HNRAO 367 Engle Rd., Industry, PA 15052
Longitude: 80° 26.259 - Latitude: 40° 40.394 N
Elevation 1202 ft.
Grid: EN90sp

Hawks Nest Radio Astronomy Observatory
Site description, system measurements and system diagrams

Observatory telescope antennas:

- One LWA style array consisting of 4 phased cross dipoles
  - Both right circular and left circular polarization.
- One Mosley MB-15 3-element yagi at 20 feet
  - Linear polarization
  - Elevation/Azimuth computer controlled, Yaesu rotor driven
    - NOVA for Windows software used for tracking.
  - Also used for interference location
- One phased JOVE Dipole Array, at 10 feet.
  - Linear polarization.

Receivers:

- JOVE II receiver
  - 24-7 operations
  - 20.1 MHz
    - 7 kHz RF BW direct conversion
    - Integration time selectable via software
  - Antenna source – Phased JOVE dipoles
  - HP computer
    - S5, CPU G40, 2.80 GHz, 6 GB Ram, 64 bit OS.
    - SkyPipe software
      - Data files saved to external 1TB hard drive.
- Icom R-75 receiver
  - As needed basis
  - Antenna feed – varies as needed
- FSX 12 bit switching dual polarization.
  - 24-7 operations
  - Antenna source – LWA style antennas
  - Gateway computer
    - SX2855, CPU G620, 2.60 GHz, 4 GB Ram, 64 bit OS.
    - Radio Sky Spectrograph software
      - Data files saved to external 1TB hard drive.
  - 15-30 MHz – simultaneous RCP and LCP
  - 300 channels per polarization (software adjustable)
  - Sweep frequency (software adjustable) (7.5. 15, 30 & 60 kHz pre-detection BW)
  - Approx. 6.7 sweeps/second, integration time = 500 µs per sample
  - Frequency resolution = 53 kHz, Δt = 150 µs

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Observatory test equipment:

- MFJ-259B Antenna Analyzer[1] – Fig 1
- HP461A noise source. – Fig 2
  - Calibrated 8 Aug 2013
    - Measured 94.1 Mk
  - Serial # 0946A04903
- Rigol DS1054Z 50 MHz Digital Oscilloscope[2] – Fig 3
  - Self-Calibrated, 15 Dec 2015
- Kay Step Attenuator, Model 30-0 – 432D – Fig 4
  - Serial # A11418
- Fluke multimeter
- Assorted BNC and UHF connectors and cables.

Figure 1 - MFJ 259B

Figure 2 - HP461A

Figure 3 - Rigol DS1054Z

Figure 4 - Kay Step Attenuator

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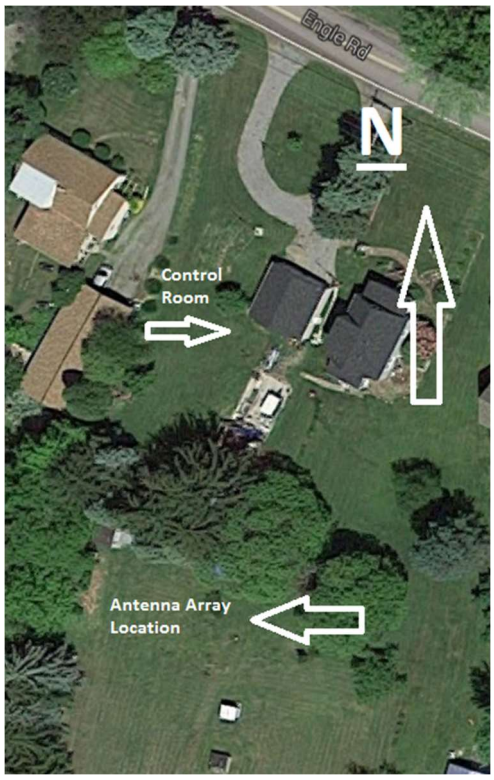
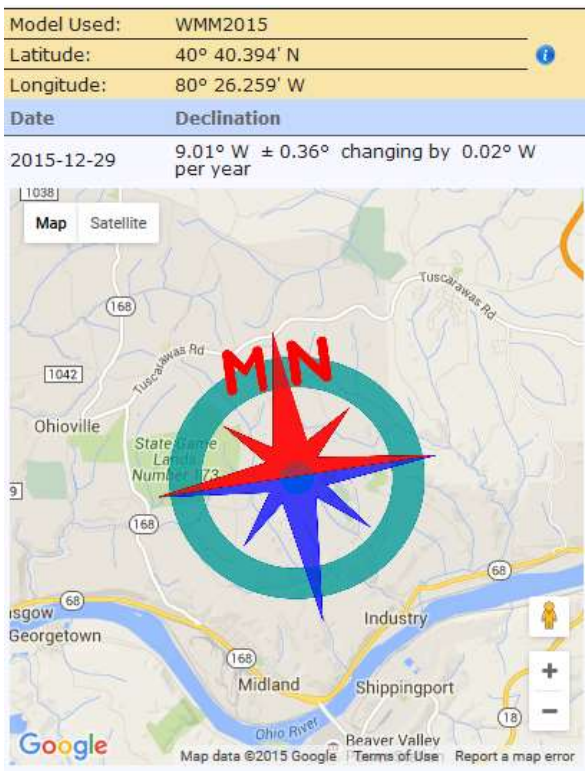
Magnetic bearing/location and soil conductivity at observatory.

- All antennas aligned to magnetic north.





