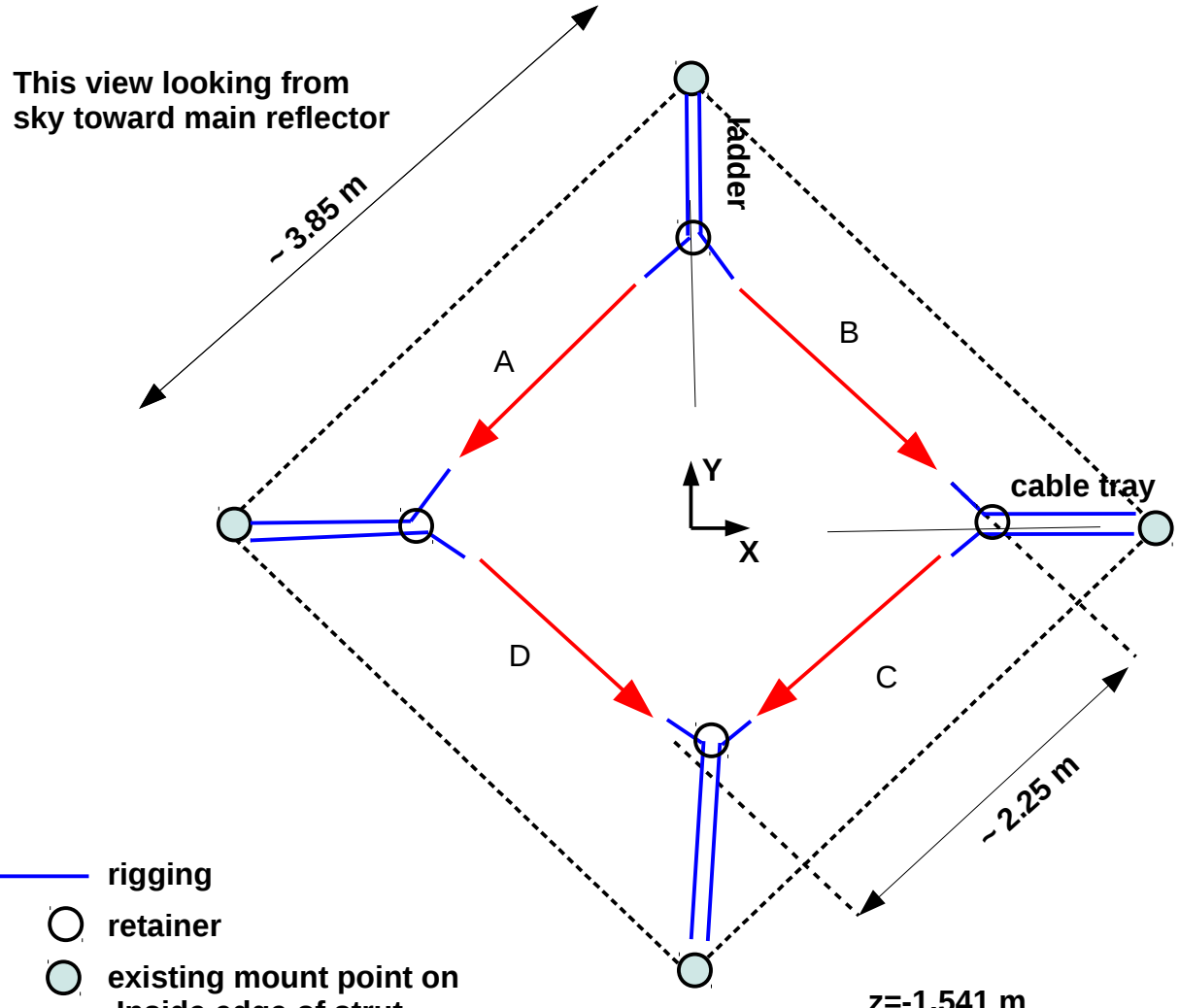
HWD =
Thin dipole,
Half-wavelength
@ 74 MHz

