The Two Meter EZ Lindenblad Revisited

Tom Planer, KJ9P
Grant Zehr, AA9LC

The Lindenblad antenna is a well-known design which lends itself to use for satellite communication and also works well as a general-purpose VHF antenna. Properly constructed, the antenna provides circular polarization and omnidirectional coverage, with gain near the horizon and good omnidirectional coverage at higher elevations. Historically this design has been used at airports for VHF communications with aircraft and is well suited to that task. Tony Monteiro, AA2TX (SK), outlined the history of the Lindenblad antenna in "An EZ-Lindenblad for 2 Meters," published in the August 2007 issue of *QST*. In that article, Monteiro described a practical way to build a Lindenblad antenna using four transmission line impedance transformers constructed from 75-ohm RG-59 cable. This allows the antenna to be fed with 50-ohm transmission line familiar to radio amateurs.

When the Central Illinois Radio Club was asked to help with a local ARISS contact (at Chiddix Jr. High School in Normal, IL), we looked carefully at the AA2TX design and decided to build a similar antenna for use with our ARISS backup station. Although the ARISS program only requires a vertical antenna, we knew that a Lindenblad would perform better as a backup antenna.

Our first antenna worked very well indeed. It was tested while monitoring transmissions from the ISS during other school contacts, during Slow Scan TV transmissions from the ISS and while monitoring the ISS downlink during our actual ARISS contact. While the Lindenblad was not needed during our ARISS contact, we feel confident that it would have worked well for that contact if needed.

Although the Lindenblad design has been around for many years, and the EZ Lindenblad design makes construction easier, there is still some confusion about constructing this type of antenna and getting it to function predictably. Building a Lindenblad just looks hard. We would like to share some of the features of our design, which might help others build a successful antenna.

Antenna Development

Tom Planer, KJ9P, did the initial work on our design and built our first antenna using 1 1/8 inch diameter tubing for the crossarms and dipoles and CPVC plumbing fittings for the tee connections (see Figure 1). The crossarms were fastened to a large diameter tubular aluminum mast. Multiple small L brackets were used to stabilize the crossarms where they attached to the mast. This provided a very sturdy antenna structure. A matching network was built using RG-11/U coaxial cable. This became the backup antenna for our ARISS contact and worked well.

While tuning this antenna, two important facts became apparent. First, the junction of the four matching sections and the SO-239 antenna connector is a critical point. The SWR of our antenna could be changed by positioning the antenna connector closer to or further from the matching network. Changing that geometry by ½ inch made very noticeable changes. Secondly, the length of the dipole elements also affected the tuning of the antenna. We found best results with antenna elements a little shorter than in the AA2TX design. Our RG-11/U matching sections were somewhat longer than AA2TX's. After adjusting these elements, an antenna was built which had good omnidirectional coverage and an SWR of 1.5:1 or less across the entire 2-meter band.

A second antenna was then built using more readily available parts, to determine if the design could be reproduced. With some minor changes, the second antenna also performed well and is discussed here.

Figure 1 — 2-meter Lindenblad used for our ARISS backup station.

Construction

Before beginning construction, the reader is encouraged to carefully read "An EZ-Lindenblad for 2 Meters," as many of the techniques used here are similar. This antenna can be built with ordinary hand tools. A tubing cutter or hacksaw with miter box is recommended for accurate tubing cuts. A tap tool with a bit for 10-32 machine screws is needed to connect the coaxial cables to the dipole elements.

1 1/8-inch diameter aluminum tubing from DX Engineering (DXE AT-1485) is used for the dipoles and crossarms. This tubing is available in either three-foot or six-foot lengths. Less material is wasted when six-foot sections are used, but the extra cost of shipping six-foot lengths is significant and should be considered when placing your order. The tubing can be obtained from other suppliers but be sure to obtain thick walled (.058") tubing so that the material can be tapped for insertion of machine screws. Care should be taken to cut the tubing at right angles, so the dipole ends are square and the crossarms fit accurately into the CPVC fittings. Either a miter box or tubing cutter can be used.

This size tubing fits perfectly into standard 1-inch size plastic CPVC plumbing fittings. Note that these are not the usual schedule 40 PVC fittings used in many amateur antenna designs. The CPVC fittings are designed for use in higher pressure water supply systems and have different dimensions. They are available in most large home centers. Four 1-inch size CPVC tee fittings are used, one at the midpoint of each dipole.

Begin with construction of the antenna crossarms. These are cut to 24 ¼ inches. Find the center of each cross arm and carefully drill a hole for a 2 ½ inch #6 machine screw which will join the two crossarms and ensure that they stay centered during construction. A section of 1 ½ inch aluminum angle stock about 22 inches long serves as the vertical mast for the antenna. The crossarms are then attached to the mast. We used ¾ inch angle stock to support the crossarms (see Figure 2). The crossarms can be connected to the angle stock with #6 or #8 machine screws or pop rivets.

Cut 8 half-dipoles from 1 1/8 inch aluminum tubing. Cutting each half dipole element to 13 5/8 inches results in a dipole 28 ½ inches long (including the CPVC fitting). Measure carefully to be sure this number works for your CPVC fittings and be sure both half dipole elements are the same length. The dipole elements should be driven firmly into

Figure 2 — Crossarms are connected to the mast using short pieces of ¾' aluminum angle stock and machine screws.

CPVC fitting until they are seated against the molded stop inside the fitting.

