

TFD Square Array

AN-TFD-24-4

Instruction Manual

January 2020



CONTENTS

Overview	1
Performance Characteristics	1
Space Requirements	2
Erection: Masts	3
Erection: Junction Boxes	3
Erection: Elements	3
Feed System	4
Surge Suppression	4
Confirming Correct Circular Polarization Sense	5
Beam Steering Cable Naming Convention	5
Element Naming Convention	5
Array Maintenance	6
Troubleshooting	8
Theory of Operation	9

APPENDICES

A – Mechanical Drawings	10
B – How to Tie a Some Knots	15
C – Electrical Schematic & Delay Cable Lengths	16
D – Optional Burial of Element Feed Lines	19

Overview

The 4-element terminated folded dipole (TFD) array with 24' elements is designed for a wide bandwidth, from 15 to 30+ MHz, for HF band radio astronomy. This array has proven very useful for observing emission from Jupiter, the Sun, and other phenomena present in the upper half of the HF band.

It is a receive-only design, although it could be used for QRPP (extremely low power) transmitting if the power input to the array is kept well below one watt at all times. The transformers in the baluns are rated for 250 mW. The power combiners and the hybrid are each rated at 1 watt.

Performance Characteristics

The array's characteristics are listed below for several frequencies. Figures shown in the tables below represent analysis based on EZNEC model element model convolved with the array factor, except where noted as measured values.

Where appropriate, figures are in terms of dBic for circular polarization, which assumes circularly polarized emission being received by a circularly polarized antenna of the same polarization sense.

Array Directivity, Beam Steered to Zenith	
Freq (MHz)	dBic
16	10
20	11
24	12
28	12
32	13

Table 1 – Calculated directivity of the array with beam steered to zenith.

Array Effective Aperture, Beam Steered to Zenith	
Freq (MHz)	m ²
16	280
20	210
24	180
28	150
32	130

Table 2 – Calculated effective aperture of the array with beam steered to zenith.

Array HPBW, Beam Steered to Zenith	
Freq (MHz)	(deg)
16	46
20	42
24	38
28	36
32	34

Table 3 – Calculated HPBW of the array with beam steered to zenith. The beam shape is circular.

Element Feed Point Impedances		
Freq (MHz)	Predicted Z (Ω)	Measured Z (Ω)
16	54 + j6	68 – j29
20	69 + j15	45 – j16
24	93 – j15	60 – j16
28	36 – j42	46 – j41
32	40 – j34	22 – j33

Table 4 – Calculated feed point impedances from the EZNEC model and measured feed point impedances using a VNA-2180 vector network analyzer. Impedances measured March, 2015 at output of 16:1 balun transformer in situ at LGM Observatory's TFD array with natural ground (no ground plane). TFD EZNEC models include a 16:1 impedance transformer. See also Plot 1 in the Array Maintenance section of this manual.

24' TFD Element Efficiency	
Freq (MHz)	Efficiency (dB)
16	- 11
20	- 5.8
24	- 3.1
28	- 2.4
32	- 3.5

Table 5 – Efficiency of the 24' TFD relative to a half-wave dipole resonant at 20.1 MHz. Includes all losses from the sky side of the TFD to the feed point end of the feed line .

The 24' TFD efficiency can be modeled by the following polynomial:

$$\eta_{24'TFD} = -4.223 \times 10^{-5} f^4 + 4.863 \times 10^{-3} f^3 - 0.2660 f^2 + 7.116 f - 7.388$$

where

- η = efficiency in terms of decibels.
- f = frequency in MHz, $14 \leq f \leq 33$.

For a complete breakdown of antenna system losses, see the *Feed System Losses* test report summary supplied with your array.

Space Requirements

The TFD dual square array with 24' elements is relatively large. The array forms a square 26' on a side. Ideally, the array should be sited such that a clear area devoid of other antennas, conductors, and structures extends one wavelength from the array at the lowest operating frequency – e.g., 61 feet for 16 MHz. This will avoid beam pattern interference. Experience at AJ4CO Observatory shows that one or two low-height – less than 6 feet – encroachments within this clear area are not harmful; however, we recommend that they be kept to a minimum.

In Figure 1, the TFD array is shown by the orange square, 26' on a side. Zone A represents the area that should be kept clear of structures, conductors, other antennas, and trees. Bushes, shrubs, and

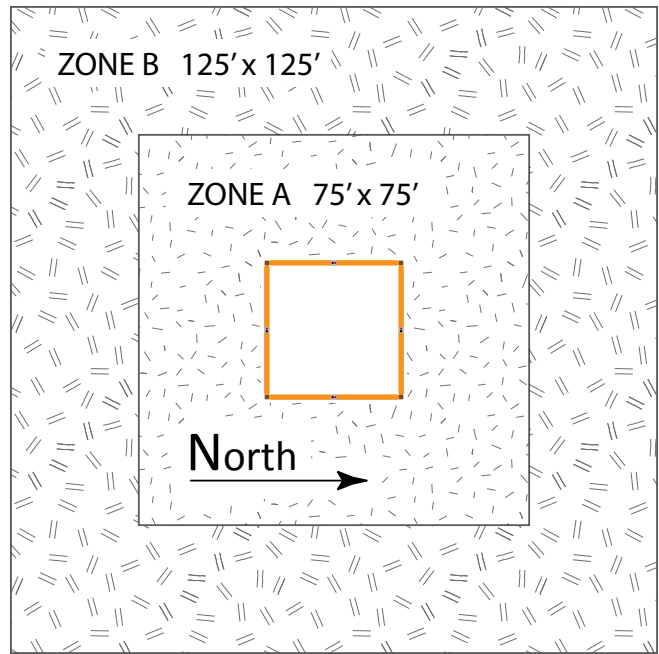


Figure 1 – 24' square array space requirements (see text).

small (under 15' tall) trees are okay toward the perimeter of Zone A. Zone B is the area that should be kept clear of conductors, large trees and large buildings. Note that there are no hard and fast rules for the clear areas. If some trees or buildings encroach a bit, it probably won't be the end of the world. The idea is to make a decent clear area without going overboard. The diagram above is an “in a perfect world” recommendation, not a must-do kind of thing.

Figure 2 provides the overall dimensions of the array and mast locations. The size, details, and location of the junction box is not critical; it serves only to provide a dry space for power combiners and time delay cables. Engineering drawings of the array construction may be found in Appendix A.

Feed lines may be buried or laid on the ground. The LMR-240DB and/or LMR-400DB coax cables supplied are rated for direct burial. The RG-58 element feeds are *not* rated for direct burial. Schematics of the array's electrical connections may be found in Appendix B.

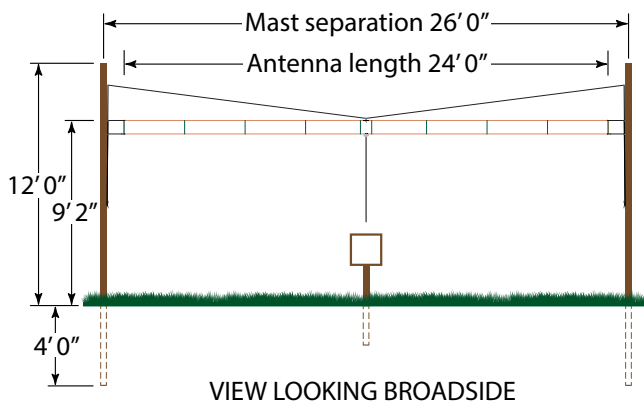


Figure 2 – Array dimensions (see text).

Erection: Masts

Suggested masts are 4x4 pressure-treated (PT) lumber, 16 feet long, in holes 4 feet deep. It is generally not necessary to use concrete to secure the masts unless the ground is exceedingly soft.

Stainless steel screw eyes and cleats are suggested for resistance to corrosion. The layout is a square, with the masts having a separation of 26 feet center to center. Precise layout isn't required; an inch or two either way will have no measurable impact on the array's performance.

After the masts are planted, the screw eyes should be installed per the installation drawings in Appendix A. If the ground is not sloped, measurements from the ground may be used.

If the ground is not flat, then some method must be employed to ensure that the screw eyes are all at the same elevation with respect to true horizontal. A laser level or water hose level may be used to mark the same convenient elevation on all four masts, then one measures upward from those marks to locate the screw eyes. The antenna height should be such that the average element height above ground is 9'2" at the top wire.

If the ground is flat, but sloped, then the elements should be located 9'2" above ground at the top wire; but, adjustments to the beam steering delay cables will need to be made to account for the built-in slope (in the case of sloped, but flat,

ground) of the array with respect to true vertical.

Erection: Junction Boxes

One junction box is required. It should be located close to the geometric center of the square array. Suggested construction is to fabricate an 18" x 18" x 12" tall box atop a 4x4 PT lumber post. Exact dimensions are not critical. The boxes function to keep the weather off the power combiners and delay cables.

Erection: Elements

The array consists of four 24' TFD elements arranged in a square.

Attach the halyards to the elements using bowline knots (see Appendix B). Ensure the positive side of each element is where it should be per the installation drawings in Appendix A. Each halyard runs from the element end, through a screw eye, and down to a cleat. We suggest 3/16" black polyester rope. All rope ends should be flame-sealed. Roughly 100' of rope is required per TFD element: four 8' to 10' halyards, plus a 50' line for each center support. Total for the array is ~400 feet.