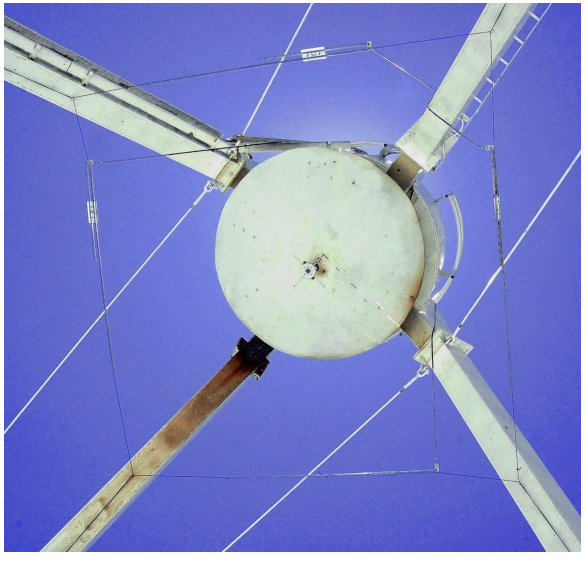
MJP-received power divided by HWD-received power



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

“MJP-B” Feed System





Original (Prototype) Rigging

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

“Production” MJP-B Feed System

Status as July 2014

- **Ruggedized MJP-B systems “permanently” installed on 4 dishes now, 6 soon**

- **Testing extremely difficult & limited for both technical & administrative reasons.**
  - **Current “best practice” depends on measuring visibility phase variance as a proxy for SEFD**

- **Measurements so far indicate:**
  - **Sensitivity roughly 75% of Erickson system overall (i.e., 74 MHz narrowband, 55-84 MHz continuum)**
  - **Sensitivity superior to Erickson system below 65 MHz**
  - **L-band sensitivity impact < 1.5% (compared to 7% for Erickson system)**
  - **Cross-pol in uncalibrated linears may be high (~40%?), compared to ~10% for Erickson system**
  - **Pattern: Extremely difficult to measure. Measurements & simulations suggest possible trouble.**
  - **Both systems have a roughly 2:1 polarization imbalance, presumably due to VLA feed support asymmetry**

- **Further testing/confirmation awaiting return to A-array**
- **No funding for further technical development, optimization, or build-out**

VLA / MJP-B vs. LWA1 & LOFAR

- **Sensitivity (SEFD):**
  - **1 MJP-equipped dish = 8% of LWA1, 45% of a LOFAR int'l station**
  - **6 MJP-equipped dishes = 50% of LWA1, 2.7 LOFAR int'l stations**
  - **27 MJP-equipped dishes = 2.2 LWA1's, 12.4 LOFAR int'l stations**

- **VLA: Many long & diverse baselines; LWA1: Not so much**

- **LWA1: Exquisitely fine time & freq. resolution; VLA: Not so much**
- **LWA1: Multiple large fields of view, very fast response; VLA: Nope**
- **VLA limited by EVLA electronics to minimum frequency of 54 MHz**

A Few More Ideas

- **Optimization of mounting geometry would be a good idea**
  - **“MJP-B” is merely the best-liked of 3 possibilities considered**
- **Polarization combining scheme is approximate; could be optimized**
- **Yagi-ization of MJPs to increase aperture efficiency**
- **2nd ring of dipoles – Harun's work shows O(50%) improvement possible**