A dipole with its CPVC tee fitting is attached to each end of the two crossarms. When inserted into the CPVC fitting a small (1/8") space is allowed rather than driving the tubing into the stop position inside the fitting. This results in a cross arm with a dipole center to center spacing of 25 ¾ inches. The crossarms will be tight in the CPVC fittings but can still be turned enough to adjust the dipole angle.

Use a drafting triangle or simple homemade gauge to adjust the angle of each dipole to 30 degrees from horizontal. Looking at a single dipole from outside the antenna, you need to rotate the dipole on the cross arm 30 degrees in a counter-clockwise direction (for right-hand circular polarization). Carefully drill through the CPVC fitting and cross arm tubing and tap the CPVC and aluminum to accept a ½ inch long #10-32 machine screw. Use care to preserve the 30-degree angle during this step. This will secure the base of the tee fitting to the antenna crossarm (see Figure 3).

Figure 3 — Machine screw on top of insulator holds dipole at 30 degrees from horizontal.

Next, build the impedance matching transformers.RG-11/U cable (DX Engineering DXE 11U) is used rather than the RG-59 specified by AA2TX. RG-11/U has copper shielding (unlike many modern versions of RG-59), provides lower loss at VHF, and can handle more transmit power. We found the larger size cable easier to work with than the smaller diameter RG-59.

Each cable is cut to 27 inches. On one end of each cable cut back the black vinyl covering to a length of 1 3/8 inches. Spread and separate the shield braid and form it into a single lead. Attach ring terminals (that can accommodate #10 machine screws) to the shield and center conductors. These should be crimped and soldered in place. Heat shrink tubing over the leads provides some protection against weather and solar UV. The terminals will be connected to the dipole elements later.

At the other end of the cable 1 ½ inch of black insulation is removed. One-quarter inch of shield (adjacent to the insulation) is tinned with solder. A large iron is needed but take care to avoid overheating and melting the foam dielectric. The shield and foam dielectric are then cut away, leaving one-quarter inch of tinned braid in place and the rest of the center conductor bare. A small rotary tool with circular cutting attachment can be used to make this task easier. If your cuts are accurate, this will result in 24 3/8 inches of cable with the shield still in place, with shield and center conductor separated at each end. The four cables are grouped together and joined as shown in Figure 4. The shields are wrapped with copper wire or soldering wick braid and soldered together. The center connectors are joined together, soldered, and then connected to the center pin of a SO-239 chassis connector (Amphenol # 83-1R). The SO-239 connector is mounted on a short piece of aluminum angle stock, which is attached to the antenna support mast (see Figure 5). A short jumper wire connects the bonded shields to a ground lug on the SO-239 connector. Keep the center connector and shield connections as short as possible, as shown in Figures 4 and 5.

A Fair-Rite brand ferrite sleeve (Fair-Rite part number 2631102002) is used on each RG-11/U cable as a choke balun. It should be positioned over the cable near the connection to the dipole (see Figure 6). It can be held in place with a cable tie.

The terminals on the free end of each RG-11/U cable are attached directly to the dipole elements. Each terminal is connected to the

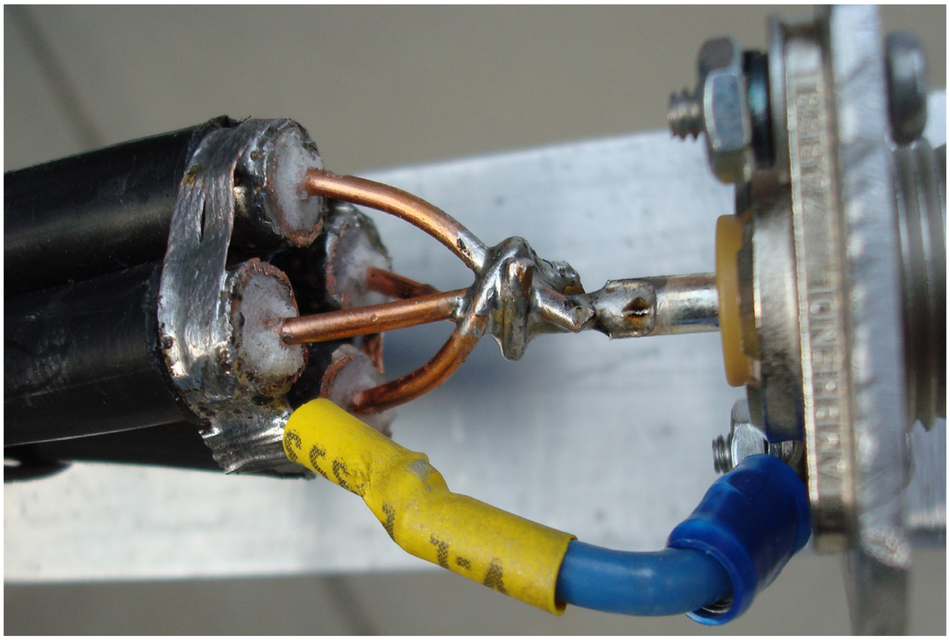


Figure 4 — Shields of the four RG-11/U matching sections are bonded together and connected to ground by a short lead.