Magnetic Field

Model Used:	WMM2015
Latitude:	40° 40.394' N
Longitude:	80° 26.259' W
Elevation:	1202.0 ft Mean Sea Level

Date	Declination (+ E | - W)	Inclination (+ D | - U)	Horizontal Intensity	North Comp (+ N | - S)	East Comp (+ E | - W)	Vertical Comp (+ D | - U)	Total Field
2015-12-29	-9.0085°	67.7243°	19,990.9 nT	19,744.3 nT	-3,130.2 nT	48,801.8 nT	52,737.6 nT
Change/year	-0.0210°/yr	-0.0849°/yr	29.4 nT/yr	27.9 nT/yr	-11.8 nT/yr	-134.4 nT/yr	-113.2 nT/yr
Uncertainty	0.36°	0.22°	133 nT	138 nT	89 nT	165 nT	152 nT

Hawks Nest Radio Astronomy Observatory

HNRAO 367 Engle Rd., Industry, PA 15052
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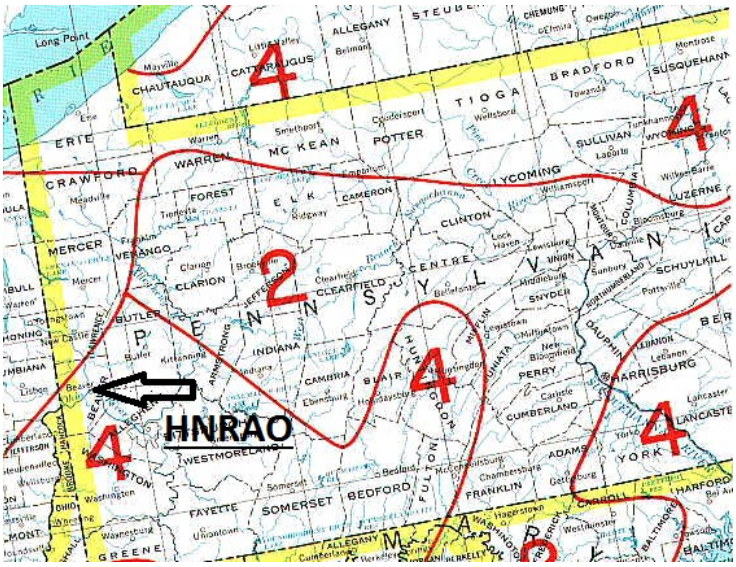
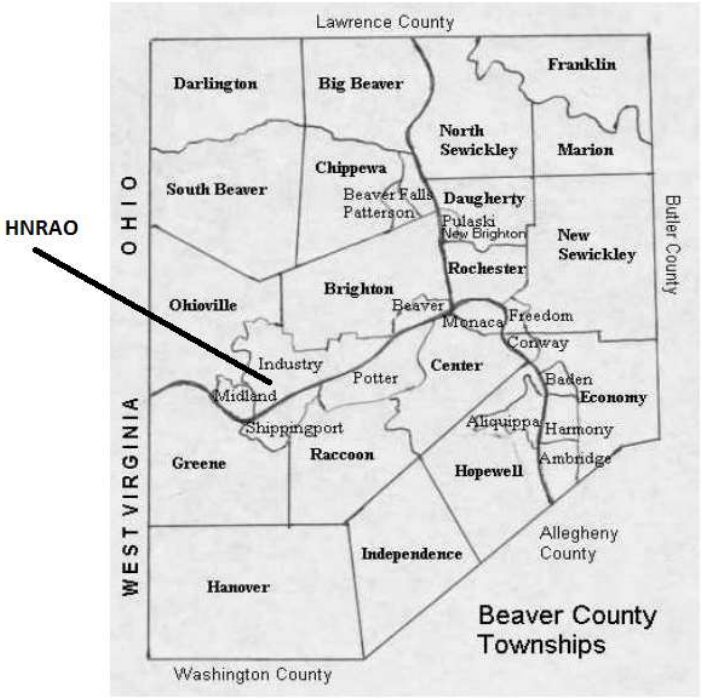
Soil Conductivity @ HNRAO is 4 mili-siemens/meter.