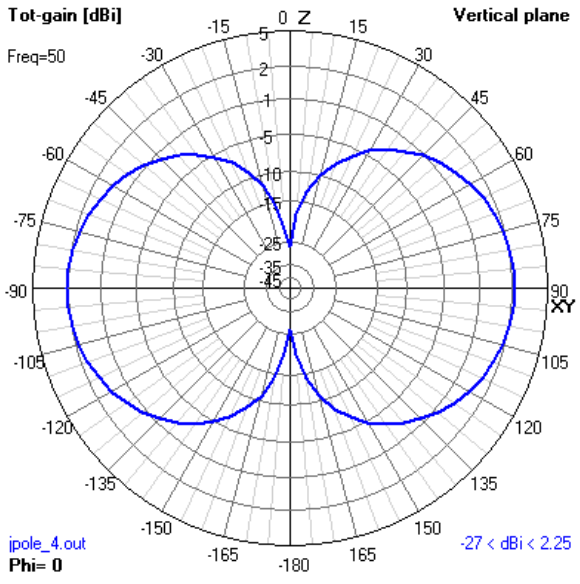
Backup Slides

Summary of Findings *(As of Sep 30, 2013)*

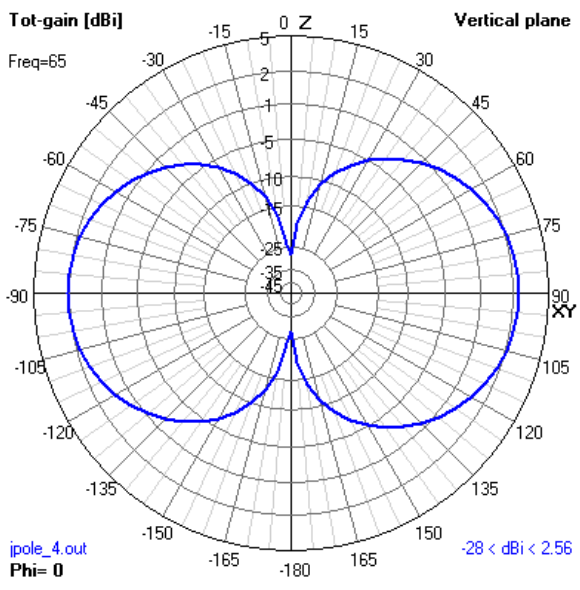
	Legacy "crossed dipoles"	Strut-straddling in same plane	"Shrunken box" in same plane	Strut-straddling closer to subreflector
	Erickson	**MJP-A**	**MJP-B**	**MJP-C**
L-band Blockage	7% [1]	"not noticeable" [2]	< 1.5% (+/-0.5%) [3]	< 1.5% (+/-0.5%) [4] 2.3% *(sim)* [6]
Sensitivity @ 74 MHz, relative to Erickson (Bigger is better)	1.00	0.25 - 0.33 [2] 0.22 *(sim.)*	0.50 – 1.00 [5] 0.75 in X, 0.50 in Y [9]	*(meas. not yet done)* 1.13 *(sim)* [6]
Same as above, scaled by available bandwidth	1.00	0.32 – 0.42 *(extrapol.)*	0.73 – 1.45 *(extrapol.)* 0.75 in X, 0.65 in Y [9]	0.40 in X, 0.35 in Y [9]
Bandwidth (Full width of visibility magnitude at ½ the 74 MHz value)	12 MHz (66-78 MHz)	20 MHz (55-75 MHz)	27 MHz (55-82 MHz)	
Uncalibrated cross-pol. @ 74 MHz	~10% [7]	~25% [7]	~45% [7]	
Pol. Imbalance [8] @ 74 MHz	1.5 2.5 *(sim)* [6]	2.8 2.5 *(sim)*	2.0 2.5 *(sim)*	2.5 *(sim)*

[1] Perley, EVLA Memo 123, 2008
[2] Subrahmanyan, "Re: Coaxial dipoles in square configuration", email dated Jan 31, 2013
[3] Intema, "Re: 4band week ahead", email dated Aug 5, 2013
[4] Ellingson, "Re: 4band week ahead", email dated Aug 5, 2013
[5] Ellingson's estimate from analysis of data from tests on June 6 and July 25, 2013 (see details)
[6] Harun & Ellingson 2011, *Radio Sci*., 46
[7] Direct measurement of raw "X" and "Y" as seen by receivers; i.e., no attempt to recover calibrated orthogonal polarizations
[8] Ratio of max(|XX|, |YY|) to min(|XX|, |YY|) close to apparent main lobe peak.
[9] Owen, "Relative Sensitivity of Erickson and MJP Dipole Feeds, EVLA Memo 174, Sep 2013.