Thread the center support rope through the top-most screw eyes and down to the cleats. Tighten the halyards while tensioning the center support rope to take some of the load at the center of the TFD element. This reduces the stress on the balun binding posts. See Appendix B for how to tie proper knots.

Feed System

Connect the feed system as shown in the installation diagrams in Appendix C. The coax cables supplied are color coded to match the cable colors shown in the diagrams. Feed lines may be buried to prevent damage from animals and lawnmowers; see Appendix D for installation details. Use of a junction box is recommended to keep the weather off of the power combiners and beam steering



Figure 3 – Top of mast showing screw eyes for halyards and center support rope.



Figure 4 – Center of TFD element. View looking north. Note that the positive (red) terminal is on the east side. This could also be looking east with the positive (red) terminal on the south side.

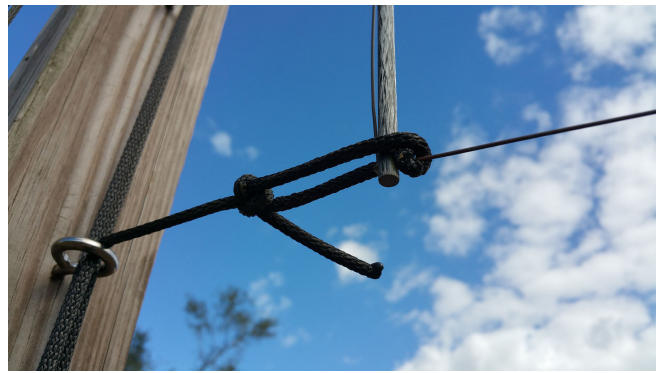


Figure 5 – End of TFD element showing bowline knots.

cables. This can be a wooden or plastic box attached to a short post or something as simple as an upside-down Styrofoam cooler laid on the ground.

If only one of the two available circular polarization (CP) outputs is used, make sure to always connect a 50 ohm terminator to the unused CP output of the hybrid. The hybrid should be located on the protected side of the surge suppressors, not in the junctions box at the array.

Surge Suppression

The array kit may include PolyPhaser surge suppressors. These are not lightning arrestors. Nothing man-made will prevent a direct hit on the antenna element from frying the receiver. However, a surge arrester will dump to ground the large, brief voltage generated in the elements by a nearby lightning strike.

The surge suppressors must be tied to ground. If left floating, they will be useless.

If possible, place them near the building's electrical entrance ground rod and bond them electrically to that ground rod with some #6 bare copper wire. Hardware for this is available at most home improvement stores.

If the building has a steel structure, simply sand some paint off a steel perlin and attach the suppressor to the steel structure. After the suppressor

is installed and after the coax is attached to the suppressor, spray paint the entire area with clear paint to prevent rust.

If it is not practical to use the existing ground rod, then a separate 8' ground rod must be installed to which the suppressors should be attached.

The surge suppressors should be located indoors or enclosed in a junction box if possible. If they must withstand the outdoor elements naked, the coax connections should be sealed using 3M Scotch 2228 Rubber Mastic Tape (available from home improvement stores).

Beam Steering Cables

Beam steering cables, if provided, are labeled with the beam steering angle from zenith. For a beam aimed at zenith, no steering cables are required. To steer the beam southward, time delay cables must be installed at points A and B in the electrical diagram. The greater the steering angle, the greater the time delays required, and thus the longer the cables are.

For example, if the observer wishes to steer the beam to 60 degrees elevation at an azimuth of 180 degrees, then the beam steering cable set labeled "30S" would be installed. An angle of 30 degrees from zenith in the southward direction places the beam at an elevation of 60 degrees at an azimuth of 180 degrees.

Refer to the two electrical installation diagram pages for the location of the beam steering time delay cables and the required lengths of each cable for a given beam elevation angle and the complementary beam steering angle from zenith.

The time delay cables (beam steering cables) supplied with the array are marked with the position (A or B) and with the zenith steering angle (the angle from the normal to the plane containing the array elements for most installations). For example, to steer southward with 40 degrees beam elevation, the cable for position A is marked with "A 50S A".

Element Naming Convention

When discussing individual elements or groups of elements within an array of dipoles, it is necessary to use well-defined terminology lest nobody understand what anyone else is talking about.

"N-S" or "NS" means north-south. "E-W" or "EW" means east-west.

"N-S element" means an element whose wire arms lie in a N-S plane.

"E-W element" means an element whose wire arms lie in an E-W plane.

The standard Radio Jove dual-dipole array has two E-W elements arrayed along a N-S line.

The TFD square array has two E-W dipoles arrayed along a N-S line (shown in orange on the mechanical and electrical diagrams) and two N-S dipoles arrayed along an E-W line (shown in blue on the diagrams).

Electrical Check

To ensure the array is operating properly, perform the test procedures 1, 2, and 3 outlined in the Array Maintenance section of this manual. Be sure to keep a record of SWR and $|Z|$ for future reference if the required test instrumentation is available.

Confirming Correct Circular Polarization Sense

To ensure that the polarization sense is correct all the way to the strip chart or spectrograph, observe Jovian DAM during an Io-B storm using each CP output. Make note of which array output has the strongest emission. This is the RCP output. Mark this output cable as RCP. Mark the other cable as LCP. Confirm the observation of RCP with another observatory's polarimeter to prevent confusion with Io-D LCP emission.

Array Maintenance

Once per year, before the beginning of an observing season or after the end of the thunderstorm season – or any time damage is suspected or proper operation is in question – the array should be inspected, cleaned, and tested for proper operation (procedures 1 and 2 below). A more in-depth impedance test (procedure 3 below) may be performed if one has access to a VNA or antenna analyzer.

1) Visual Inspection and Cleaning

- a) Adjust element halyards and center support ropes as necessary to keep the elements in a horizontal plane. The droop at the element feed point should be kept to a minimum.
- b) Inspect all coax sheaths for damage (cracks, cuts, abrasion, etcetera); all damaged coax should be replaced with new coax of the appropriate electrical length and impedance.
- c) Remove insect debris from the junction box(es), baluns, and terminating resistors. Have a spray can of wasp & hornet killer on hand when opening the junction box(es).

CAUTION: Never attempt to remove corrosion from the copper-clad antenna wires with a file or coarse sandpaper. The copper layer is very thin. If it is removed, the steel core will be exposed and will rapidly rust. If the wires must be cleaned where they connect to the balun binding posts, use 400-grit or higher emery cloth.

- d) Ensure that all balun binding posts are tight. DO NOT OVERTIGHTEN. The balun housing and binding post keyways are plastic.
- e) Ensure that the terminating resistor PL-259 plugs are tight. DO NOT OVERTIGHTEN. The Budwig housing is fiberglass reinforced plastic.

2) Operational Verification Test

- a) Disconnect all elements feeds from the power combiners in the junction box.
- b) With a strip chart or spectrograph recording

the signal from the array, connect one element for 10 to 15 seconds, then disconnect. Repeat for the remaining elements. It is not necessary to terminate the disconnected element feeds or the open combiner ports for this test (but it won't hurt, either). See Figures 6 and 7.

- c) Review the recorded data to ensure all elements are producing signals at similar amplitudes.
- d) If all elements produce similar signal levels, reconnect all element feeds to the proper combiner ports. If one or more elements are markedly weaker than the others, determine the cause and repair the array (see the Troubleshooting section of this manual), then perform this Operational Verification test again.

3) Element SWR and Impedance Test

- a) Ensure all elements are connected.
- b) Disconnect one element feed from its associated power combiner.

CAUTION: Never connect a VNA or antenna analyzer to a feed line leading to a receiver or amplifier; the signal produced by the test instrument can be strong enough to fry the receiver or amplifier.

- c) Use a VNA or antenna analyzer looking into the 26-foot element feed line toward the TFD element to measure the element SWR and impedance and from 10 to 40 MHz.
- d) Record the measured SWR and impedance in the station engineering log.
- e) Compare with the values previously recorded in the station engineering log or with those shown in Plot 1 in the Troubleshooting section of this manual.
- f) If one or more elements diverge markedly from the others (or diverge wildly from Plot 1 below with no ground plane is present), determine the cause and repair the array (see the Troubleshooting section of this manual), then perform the Element SWR and Impedance Test and Operational Verification Test again.
- g) Repeat this procedure for each array element.