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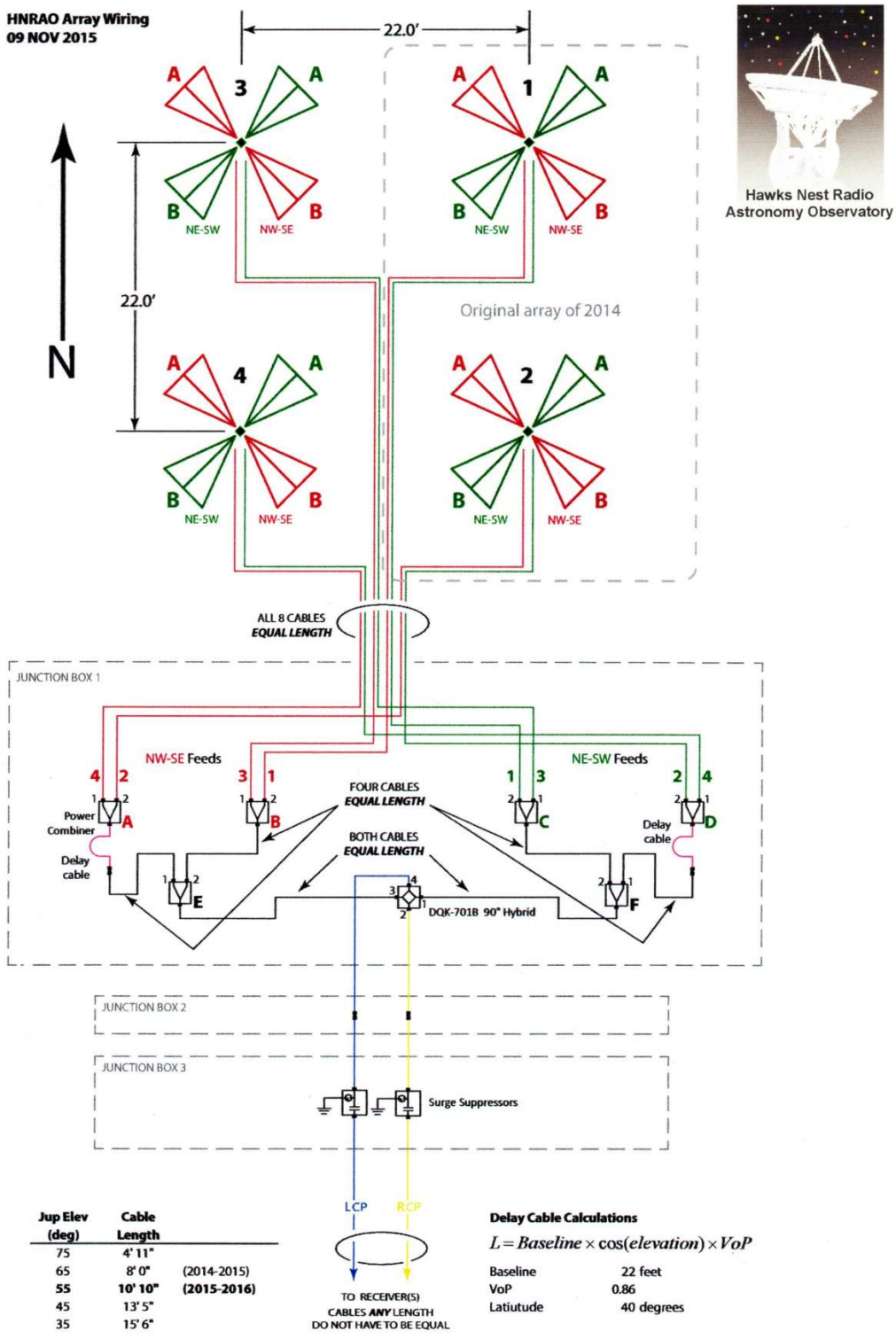

Jup Elev (deg)	Cable Length	
75	4' 11"	
65	8' 0"	(2014-2015)
55	**10' 10"**	**(2015-2016)**
45	13' 5"	
35	15' 6"	

Delay Cable Calculations

$$L = Baseline \times \cos(elevation) \times VoP$$

Baseline	22 feet
VoP	0.86
Latiutude	40 degrees

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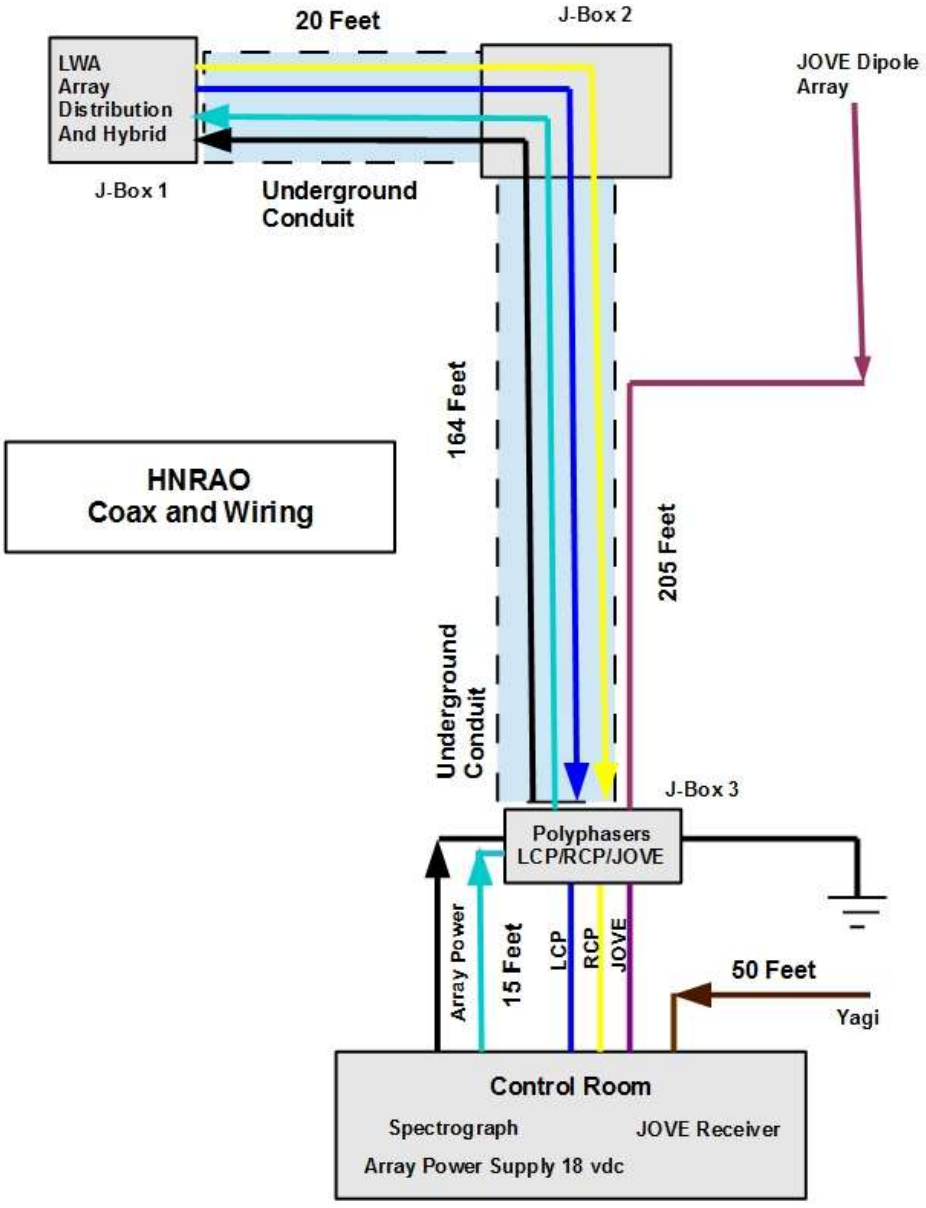