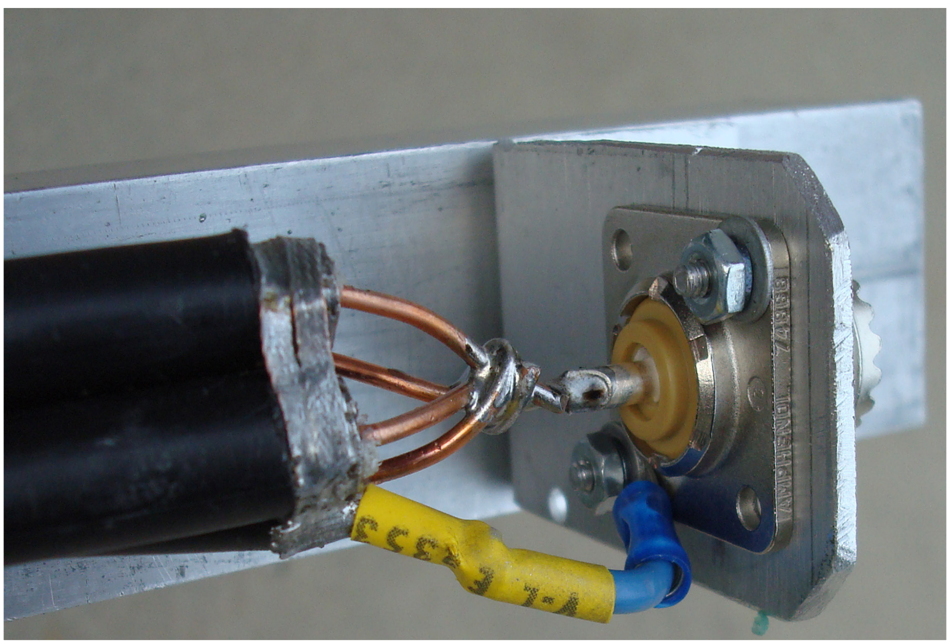


Figure 5 — Center conductors of the four RG-11/U matching sections are connected. One center conductor continues and is connected to the center pin of a SO-239 chassis connector..

antenna by drilling through the tee fitting and tapping the CPVC and aluminum tubing inside for a ½ inch long #10-32 machine screw. The number 32 specifies 32 threads per inch, which is preferred over #10-24 hardware with 24 threads per inch. With more threads per inch, #10-32 screws will provide more surface area and better electrical contact into the aluminum tubing. The CPVC material is also threaded, with provides needed mechanical strength and secures the screw in the aluminum tubing. Sheet metal screws will not provide a solid contact and should be avoided.

NOALOX or a similar anti-oxidant compound is used on each screw connection to prevent oxidation and improve conduction. The center conductor attaches to the end of the dipole, which is angled upward, and the shield to the end of the dipole, which slants downward. If you have turned your antenna over to access the bottom surface, be careful to select the correct end!

The cables making up the matching network should be attached to the crossarms and main mast. Cable ties can be used. We built a bracket from two pieces of ¾ inch angle stock to secure the RG-11/U cables to the antenna mast.

CPVC caps are used for the top of each dipole to prevent water from entering the system. The lower end of each dipole can be left open. If caps are used on the lower ends (to prevent entrance of insects and debris), be sure to leave a drain hole at the lowest point to avoid collecting water there.

Before final installation, be sure to waterproof the electrical connections. We used inexpensive hot glue from the Home Center. Fill in the area around the antenna connector and cover the screws attaching the coaxial cable to the dipole elements. Alternatively, you can use your favorite acid-free silicone sealer. Painting the CPVC fittings is prudent to avoid UV damage from sun exposure.

After the antenna has been constructed, mount it temporarily about 10 feet above the ground and check the SWR across the desired portion of the band. This is easily done with a modern antenna analyzer such as the Rig Expert AA-600 which was used here. A carefully constructed antenna should have an SWR of 1.5:1 or better across the 2-meter band.

In case of problems, if the SWR is higher than 2:1 carefully examine the connection between the matching coaxial cable transformers and the SO-239 connector. Shortening or bending the wires there may improve the SWR since you will be adjusting the stray inductance and capacitance at that connection.

If the antenna is nicely resonant, but above or below the two-meter band, the dipole elements can be adjusted to shift the resonant frequency. The dipole elements can be cut to a shorter length if the resonant frequency is too low. If the resonant frequency is too high, short lengths of aluminum tubing can be inserted into each dipole element and held in place with #6 screws. The outer tubing can be drilled and tapped to secure short #6 screws which hold short (2-3 inch) segments of 1-inch tubing (DXE 1498) in place (see Figure 7). This allows fine tuning of the antenna, so the resonant point can be centered in the two-meter band. Be careful to change each dipole half the same amount.

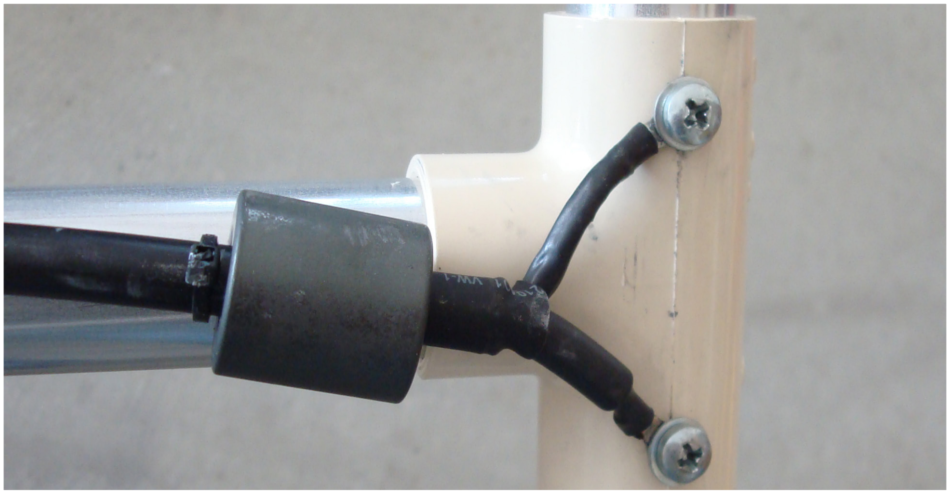


Figure 6 — CPVC tee fittings serve as center insulators for dipole elements, here viewed from the bottom of the antenna.