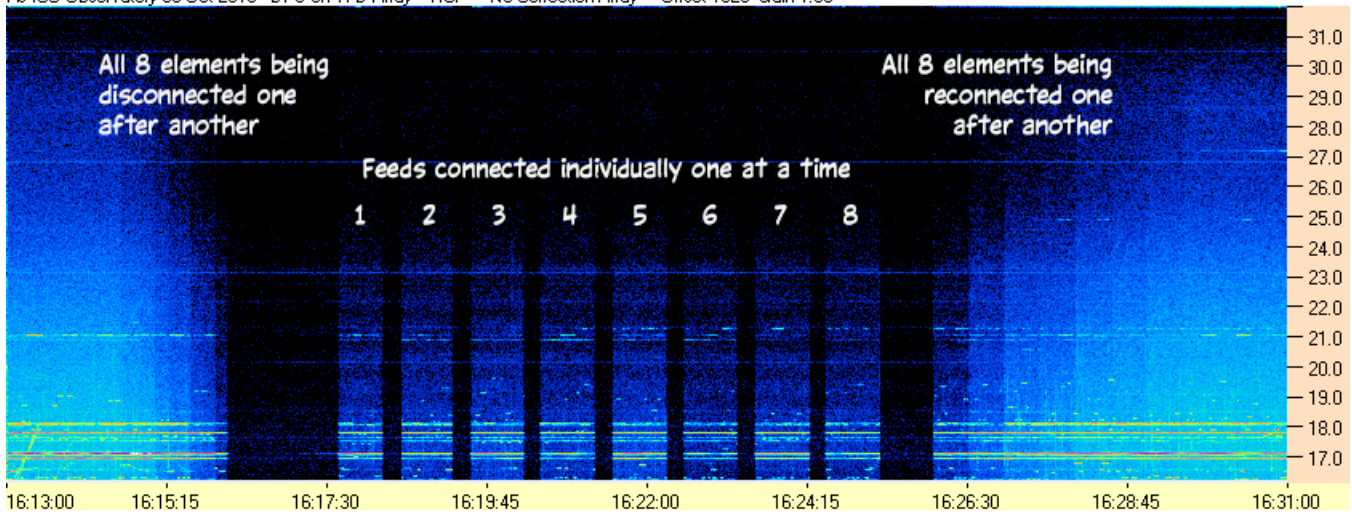


Figure 6 – Spectrogram of operational verification test procedure performed on the AJ4CO 8-element TFD array.

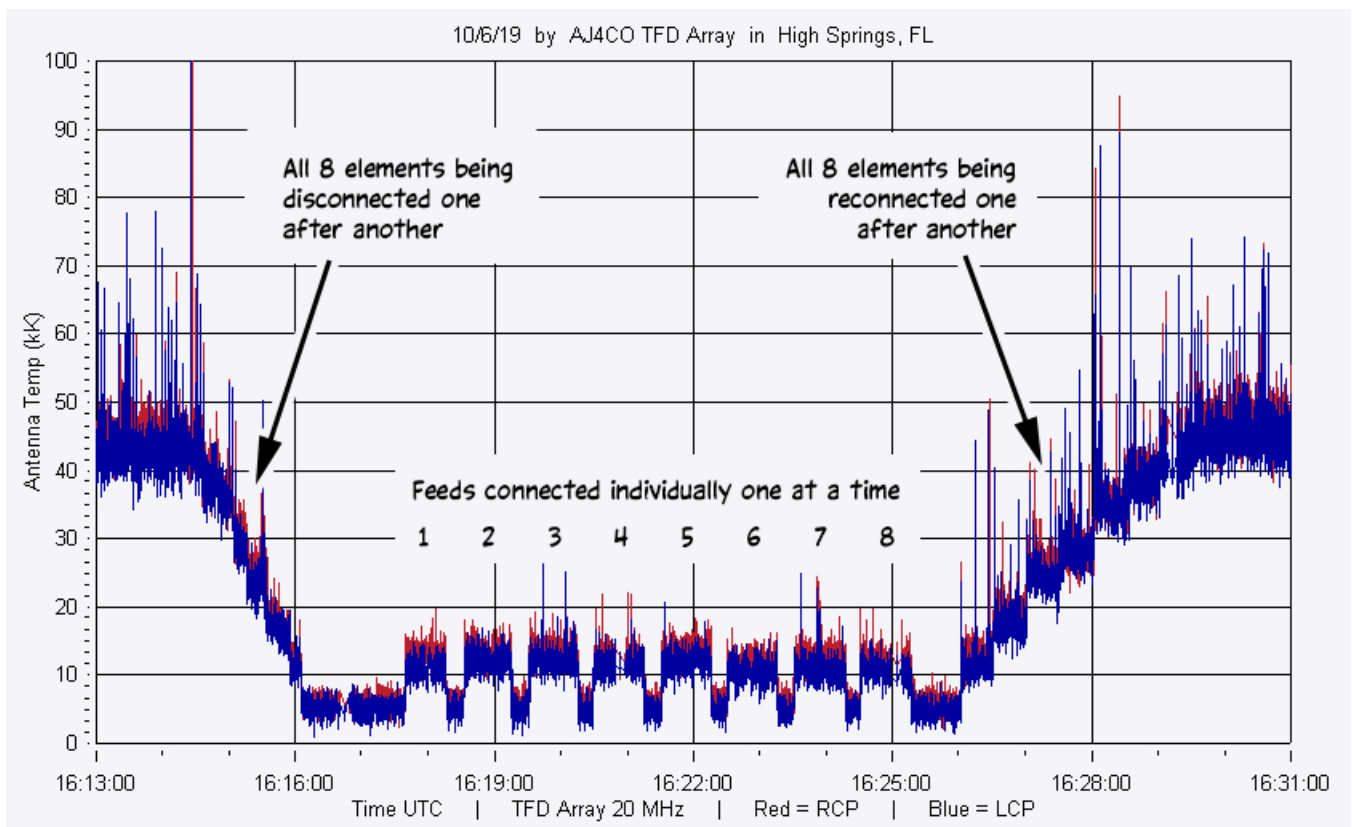


Figure 7 – Strip chart of operational verification test procedure performed on the AJ4CO 8-element TFD array. Elements connected for 45 seconds apiece, with 15 second pause between individual element tests. Brief missing data in element 4 and 8 tests due to RSP computer hardware/software glitches.

Troubleshooting

Should an element fail one of the checks outlined in the Array Maintenance section of this manual, the following steps may be taken to determine the cause and repair the array.

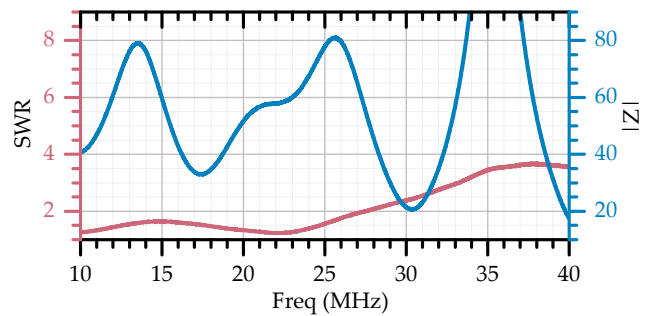
1) Using a DVM

- Disconnect the array wires from the balun binding posts.
- Disconnect the coax from the balun.
- Measure the resistance across the wires; it should be $800\ \Omega$. If it's not $800\ \Omega$, remove and measure the terminating resistor PL-259 plug from the Budwig center insulator. If it's open (infinite resistance) or shorted ($0\ \Omega$), lightning may have blown or welded the termination resistor; replace it. If it is okay, look for shorts or open connections elsewhere on the element wires and repair as necessary.
- Measure the resistance across the balun binding posts (no coax or antenna wires connected). This should read close to $0\ \Omega$. If it reads infinite resistance, the balun's antenna side winding was probably blown open by lightning and a new balun is required.

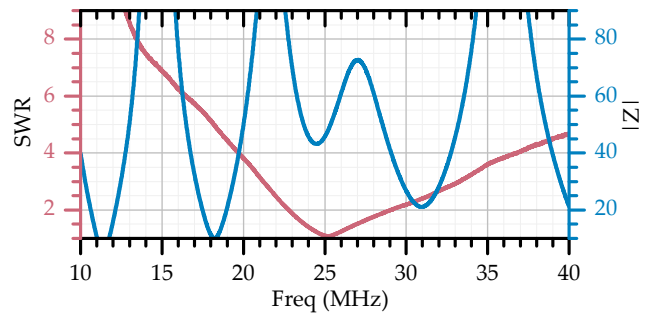
1) Using a VNA or Antenna Analyzer

- Disconnect the element feed line at the point where it connects to the power combiner or delay cable.
- Sweep the combiner end of the feed line with the feed line connected to the element. Compare with plots 1 through 4. If SWR and $|Z|$ look similar to Plots 2, 3, or 4, repair or replace the affected components noted in the text for each plot.

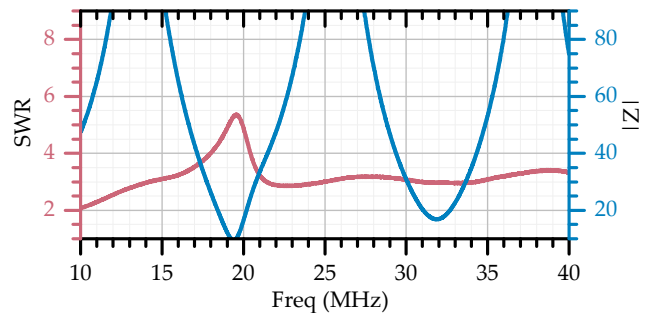
NOTE: While the SWR for a good element will substantially match that shown in Plot 1, the impedance measured may vary depending on the length of the element feed line. Plots 1 through 4 were made by measuring an element with a 26-foot RG-58 element feed line.



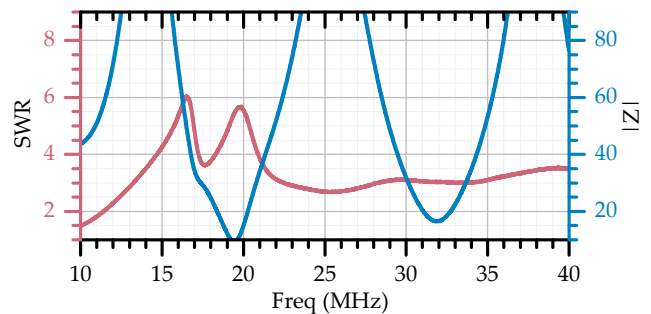
Plot 1 – TFD element SWR and $|Z|$ looking into 26' RG-58 element feed line measured in-situ at LGM Observatory, July 2018. This is a known good TFD element.