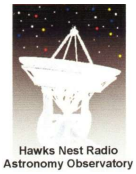

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HNRAO LWA Wiring Table

Cable ID	End 1	End 2	Type	Length	Vp	Loss @ 20 MHz	Manuf.	Location
Red 1	LWA 1 Active balun #24	Combiner #B1	RG-8x	27’	.84	C -0.38 dB	CQ Mini 8	underground
Green 1	LWA 1 Active balun #23	Combiner #C2	RG-8x	27’	.84	C -0.38 dB	CQ Mini 8	underground
Red 2	LWA 2 Active balun #21	Combiner #A2	RG-8x	27’	.84	C -0.38 dB	CQ Mini 8	underground
Green 2	LWA 2 Active balun #22	Combiner #D2	RG-8x	27’	.84	C -0.38 dB	CQ Mini 8	underground
Red 3	LWA 3 Active balun #27	Combiner #B1	RF240	27’	.86	C -0.27 dB	Belden	underground
Green 3	LWA 3 Active balun #28	Combiner #C1	RF240	27’	.86	C -0.27 dB	Belden	underground
Red 4	LWA 4 Active balun #25	Combiner #A1	RF240	27’	.86	C -0.27 dB	Belden	underground
Green 4	LWA 4 Active balun #26	Combiner #D1	RF240	27’	.86	C -0.27 dB	Belden	underground
	Combiner A out*	Combiner E in	RG-8X	10’ 10”	.84	M -0.18 dB	CQ Mini 8	J-Box 01
	Combiner B out	Combiner E in	RG-8X	14”	.84	M -0.00 dB	CQ Mini 8	J-Box 01
	Combiner C out	Combiner F in	RG-8X	14”	.84	M -0.00 dB	CQ Mini 8	J-Box 01
	Combiner D out*	Combiner F in	RG-8X	10’ 10”	.84	M -0.18 dB	CQ Mini 8	J-Box 01
	Combiner E out	Hybrid port 3 in	RG-8X	8”	.84	M -0.00 dB	CQ Mini 8	J-Box 01
	Combiner F out	Hybrid Port 1 in	RG-8X	8”	.84	M -0.00 dB	CQ Mini 8	J-Box 01
	Hybrid Port 2 out	J-Box 2 bullet	RG-8X	20’	.84	C -0.28 dB	CQ Mini 8	underground
	Hybrid Port 4 out	J-Box 2 bullet	RG-8X	20’	.84	C -0.28 dB	CQ Mini 8	underground
	J-Box 2 bullet	Polyphasor #01	RF240	164‘	.86	C -1.64 dB	Belden	J-Box 02
	J-Box 2 bullet	Polyphasor #02	RF240	164’	.86	C -1.64 dB	Belden	J-Box 02
	Polyphasor #01 RCP	Spectrograph	RF240	15’	.86	C -0.15 dB	Belden	J-Box 03
	Polyphasor #02 LCP	Spectrograph	RF240	15’	.86	C -0.15 dB	Belden	J-Box 03

***This is the phasing cable length for 55 degrees elevation angle. Phasing cable is attached to a 14” jumper using a bullet**.

Device	Desig	Model	Manuf	Conn Type	Loss/ Gain*	Location	Connected to
Active Balun	21		RF Assoc	UHF/BNC	M +19 dB	Antenna #2	Port A to NW arm, Port B to SE arm
Active Balun	22		RF Assoc	UHF/BNC	M +19 dB	Antenna #2	Port A to NE arm, Port B to SW arm
Active Balun	23		RF Assoc	UHF/BNC	M +19 dB	Antenna #1	Port A to NW arm, Port B to SE arm
Active Balun	24		RF Assoc	UHF/BNC	M +19 dB	Antenna #1	Port A to NE arm, Port B to SW arm
Active Balun	25		RF Assoc	UHF/BNC	M +19 dB	Antenna #4	Port A to NW arm, Port B to SE arm
Active Balun	26		RF Assoc	UHF/BNC	M +19 dB	Antenna #4	Port A to NE arm, Port B to SW arm
Active Balun	27		RF Assoc	UHF/BNC	M +19 dB	Antenna #3	Port A to NW arm, Port B to SE arm
Active Balun	28		RF Assoc	UHF/BNC	M +19 dB	Antenna #3	Port A to NE arm, Port B to SW arm
Combiner	A	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Combiner	B	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Combiner	C	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Combiner	D	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Combiner	E	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Combiner	F	ZSC-2-1	MCL	BNC	M -0.42 dB	J-Box 1	See table above
Hybrid		DQK-701B	Synergy	BNC	M -0.29 dB	J-Box 1	See table above
BNC Bullet				BNC	C 0.0 dB	J-Box 2	
BNC Bullet				BNC	C 0.0 dB	J-Box 2	
Arrestor	#01	IS-50UX-C1	Polyphasor	UHF	M -0.01 dB	J-Box 3	
Arrestor	#02	IS-50UX-C1	Polyphasor	UHF	M -0.01 dB	J-Box 3	

*** M = Measured, C = calculated from data sheet**

Measurements made with MFJ-259B as RF source, Rigol oscilloscope with 9 dB pad on input, and 50-ohm termination.