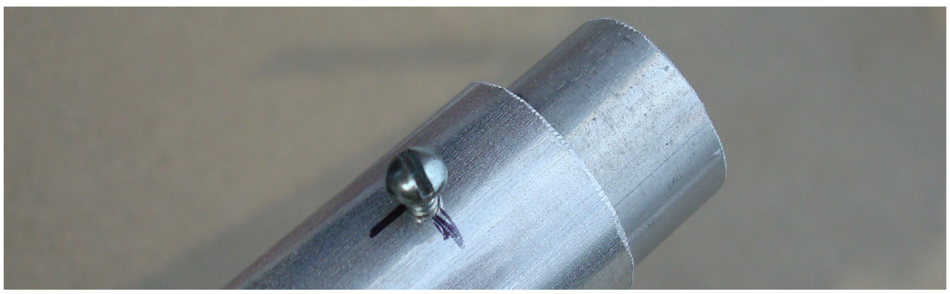


Figure 7 — If it is necessary to tune the antenna to a lower frequency, adjustable sections can be added to each dipole element.

We found that changing the length of each half-dipole by ½ inch moved the resonant frequency about 3 MHz. When a desired setting has been found, pop rivets can be used to secure the setting or new elements can be cut to the correct length. We were able to achieve an SWR of less than 1.3:1 across the entire 2-meter band (see Figure 8-9).

Antenna Modeling

We created an EZNEC model of our Lindenblad antenna to see its radiation pattern. Two of the dipoles were moved 1.125 inches lower than the other pair to duplicate the offset created by our construction method. The typical omnidirectional pattern expected with a Lindenblad antenna resulted, with no detectable change caused by the vertical offset (see Figures 10-11).

Results

The Lindenblad array antenna described here performs well on the two-meter band. We monitored many transmissions from the ISS leading up to our ARISS contact and always had good reception. We were able to hear the ISS with good signals at the horizon, although full quieting did not occur until the space station was at 5-7 degrees elevation. Using a conventional amateur transceiver

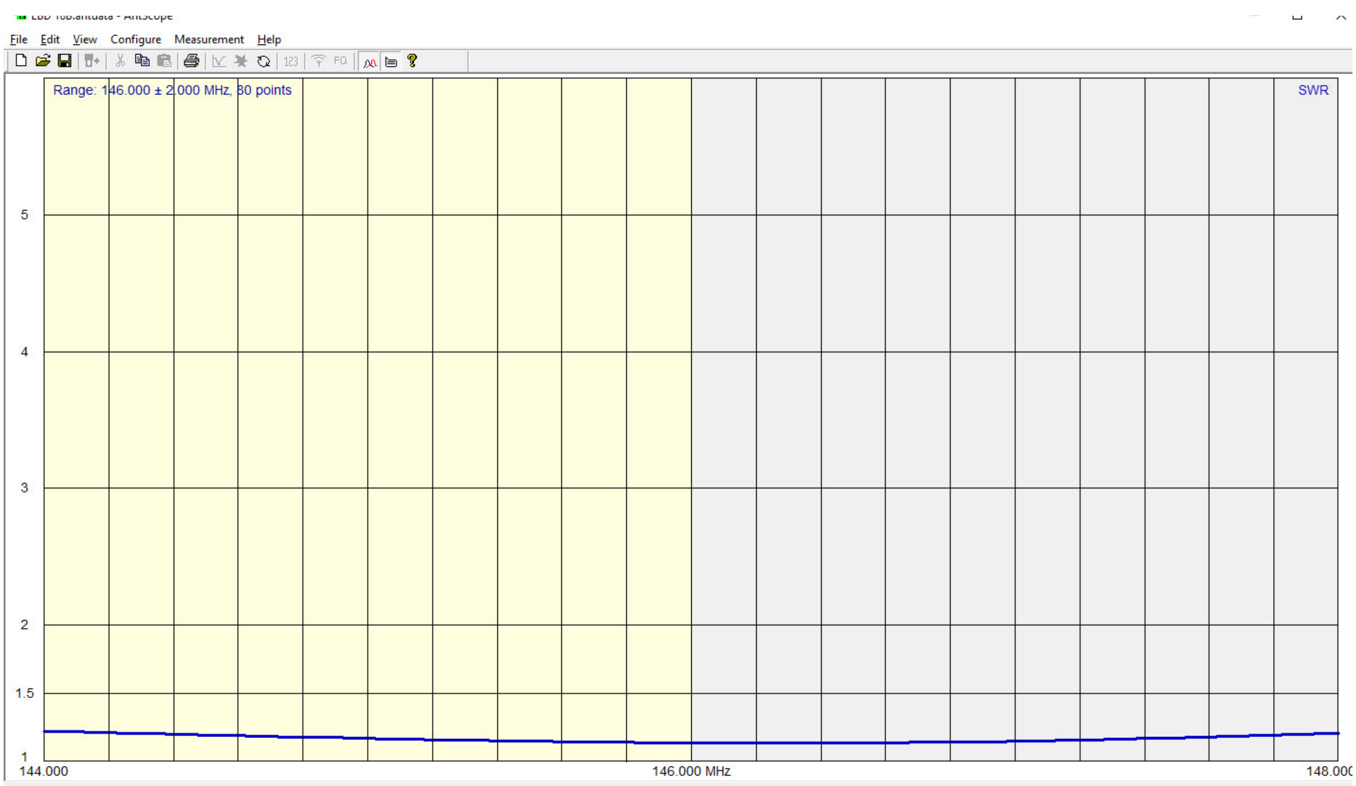


Figure 8 — SWR from 144 to 148 MHz is less than 1.5:1.