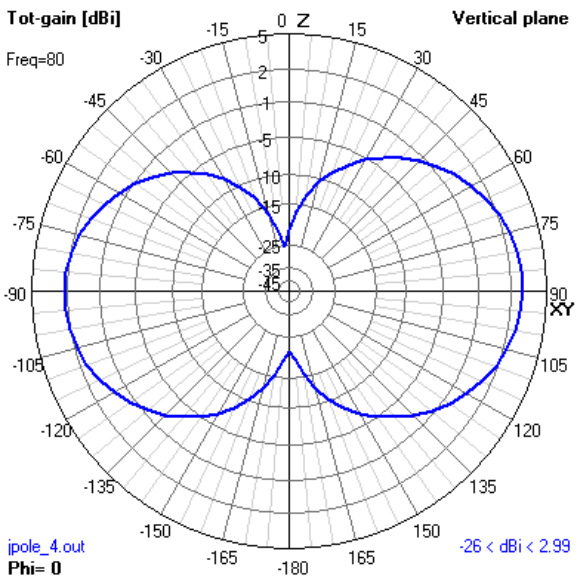
Modified J-Pole Prototype Pattern *(sim.)*



50 MHz

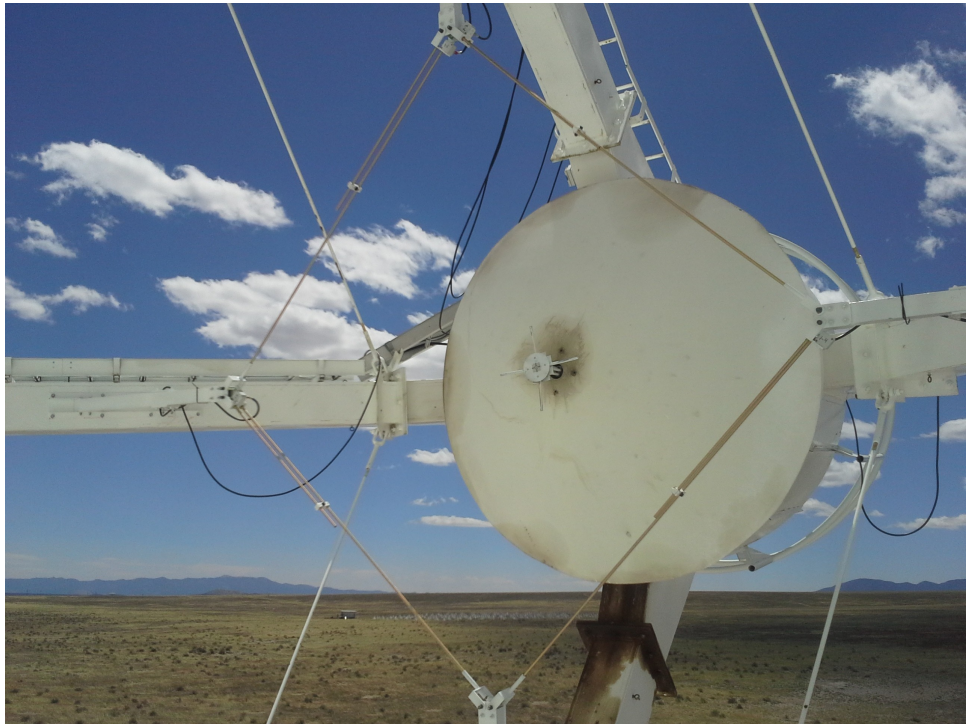


65 MHz



80 MHz

Note directivity is never worse than 0.5 dB less that of a $\lambda/2$ dipole, and increases monotonically with frequency



R. Subrahmanyan's Experiments (-Jan 2013)

- Designed/Built (w/Mertley & Coffey):
  - 74 MHz-resonant sleeve (end-fed) dipoles
  - Analog polarization combining scheme to synthesize H & V pols for LBR
  - Installed on two dishes
- Observed “negligible blocking” to L- and S-bands
- Sensitivity relative to Erickson system inferred from variance of visibility phases; implied 74 MHz sensitivity down by a factor of 3-4
  - Harun's work suggests this factor should be ~1
  - In July 2013, we determined that these dipoles, mounted in the plane of the existing Erickson dipoles, are NOT in the plane specified by Harun.
- Another concern was that fractional bandwidth ~3.4% (for $|\Gamma|<0.1$) for sleeve dipoles is near theoretical *minimum* for any feed of this dimension; much less than Erickson dipoles

Picture: P. Harden