HNRAO LWA Coax Loss Measurements From Spectrograph to J-Box 1 in dB — **1-Dec-15**

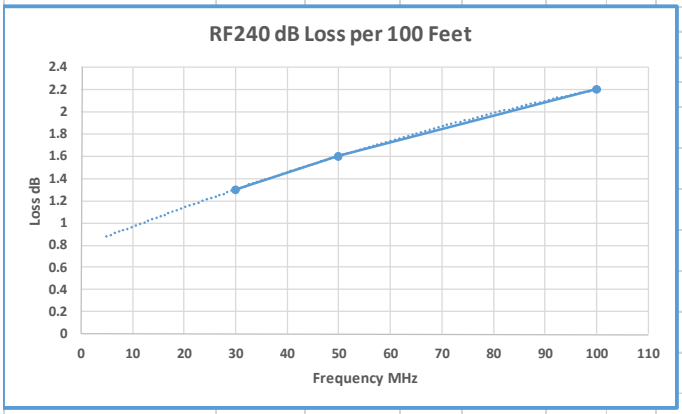
Cable	Location	From	To	Location	Length	Units	Coax Type	vf	Reference Vrms	Measured Vrms	Loss Calculated		Loss Measured	
NW/SE Delay/w 14" tail.	Comb A	Sum Port	Input 1	Comb E	12.00	Ft	RG-8X	0.84	1.98	1.94	-0.16	dB	-0.18	dB
14" cable	Comb B	Sum Port	Input 2	Comb E	1.17	Ft	RG-8X	0.84	1.98	1.98	-0.02	dB	0.00	dB
14" cable	Comb C	Sum Port	Input 2	Comb F	1.17	Ft	RG-8X	0.84	1.98	1.98	-0.02	dB	0.00	dB
NE/SW Delay/w 14" tail	Comb D	Sum Port	Input 1	Comb F	12.00	Ft	RG-8X	0.84	1.98	1.94	-0.16	dB	-0.18	dB
8" cable	Comb E	Sum Port	Port 3	Hybrid	0.67	Ft	RG-8X	0.84	1.98	1.98	-0.01	dB	0.00	dB
8" cable	Comb F	Sum Port	Port 1	Hybrid	0.67	Ft	RG-8X	0.84	1.98	1.98	-0.01	dB	0.00	dB
Blue/Yellow Coax (joined)	Spectro			Spectro	328.00	Ft	RF240	0.86	1.95	1.12	-3.58	dB	-4.82	dB

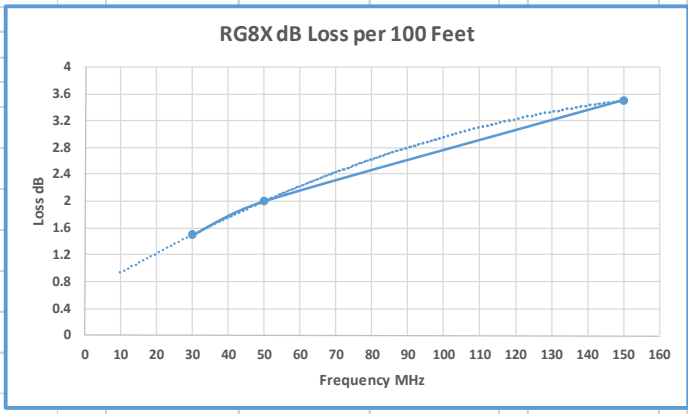
Joined Test: This test involves joining the two polorization coax lines in J-Box #1 with a BNC bullet and measuring the loss at the spectrograph, through the PolyPhasors. The precise length of these cables is not known.

Coax	Loss @ 20 MHz
RG-8X	1.2 dB/100 Ft
RF240	1.1 dB/100 Ft

Reference Vrms: MFJ259B @ 20.1 MHz --> Rigol DS1054Z

Measurements taken with Rigol DS1054Z - Self Calibration 28. Nov 2015





Formula used: 20 Log(Vrms1/Vrms2)	Total Measured Loss from Spectrograph through last combiner before antennas per/polorization @ 20 MHz	-2.76	dB

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Measurements below made with HP461A as noise source and JOVE II receiver feeding SkyPipe to record temperature. Actual loss measured with Rigol oscilloscope and MFJ 259B as RF source produce a result of -3.1 dB loss per port. All combiners tested were functioning normally.

HNRAO LWA Combiner Bench Test 7 Nov. 2015

Mini-Circuits Combiner	Model	Measured Initial Temp Deg. Kelvin Temp	Measured Temp Kelvin Through Port 1	Measuured Temp Kelvin Through port 2	Attenuation Port 2 -> Port 3		Attenuation Port 2 -> Port 1	
A	ZSC-2-1	23310	12150	12130	2.8	dB	2.8	dB
B	ZSC-2-1	23630	12170	12100	2.9	dB	2.9	dB
C	ZSC-2-1	23200	12190	12110	2.8	dB	2.8	dB
D	ZSC-2-1	23560	12190	12200	2.9	dB	2.9	dB
E	ZSC-2-1	23670	12340	12230	2.8	dB	2.9	dB
F	ZSC-S-1	23950	12410	12420	2.9	dB	2.9	dB

Mini-Circuits Combiner ZSC-2-1 --- 2 Way- 0° 50Ω - 0.1 to 400 MHz
low insertion loss, 0.4 dB typ.
25 dB isolation typ

http://www.minicircuits.com/pdfs/ZSC-2-1.pdf

Instrumentation:

Jove II Receiver - Calibrated to HP noise source
HP461A noise source. Calibrated 8 Aug 2013
Kay step attenuator
RG8X coax test cable
BNC Bullet

Formula used: 10 Log(T1/T2)

Hawks Nest Radio
Astronomy Observatory

HNRAO 367 Engle Rd., Industry, PA 15052
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HNRAO FS-X (10-bit) Spectrograph Step Calibration

08-Aug-2013 21:08 UTC

HP461A noise source + Kay 431D step attenuator

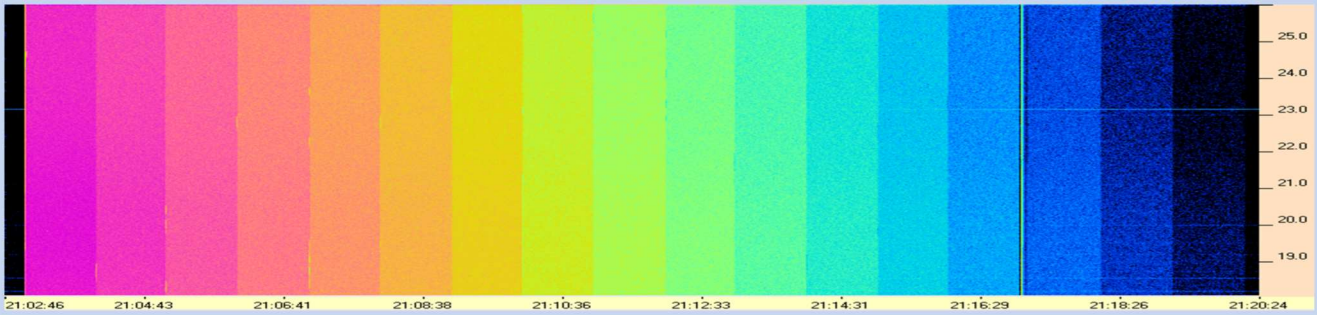
Calibration Plane: Multicoupler Input

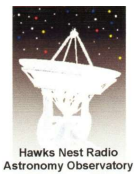
T0 (K)	**290**
Noise source temperature (MK)	**74.8**
Feed loss, cal plane to antenna (dB)	**3.7**
Receiver noise figure (dB)	**6.0**

Att. dB	Source Temp (kK)	Equiv. Ant. Temp. (kK)	50 s Avg. @ Average MHz
0.1	73,098	**171,357**	**718**
3.1	36,636	**85,882**	**687**
6.1	18,362	**43,043**	**657**
9.1	9,204	**21,573**	**627**
11.9	4,831	**11,322**	**602**
14.8	2,478	**5,807**	**574**
17.8	1,243	**2,910**	**544**
21.1	582	**1,361**	**507**
24.1	292	**682**	**478**
27.0	150	**350**	**448**
29.7	81	**188**	**422**
32.6	42	**97**	**393**
35.6	22	**49**	**366**
38.7	11	**24**	**340**
42.2	5.7	**10.9**	**313**
45.1	3.5	**5.7**	**294**
48.1	2.3	**3.0**	**279**

Image Below Offset: 280

RSS Color Offset:	**280**	**280**	**0.00**	**0.00**
RSS Color Gain:	**2.00**	**3.15**	**1.00**	**1.00**
	Solar ↓	**Jupiter** ↓	**Custom 1** ↓	**Custom 2** ↓
	Adjusted Value	**Adjusted Value**	**Adjusted Value**	**Adjusted Value**
	876	1024	718	718
	814	1024	687	687
	754	1024	657	657
	694	1024	627	627
	644	1014	602	602
	588	926	574	574
	528	832	544	544
	454	715	507	507
	396	624	478	478
	336	529	448	448
	284	447	422	422
	226	356	393	393
	172	271	366	366
	120	189	340	340
	66	104	313	313
	28	44	294	294
	0	0	279	279