Plot 2 – Same as Plot 1, but with bad (open) termination resistor.



Plot 3 – Same as Plot 1, but with bad (open) antenna-side winding in balun.



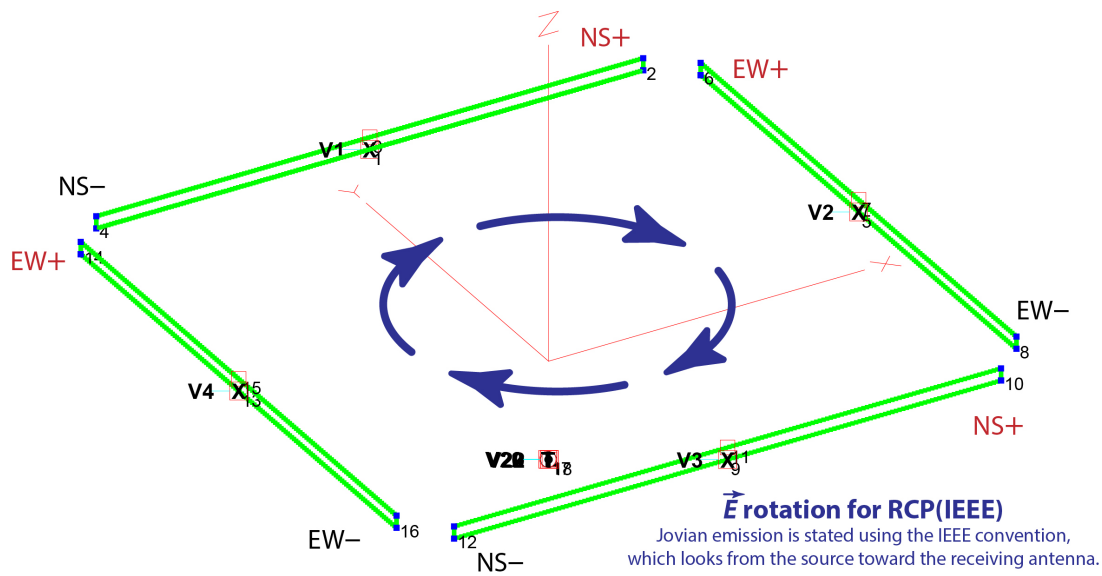
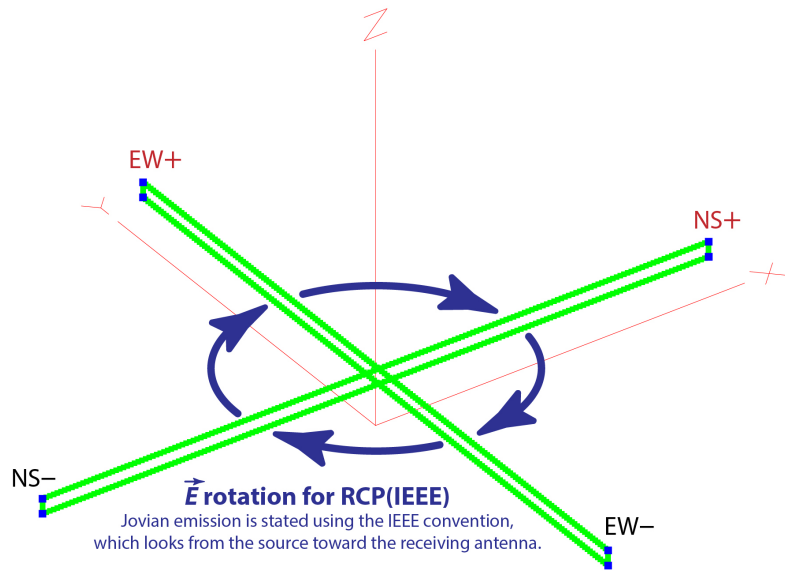
Plot 4 – Same as Plot 1, but with bad (open) antenna-side winding in balun and bad (open) termination resistor.

Theory of Operation

A square array consists of two dual-dipole arrays orthogonal to each other and located in the same place. Each pair of like-oriented elements (NS elements or EW elements) may be thought of as functioning like a single dipole element of the same orientation but with higher gain. Thus, for purposes of generating circular polarization, a square array functions the same as a pair of crossed dipoles. The difference is that a square array permits beam steering using time delay cables, while a pair of crossed dipoles does not. Also, a


square array has twice the gain of a pair of crossed dipoles.

A square array's ability to discriminate between RCP and LCP falls off as the source moves away from zenith. Likewise, the polarization discrimination falls off as the beam is steered away from zenith. Experience shows that steering angles and/or source locations up to 30° from zenith produce negligible polarization discrimination problems. However, by the time the source location or beam steering angle gets to 60° from zenith (30° elevation), the polarization outputs may not always perfectly reflect the true signal polarization.

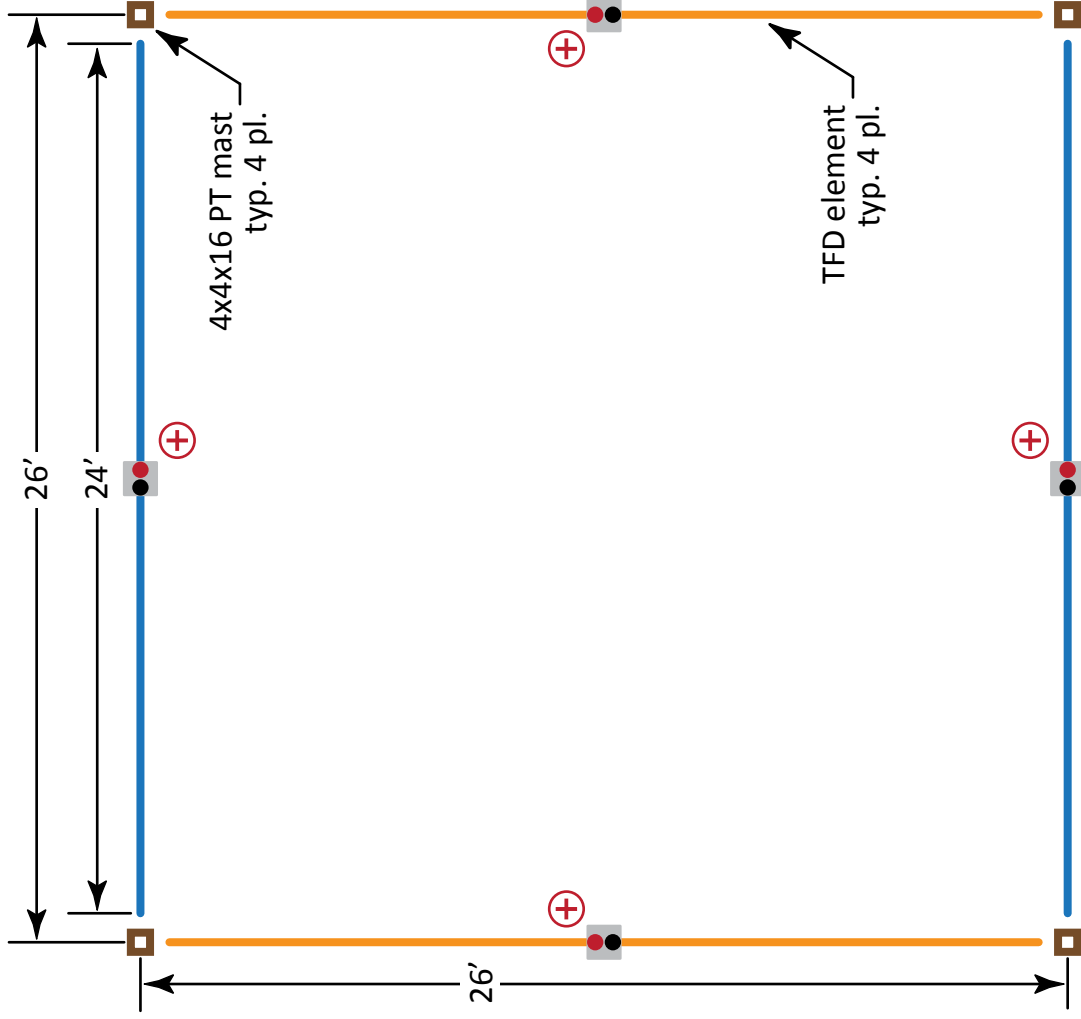


Appendix A – 24' TFD Array Mechanical Drawings

North

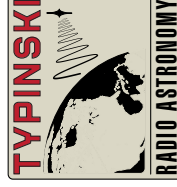


CAUTION
 ORIENT ELEMENTS DURING INSTALLATION SO THAT
 POSITIVE RED TERMINALS ON BALUNS MATCH THE
 POSITIVE SIDES SHOWN IN THIS DRAWING (AS
 VIEWED FROM ABOVE THE ARRAY).