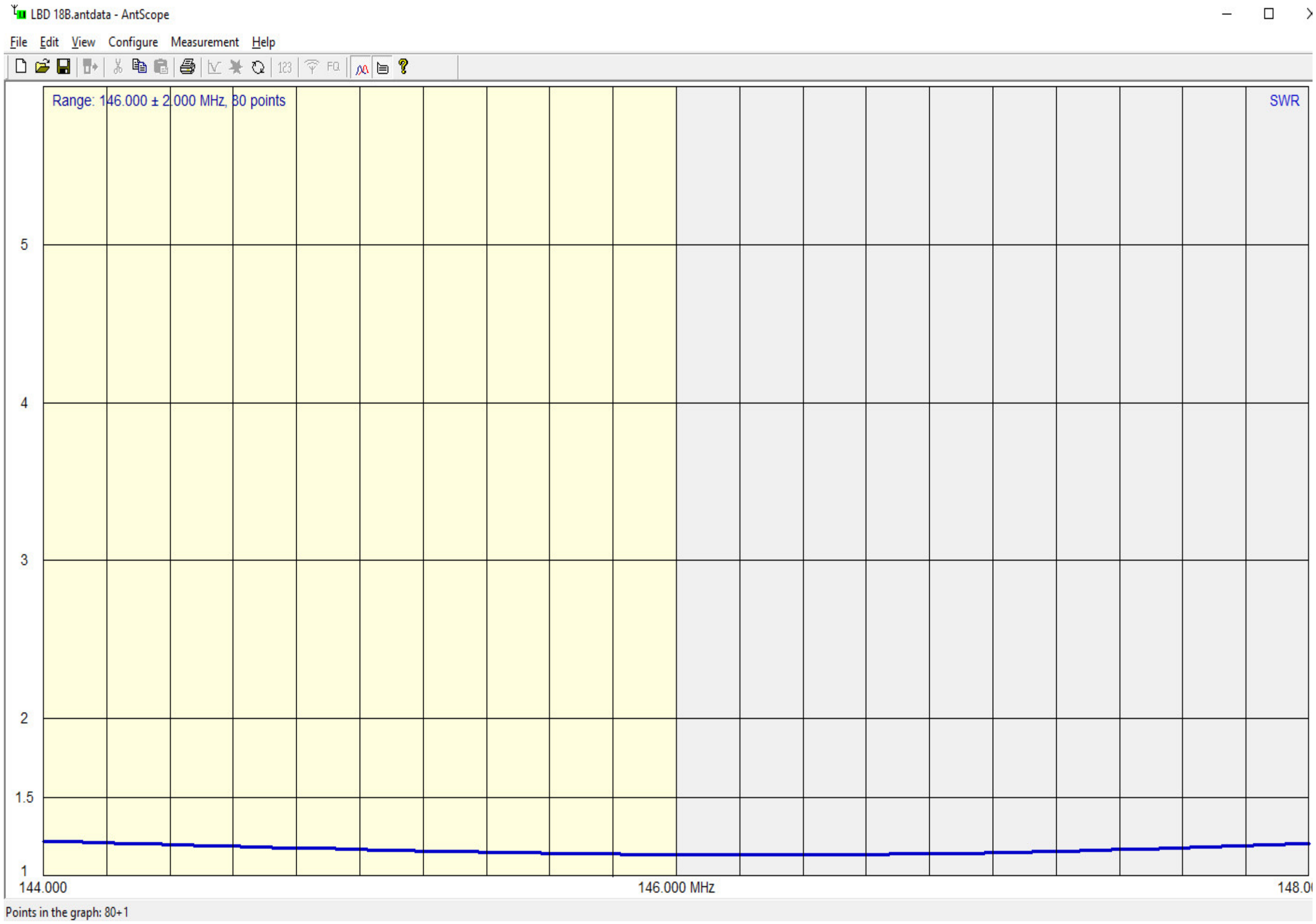


Figure 9 — SWR from 136 to 156 MHz is less than 2.5: 1.