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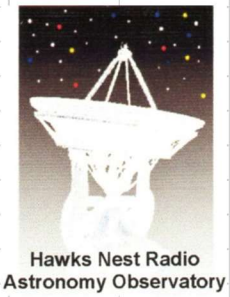
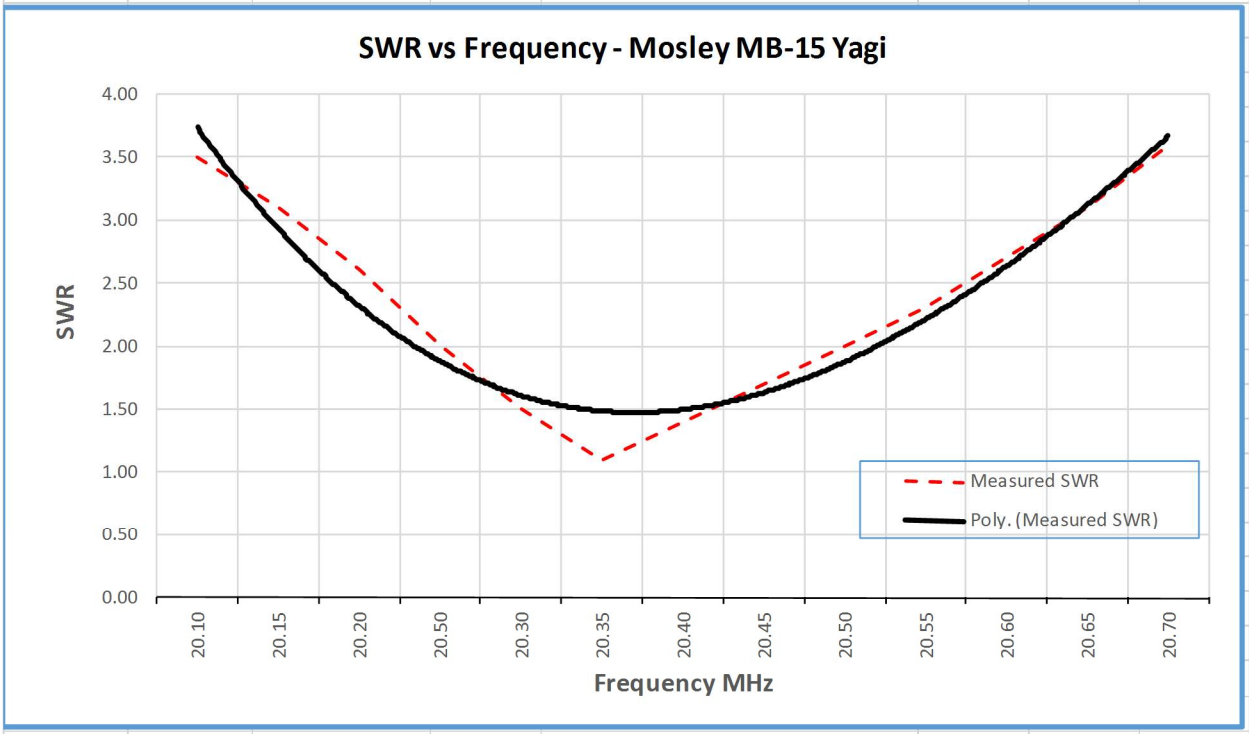
HNRAO
Mosely MB-15 - 3 Element Yagi
SWR vs Frequency

Frequency	Measured SWR
20.10	3.50
20.15	3.10
20.20	2.60
20.50	2.00
20.30	1.50
20.35	1.10
20.40	1.40
20.45	1.70
20.50	2.00
20.55	2.30
20.60	2.70
20.65	3.10
20.70	3.60

Antenna Specifications	
Frequency, MHz	20.3
Forward Gain, dBd	8.4
Front-to Back Ratio, dB	20-25
VSWR at frequency	1.5/1
Feed Point Impedance, ohms	50-52
Number of Elements	3
Boom Length, ft.	14
Turning Radius, ft.	14
Mast Size, in. hardware equipped	2 OD
Maximum Element Length, ft.	24.083
Assembled weight, lbs. (approx.)	30
Wind Surface Area, sq. ft.	5.43
Wind Load, EIA 80 MPH	111
Recommended Coax	RG-8/U





Data obtained with MFJ-259B Antenna Analyzer

HNRAO 367 Engle Rd., Industry, PA 15052
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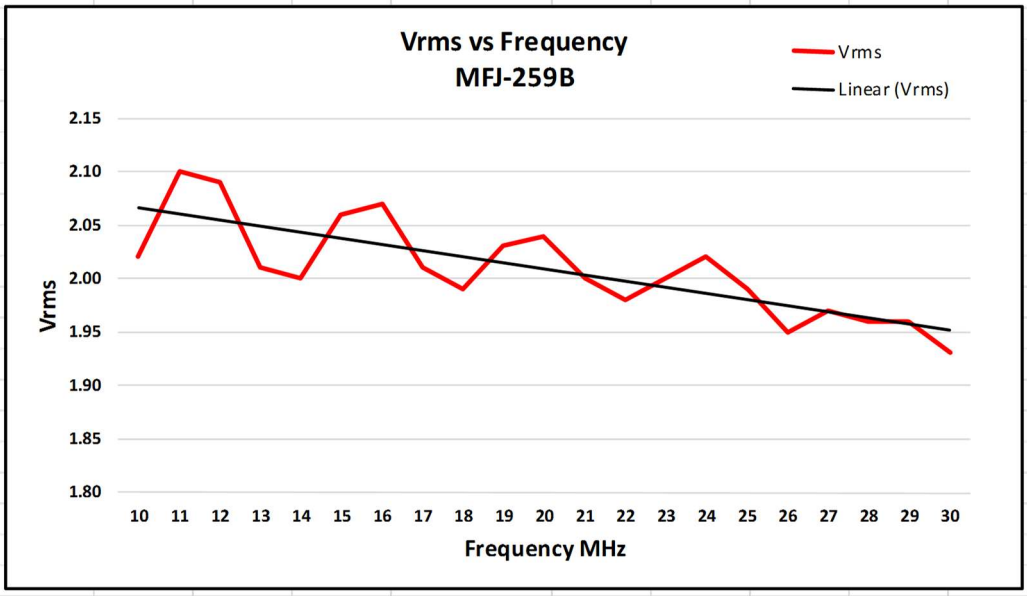
Measurements made with Rigol oscilloscope with 9 dB pad on input, and 50-ohm termination.

HNRAO
Vrms vs Frequency of MFJ - 259B SWR Analyzer

Frequency MHz	Vrms
10	2.02
11	2.10
12	2.09
13	2.01
14	2.00
15	2.06
16	2.07
17	2.01
18	1.99
19	2.03
20	2.04
21	2.00
22	1.98
23	2.00
24	2.02
25	1.99
26	1.95
27	1.97
28	1.96
29	1.96
30	1.93



JOVE Dipole Array

Standard phased pair of JOVE dipoles at 10 feet with a 90-degree phase cable for Jupiter at 55 degrees at transit (2015-16). Gain: 8.5 dBi.

Measurements made with Rigol oscilloscope with 9 dB pad on input, and 50-ohm termination.