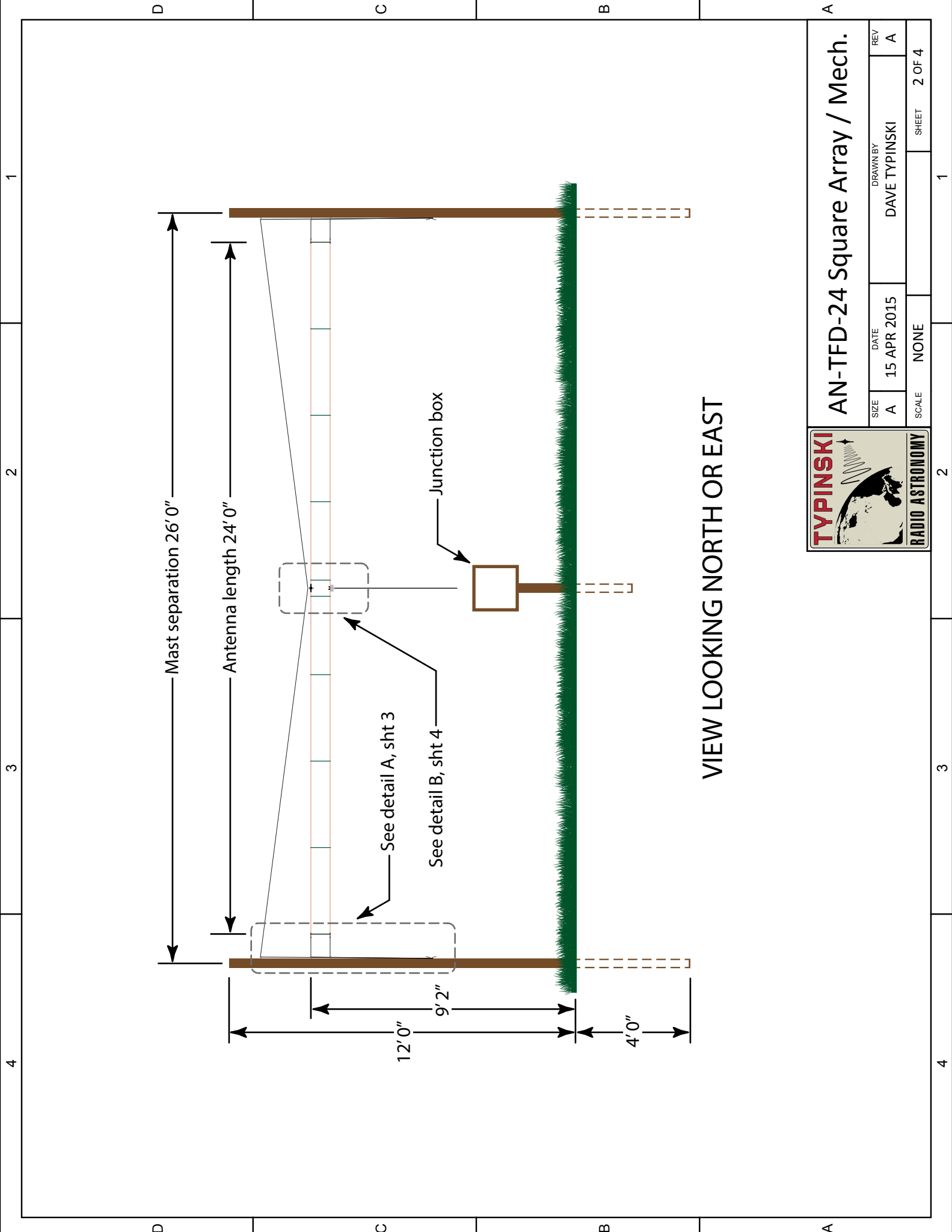
NOTES:

- 1) Mast locations are good enough if they are within an inch or two of the dimensions shown on this diagram.



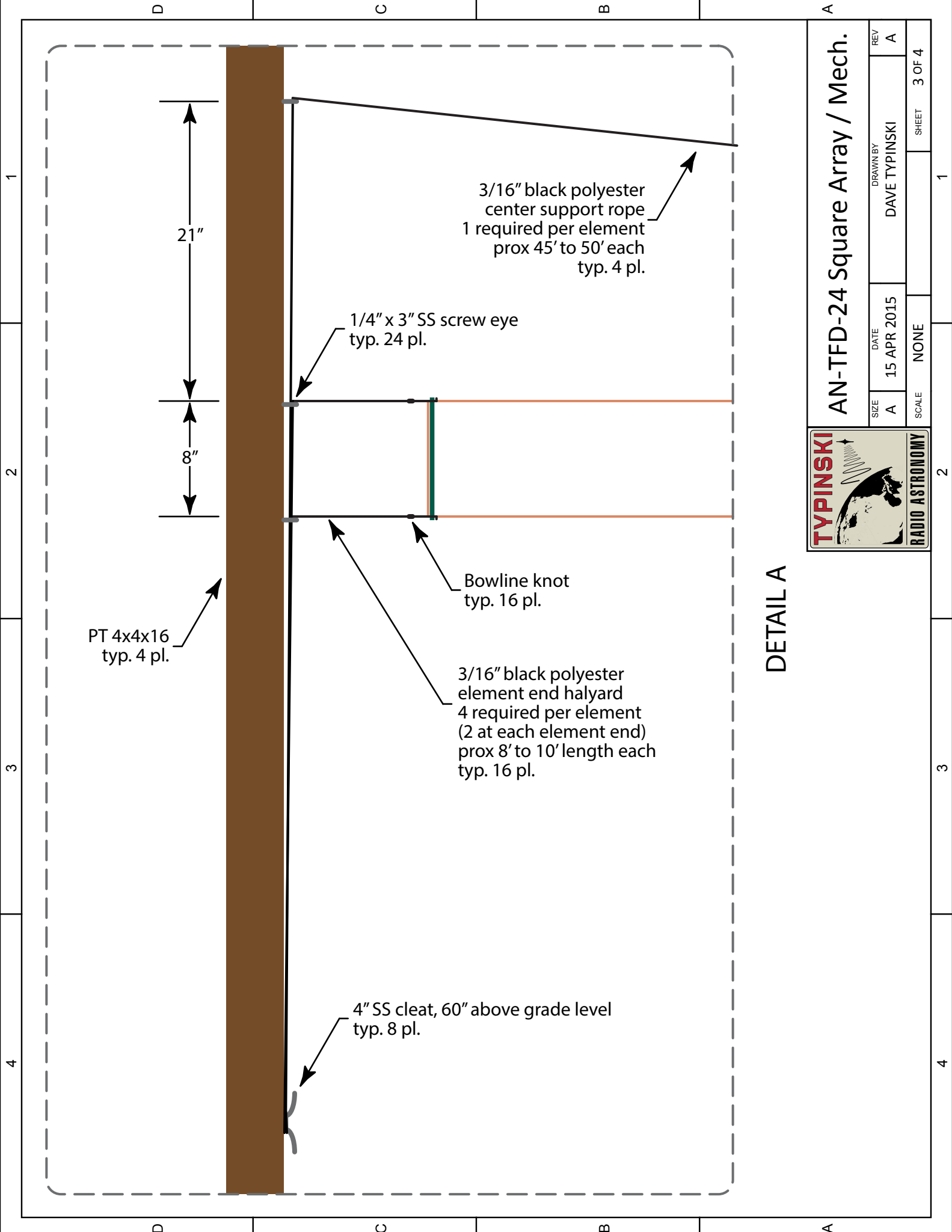
AN-TFD-24 Square Array / Mech.

SIZE	DATE	DRAWN BY	REV
A	15-APR-2015	DAVE TYPINSKI	1
SCALE	NONE	SHEET	1 OF 4



AN-TFD-24 Square Array / Mech.

SIZE	DATE	DRAWN BY	REV
A	15 APR 2015	DAVE TYPINSKI	A
SCALE		SHEET	
NONE		2 OF 4	



PT 4x4x16
typ. 4 pl.

21"
8"

3/16" black polyester
center support rope
1 required per element
prox 45' to 50' each
typ. 4 pl.

1/4" x 3" SS screw eye
typ. 24 pl.

Bowline knot
typ. 16 pl.

3/16" black polyester
element end halyard
4 required per element
(2 at each element end)
prox 8' to 10' length each
typ. 16 pl.