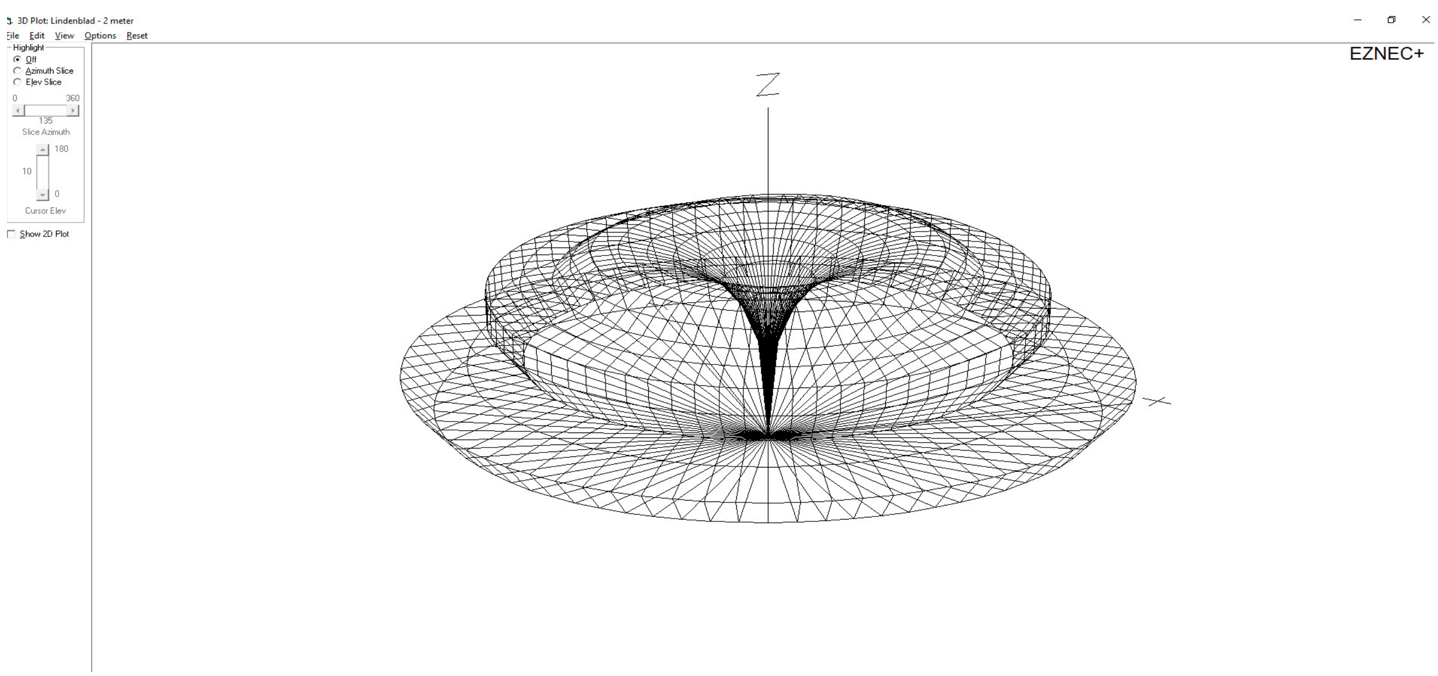


Figure 10 — Lindenblad radiation pattern.