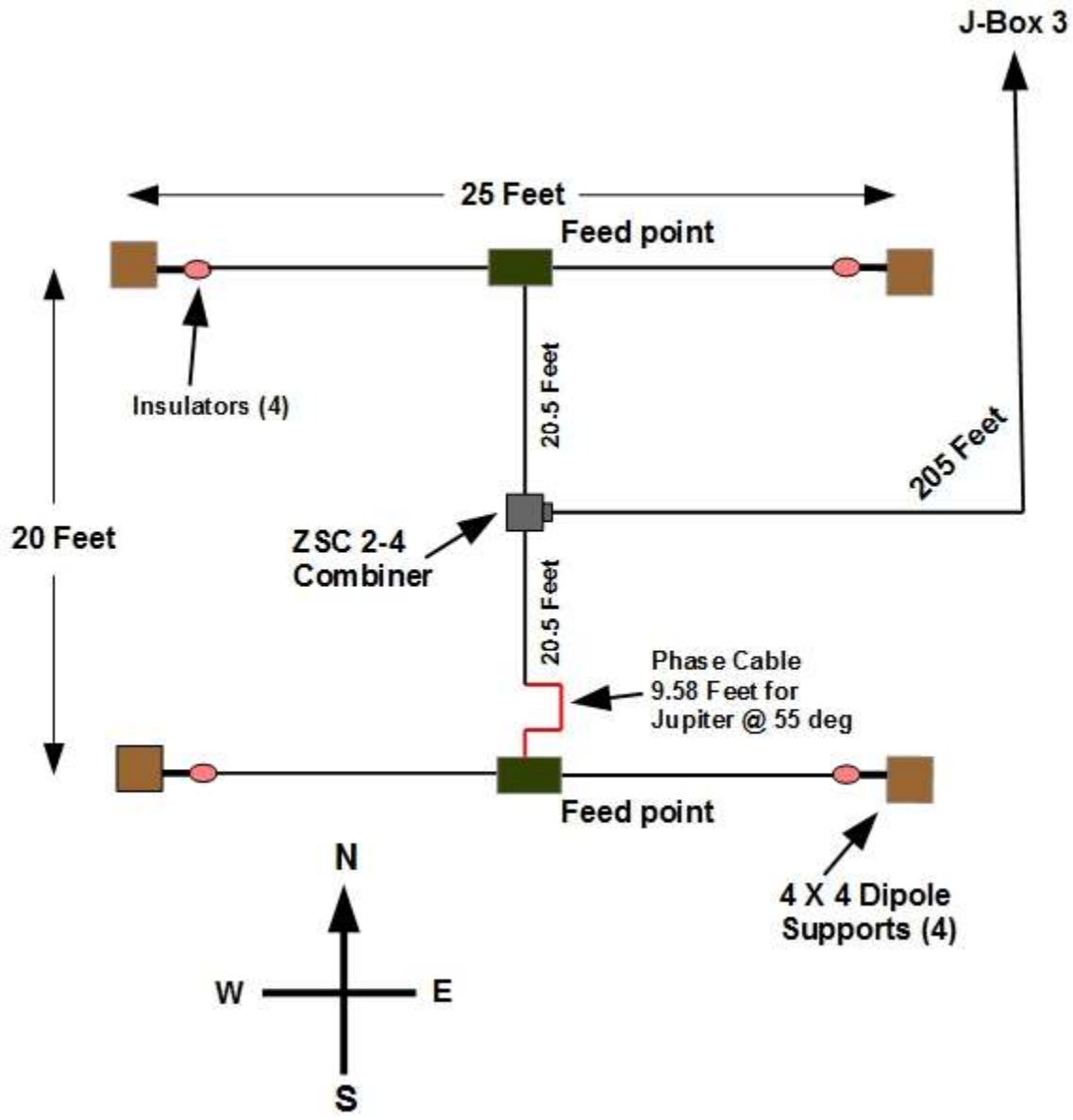
HNRAO JOVE Dipoles			
System Loss	**Length FT**		**Loss dB**
5 λ RG-8X – Multi-coupler to Mini-circuits combiner	205.00	M	-2.32
1/2 λ RG-8X – Combiner to north dipole	20.50	M	-0.36
1/2 λ RG-8X – Combiner to south dipole	20.50	M	-0.31
RG-8X – 90-degree phase cable (Jupiter @ 55 deg)	9.60	M	-0.18
Mini-circuits ZSC-2-4 combiner		M	-0.42
RF Multi-Coupler		M	3.00

RG8-X coax loss (see specifications above)

(M=measured. C=calculated)

For Jupiter at 55 degrees at transit (2015-16)
Assuming 20' between dipoles
Phase cable = 20' cos (55) = 20' * 0.57 = 11.4 *.84 vf (RG8X) = 9.64 feet

Year	Jupiter at Transit/Degrees	Phase Cable Length in Feet
2017-18	35	13.76
2016-17	45	11.88
2015-16	55	9.64
2014-15	65	7.10
2013-14	75	4.35
2012-13	85	1.46



JOVE Dipole Array

[1] The MFJ-259B RF analyzer is a compact battery powered RF impedance analyzer. This unit combines four basic circuits; a 1.8-170 MHz variable frequency oscillator, a frequency counter, a 50 ohm RF bridge, and an eight-bit micro-controller.

[2] The Rigol DS1054Z 4 channel oscilloscope 50 MHz Bandwidth, 4 channels, 1G Sa/s Real-time Sample Rate, 12Mpts, Memory Depth, up to 30,000wfms/s Waveform Capture Rate, 7 Inch WVGA (800x480), multiple intensity levels waveform display.