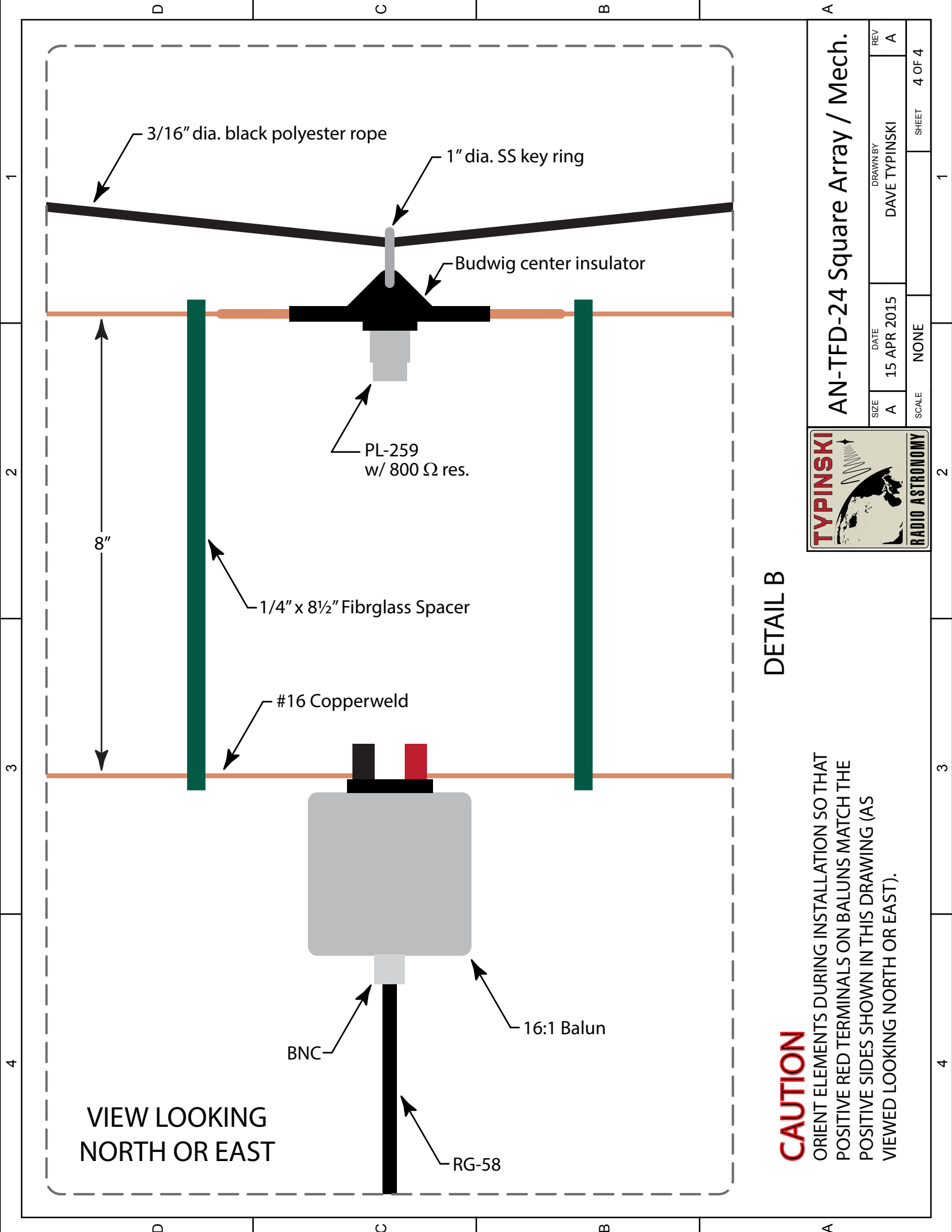
4" SS cleat, 60" above grade level
typ. 8 pl.

DETAIL A



AN-TFD-24 Square Array / Mech.

SIZE	DATE	DRAWN BY	REV
A	15 APR 2015	DAVE TYPINSKI	A
SCALE		NONE	SHEET
			3 OF 4



AN-TFD-24 Square Array / Mech.

SIZE	DATE	DRAWN BY	REV
A	15 APR 2015	DAVE TYPINSKI	A
SCALE		NONE	SHEET 4 OF 4



DETAIL B

CAUTION
 ORIENT ELEMENTS DURING INSTALLATION SO THAT POSITIVE RED TERMINALS ON BALUNS MATCH THE POSITIVE SIDES SHOWN IN THIS DRAWING (AS VIEWED LOOKING NORTH OR EAST).

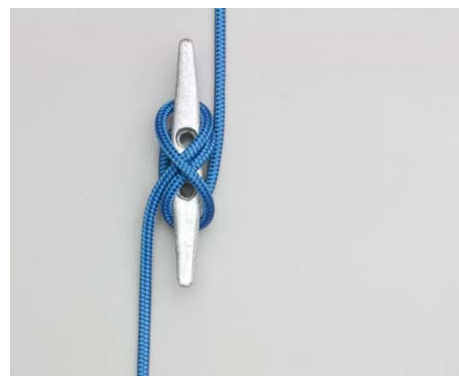
VIEW LOOKING NORTH OR EAST

Appendix B – How to Tie Some Knots

After a halyard is looped around the wire and rod, bowline knots are used. In the pictures below, the fiberglass rod would be at the bottom of the images.



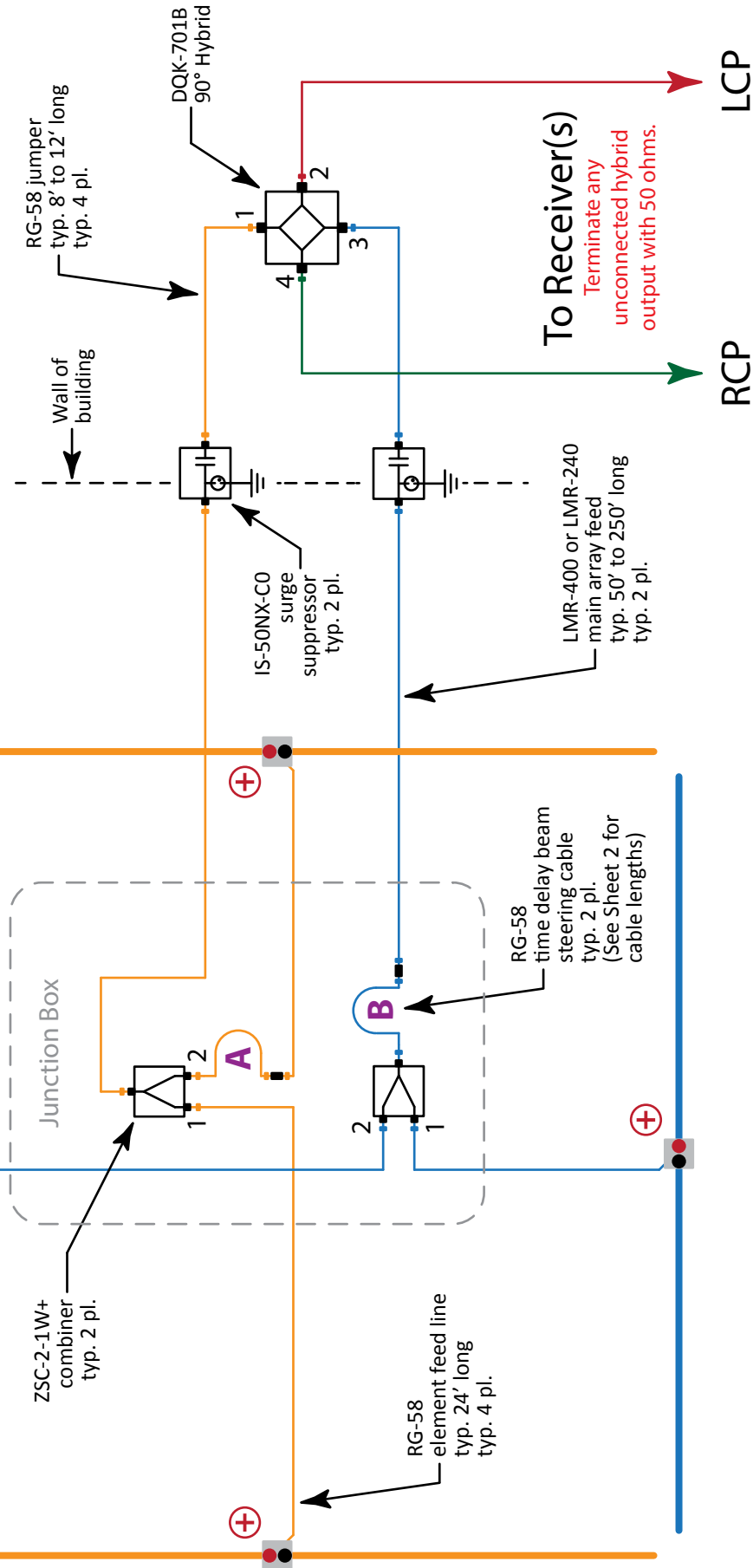
Cleat hitches should be used to secure the halyards and center support ropes to the cleats. Knot images are courtesy of www.animatedknots.com which contains many excellent explanations of how to tie proper knots.



Appendix C – 24' TFD Array Electrical Drawings

North

CAUTION
ORIENT ELEMENTS DURING INSTALLATION SO THAT POSITIVE RED TERMINALS ON BALUNS MATCH THE POSITIVE SIDES SHOWN IN THIS DRAWING (AS VIEWED FROM ABOVE THE ARRAY).



NOTES:

- 1) Coax is 50 Ω Belden 8259 RG-58 or Times Microwave LMR-240 or LMR-400 cable.
- 2) All coax terminated with AMP or Times crimp-type BNC or N connectors.
- 3) Main feeds cut to customer specified length.
- 4) Feed system supplied with two BNC-F to BNC-F adapters for use with time delay cables.
- 5) Cables individually trimmed to proper electrical length using a VNA.
- 6) Cable test reports include measured 20 MHz phase error and loss from 10 to 40 MHz.



AN-TFD-24 Square Array / Elec.