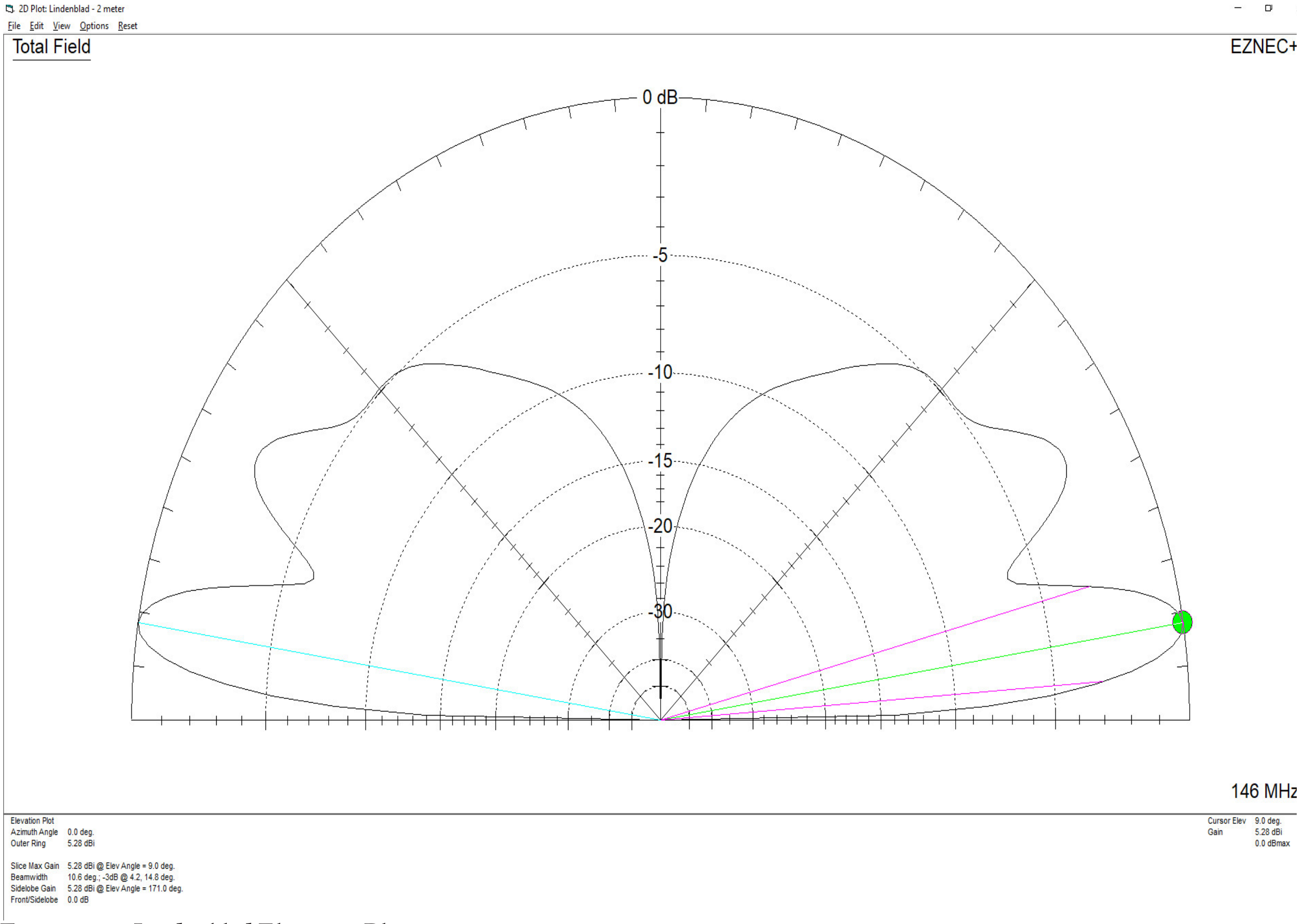


Figure 11 — Lindenblad Elevation Plot.

Figure 12 — Final antenna mounted for testing.

and amplifier (as suggested by ARISS) this antenna should provide solid uplink signals to the ISS from horizon to horizon, ideal for a backup station. Many QSOs on amateur satellites have been made from the station of AA9LC using this antenna, and it is an excellent choice for amateurs who do not wish to install a steerable AZ/EL gain antenna for the satellite operation on two meters.

Thanks again to Tony Monteiro, AA2TX, for his excellent original design. We have enjoyed building and using this rugged antenna (see Figure 12) and hope that our experience will encourage others to build a Lindenblad for their station or as a backup station antenna for an ARISS contact.

Materials:

- Aluminum tubing – 1.125" outside diameter, .058" thickness
- Either: DXE-AT 1485, 1.125 in. 6-foot length, quantity 3
- or: DXE-AT 1499, 1.125 in. 3-foot length, quantity 6

- Schedule 40 CPVC 1-inch tee fitting, quantity 4 -NIBCO brand available at Menards Home Center #T00202C
- Schedule 40 CPVC 1 inch cap, quantity 4 – NIBCO brand available at Menards Home Center # T00225C
- 1 ½ inch angle stock 1/8 x 1 ½ inch x 36 inches long – available at Menards Home Center
- ¾ inch aluminum stock – 1/16 x ¾ inch x 36 inches long – available at Menards Home Center
- RG-11/U coaxial cable – DX Engineering DXE 11/U – 10 feet
- Ferrite chokes – Fair-Rite brand PN 2631102002 – available from Mouser Electronics
- Panel mount SO-239 connector – Amphenol 83-1R – available from Mouser Electronics
- Ring terminals, uninsulated 12-10 gauge for 8-10 stud, quantity 8
- Machine screws # 10-32 x 1/2" long, quantity 12
- Machine screw # 6 x 2.5 inches, quantity 1
- Machine screws # 6 or # 8 or POP rivets as preferred to secure crossarms to the antenna mast
- NOALOX .5 oz. anti-oxidant compound for electrical connections

Contact information:

Grant Zehr AA9LC
9781 Old Sawmill Rd.
Bloomington, IL 61705
Email: grant@dzehr.com

or

Tom Planer KJ9P
2354 Callard Lane
Normal, IL 61761
Email: kj9p309@gmail.com

Phase 4 Ground Update

Michelle Thompson, W5NYV

Phase 4 Ground is a project supported by open source hardware and software technology. The goal of the Phase 4 Ground project is a modular and reusable "five and dime" (5 GHz uplink, 10 GHz downlink) ground station for amateur radio space and terrestrial use. Phase 4 Ground uses the digital video broadcast satellite second revision (DVB-S2) standard as a downlink. The project also supports an extension to DVB-S2 that includes functions to improve reception of very low signal to noise (VLSNR) ratios. The extension is called DVB-S2X. We refer to the combined standards as DVB-S2/X.

The mission of Phase 4 Ground is to create a re-usable affordable amateur radio ground station that provides a frequency-division multiple access uplink (~100 channels of 4-ary minimum shift keyed access) that are combined in the payload into one-time division multiplexed downlink (DVB-S2/X). Any payload that complies with the air interface can use this system!

The primary tool for all this digital waveform radio design is GNU Radio (https://www.gnuradio.org). GNU radio is a free and open source toolkit for software defined radio (SDR) and digital signal processing (DSP). GNU Radio is known and used across the amateur radio community. ARRL's QEX started covering what we would recognize as SDR in the late 1990s. QEX articles over the past two decades cover a variety of tools and techniques, including but not limited to GNU Radio.

The most common introductory radio design for SDR is a frequency modulation (FM) broadcast receiver. GNU Radio blocks have inputs or outputs or both. When the output from a block is connected to another block's input, the data flows from one block to the other. Each block does a task, such as filtering or amplifying. GNU Radio provides a graphical user interface for connecting blocks.

When the flow graph is ready for testing, the "play" button is pressed, and data begins to flow. Data can be sourced from a file, a TCP/UDP socket, live radio signals, or generated by mathematical constructions. Various graphical user interface elements can be placed in the flow graph to see the results. Time and frequency visualizers provide oscilloscope and spectrum analysis. Waterfall displays, constellation diagrams, baseband results, filter representations, and many other visuals can be attached to the flow graph.