SIZE	DATE	DRAWN BY	REV
A	16-NOV-2016	DAVE TYPINSKI	1
SCALE	NONE	SHEET	1 OF 2

TFD Square Array Southward Beam Steering

Array elements baseline spacing (feet): 26
 Time Delay Cable VoP: 66%
 Allowance for one crimp connector (inches): 0.25
 Allowance for one bullet (inches): 1.00

Free Space 1/4λ Stub Frequency (MHz)
 including two crimp connectors and a bullet

Assy Length (nominal, ft & in)
 including two crimp connectors and a bullet

Cut Coax to Lengths (ft & in)
 (BARE COAX ONLY - APPROXIMATE)

AZ (degrees)	EL (degrees)	ZENITH (degrees)	ZENITH	φ (degrees)	A	B	A	B	A	B
			0 S		n/a	n/a	n/a	n/a	n/a	n/a
180	85	85	5 S		1' 4-1/2"	7-1/2"	1' 6"	9"	108.512	217.023
180	80	80	10 S		2' 10-1/4"	1' 4-3/8"	3' 0"	1' 6"	54.463	108.926
180	75	75	15 S		4' 3-3/4"	2' 1-1/8"	4' 5"	2' 3"	36.541	73.081
180	70	70	20 S		5' 8-7/8"	2' 9-3/4"	5' 10"	2' 11"	27.652	55.303
180	65	65	25 S		7' 1-1/2"	3' 6"	7' 3"	3' 8"	22.378	44.756
180	60	60	30 S		8' 5-1/2"	4' 2"	8' 7"	4' 3"	18.915	37.830
180	55	55	35 S		9' 8-5/8"	4' 9-1/2"	9' 10"	4' 11"	16.488	32.977
180	50	50	40 S		10' 10-7/8"	5' 4-5/8"	11' 0"	5' 6"	14.713	29.426
180	45	45	45 S		12' 0-1/8"	5' 11-1/4"	12' 2"	6' 1"	13.375	26.750
180	40	40	50 S		13' 0-1/4"	6' 5-3/8"	13' 2"	6' 7"	12.346	24.692
180	35	35	55 S		13' 11-1/8"	6' 10-7/8"	14' 1"	7' 0"	11.545	23.091
180	30	30	60 S		14' 8-7/8"	7' 3-5/8"	14' 10"	7' 5"	10.920	21.841

Delay cable assy length (ft) = Baseline(ft) × sin φ × VoP

Bare coax length (ft) = Baseline(ft) × sin φ × VoP - 2 × Crimp Connector Length(ft) - Bullet Length(ft)

$$f_{\text{stub}} = \frac{nc}{4 \times \text{Baseline}(m) \times \sin \phi}$$

NOTE: BNC crimp connectors and BNC bullets measured with a VNA in 2014 show VoP for these components to be 66%.
 Given their short lengths, variation in connector and bullet VoP will not change the cable assy electrical length enough to make a meaningful difference for operation in the HF band.
 For example, a change from 66% to 85% VoP in the connectors & bullet would make the cable lengths stated above slightly too long, leading to a beam steering error of 0.09 degrees.
 Close enough.

http://www.typinski.net/AJ4CO/Calculators/Phased_Array_Delay_Cable_Length.htm



AN-TFD-24 Square Array / Elec.

SIZE	DATE	DRAWN BY	REV
A	19-MAY-2018	DAVE TYPINSKI	2
SCALE		NONE	SHEET 2 OF 2

Appendix D – Optional Burial of Element Feed Lines

The element feed lines and main feed lines (between the array and the receiver) can be buried to protect the coax from damage from animals and lawnmowers.

While direct burial cable exists, it does not protect the coax from damage from rocks due to heaving (freeze-thaw cycling of rocky soil). Likewise, it cannot protect from abrasion if the burial depth is too shallow.

We recommend the use of PVC conduit. When using conduit, the interior must be sealed to prevent the accumulation of condensation. This is accomplished by using PVC cement on all intermediate joints, sealing tape on the end caps, and waterproof bulkhead BNC fitting on the end caps.

Element Feed Conduits

Assemble the conduit as shown in drawing sheets 1 through 3 in this appendix. Assembly of the element feed conduits should proceed from the junction box end to the element end.

NOTE: We recommend the use of gray electrical conduit and fittings wherever possible to increase the assembly's resistance to solar UV radiation. Some fittings such as pipe caps and small elbows are not readily available in gray PVC. In such cases, use of white plumbing PVC parts is acceptable.

NOTE: Sweep elbows must be used to allow the coax to be pulled through the conduit. Do not use small elbows in lieu of sweep elbows.

CAUTION: The BNC connectors on the coax should be covered with masking tape to protect against contamination when pulling the coax through the conduit.

CAUTION: For each conduit run, do not use PVC cement on the two end caps, otherwise it will become impossible to replace the coax should the need ever arise. A tight slip-fit assembly sealed with waterproof electrical sealing tape is enough to keep the cap in place and keep water out of the inside of the conduit. In contrast, PVC cement should be used on all intermediate conduit joints.

Upon final assembly at the element end of the conduit, several inches of coax is provided as slack to allow installation of the BNC connector onto the inside of the pipe cap fitting prior to the pipe cap's installation. After the element-end pipe cap is installed and taped, the slack in the coax is coiled within the space provided by the waterproof 90° conduit body and then the conduit body cover and its gasket are installed with two screws.

Main Feed Conduits

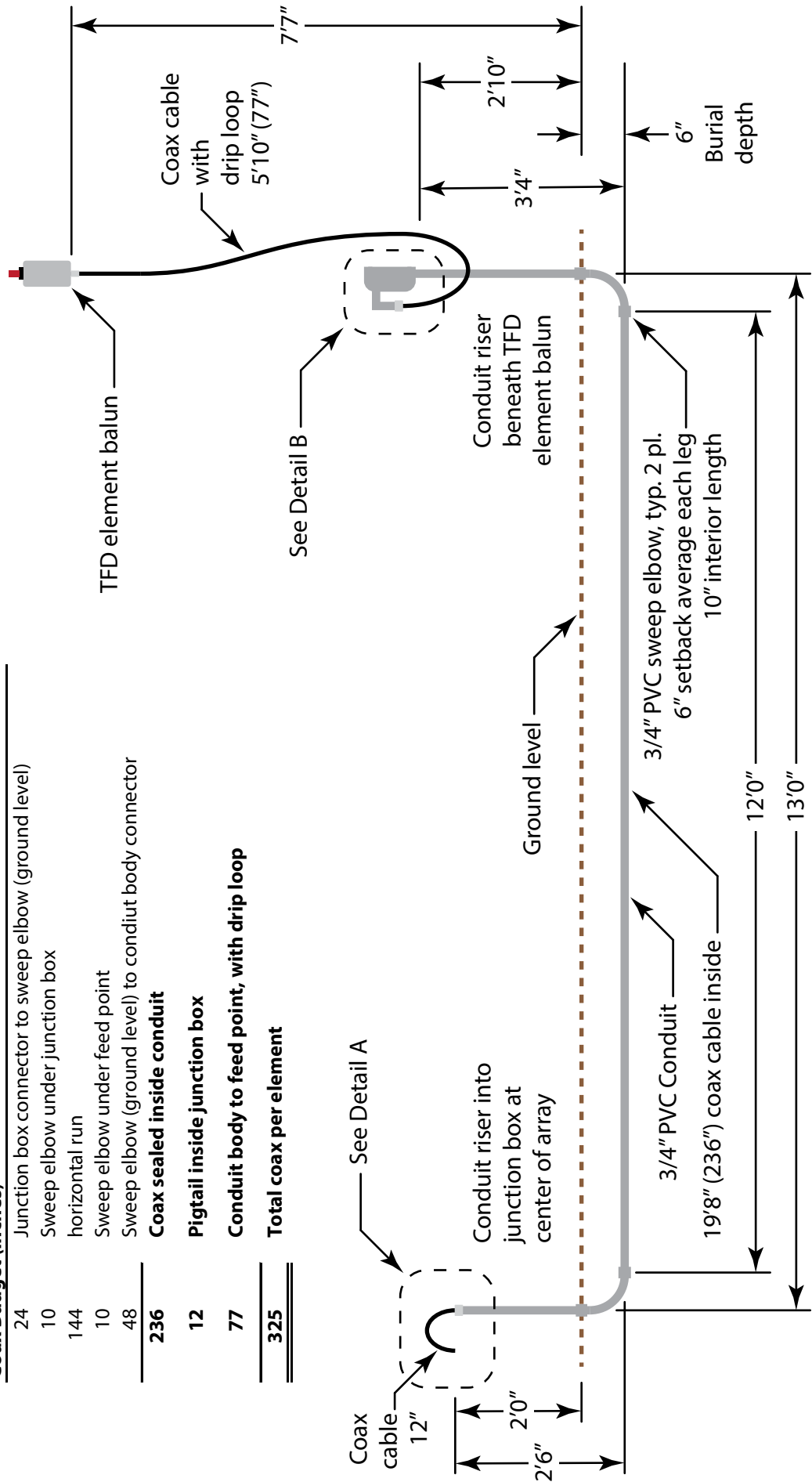
The main feed lines should be buried in a larger conduit than the conduit used for the element feeds. The diameter of the conduit should be 2" to 3". Construction and assembly of the main feeds conduit is similar to the element feed conduits. The design, however, will be specific to the station being built.

CAUTION: If the two main feed cables are buried, use coax having a foil-shield. Coax having only a braided shield (e.g., Belden 8259 RG-58) will allow the two parallel cables lying against each other for the length of the conduit to affect each other electrically and will degrade the performance of the array. We recommend the use of LMR-240 for runs less than 100 feet and LMR-400 for runs over 100 feet. RG-58 will work for above-ground runs less than 50 feet, but in this case care should be taken to ensure the two cables are kept several inches apart.

Buried feed line conduit arrangement, typical 4 places in array

Coax Budget (inches)

24	Junction box connector to sweep elbow (ground level)
10	Sweep elbow under junction box horizontal run
144	Sweep elbow under feed point
10	Sweep elbow (ground level) to conduit body connector
48	Coax sealed inside conduit
236	
12	Pigtail inside junction box
77	Conduit body to feed point, with drip loop
325	Total coax per element



NOTES:

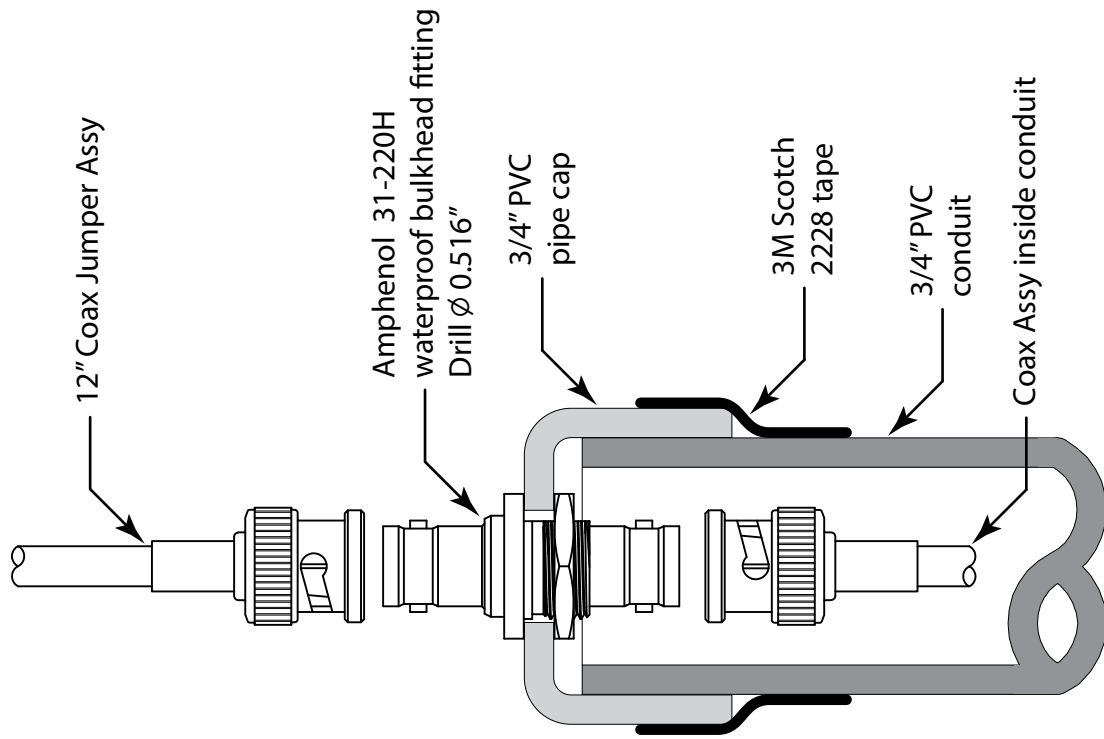
- 1) Gray non-metallic PVC conduit preferred over plumbing PVC for UV resistance.



AN-TFD-24 / Buried Feeds

SIZE	DATE	DRAWN BY	REV
A	30-JUN-2019	DAVE TYPINSKI	B
SCALE	NONE	SHEET	1 OF 3

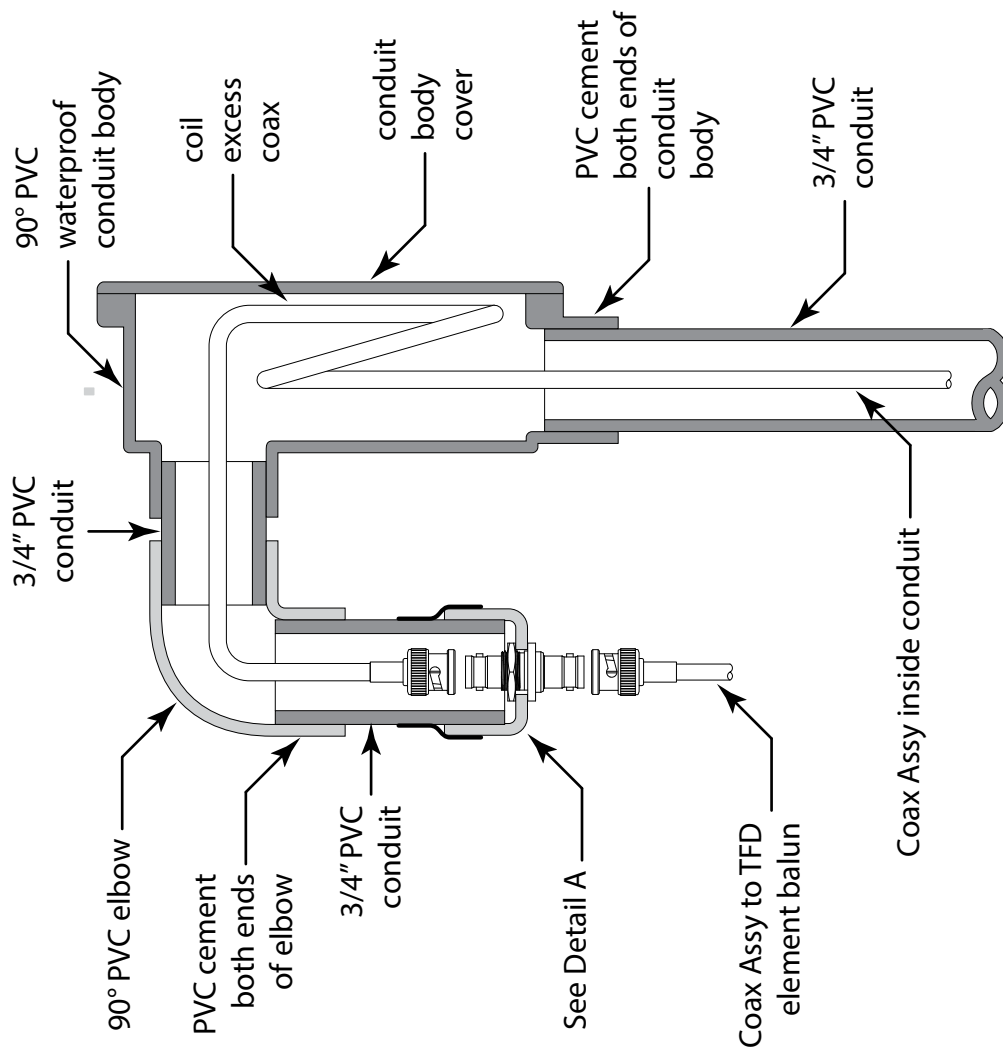
Buried feed line conduit arrangement, detail views



DETAIL A

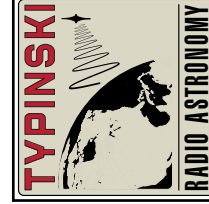
NOTES:

- 1) Gray non-metallic PVC conduit preferred over plumbing pipe PVC for UV resistance.
- 2) Use plumbing PVC for pipe caps and elbows if gray PVC fittings are unavailable.



DETAIL B

See Images 1 and 2



AN-TFD-24 / Buried Feeds

SIZE	DATE	DRAWN BY	REV
A	11-MAY-2019	DAVE TYPINSKI	A
SCALE	NONE	SHEET	2 OF 3

Buried feed line conduit arrangement, images

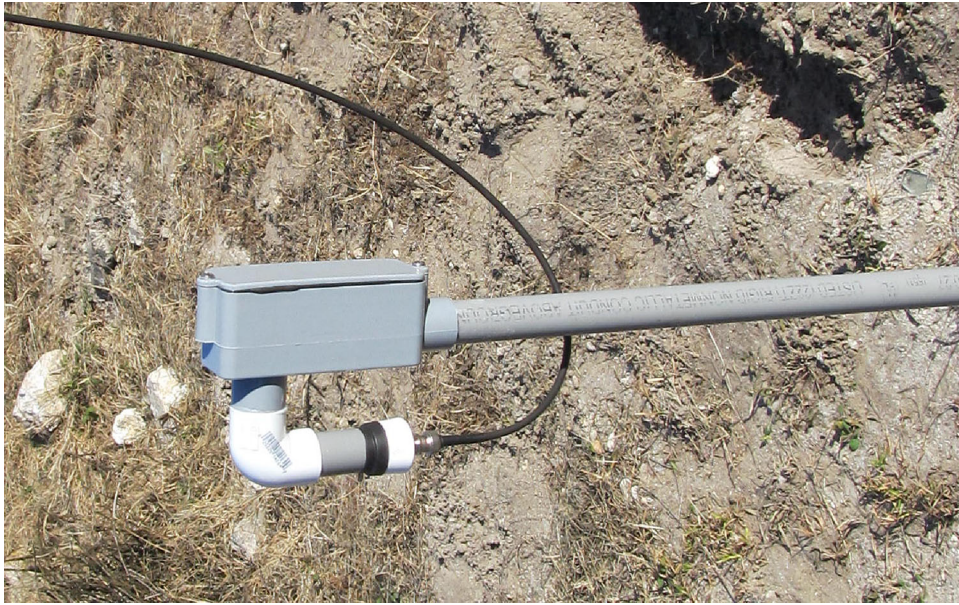


Image 1



Image 2



AN-TFD-24 / Buried Feeds		DRAWN BY		REV
SIZE	DATE	DAVE TYPINSKI		A
A	11-MAY-2019			
SCALE		NONE	SHEET 3 OF 3	

Grid lines: 1, 2, 3, 4 (horizontal); A, B, C, D (vertical)