Specially formatted computer software functions define each graphical drag-and-drop block. These functions work underneath the user interface. The functions are written in either Python or C++. In general, a Python block is easier to get up and running, and a C++ block has higher performance. A common practice is to experiment with different algorithms in Python. Once the right series of steps is determined, that algorithm is implemented in C++.

GNU Radio is one of the most recognizable and most advanced software defined radio prototyping tools available. Like any other powerful tool, it has a learning curve. Here is what we recommend for learning how to use GNU Radio: **wiki.gnuradio.org/index.php/Tutorials#Guided_Tutorials.**

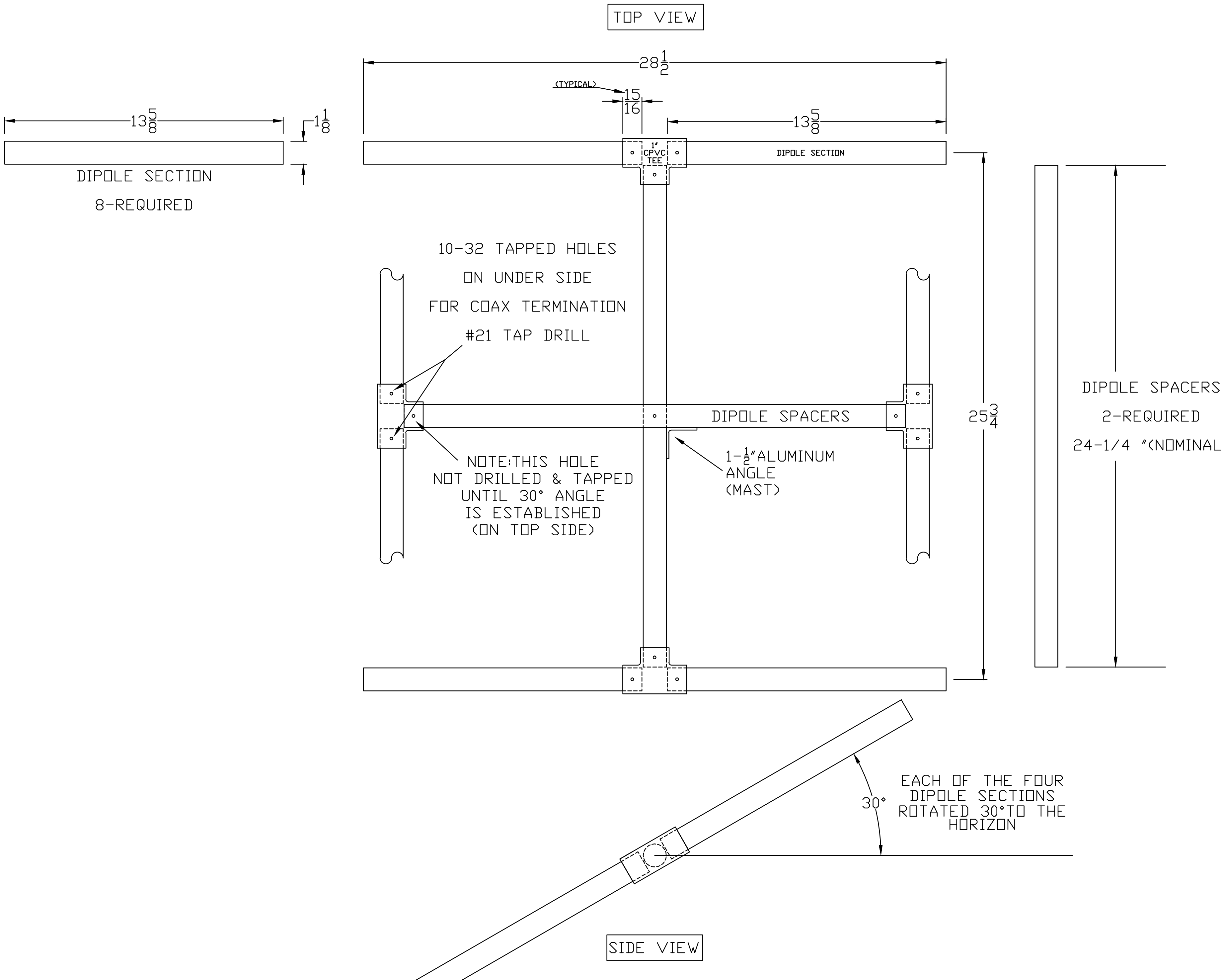
Generic Stream Encapsulation (GSE) is a standard from DVB. It's important for amateur communications over DVB-S2/X, as it enables any data stream, not just MPEG, to be transported over the communications link. Current efforts include integrating IP Multicast, Real Time Protocol (RTP), and GSE into a powerful distributed radio architecture.

A correlation block has been written by a contributor from Libre Space Foundation and Low Density Parity Check (LDPC) forward error correction code donation from active community members. The DVB-S2 specific correlation block is another step forward in broadband digital multiple access protocols. The LDPC code donation is state of the art.

GNU Radio has block creation boilerplate that helps set up the directory and template structure to get a block done. We also plan to develop an FPGA based radio. We have secured funding for the development boards.

As of today, complete DVB-S2 transmitters are available in GNU Radio, but GNU Radio does not have complete DVB-S2 receivers. Progress on getting complete receivers working has been good, but it is an ambitious goal. Amateur radio is worth the effort! Imagine having a powerful multiple-access broadband digital system that can be used for both terrestrial and space applications.

DVB-S2 receiver flow graphs are composed of open source blocks that implement



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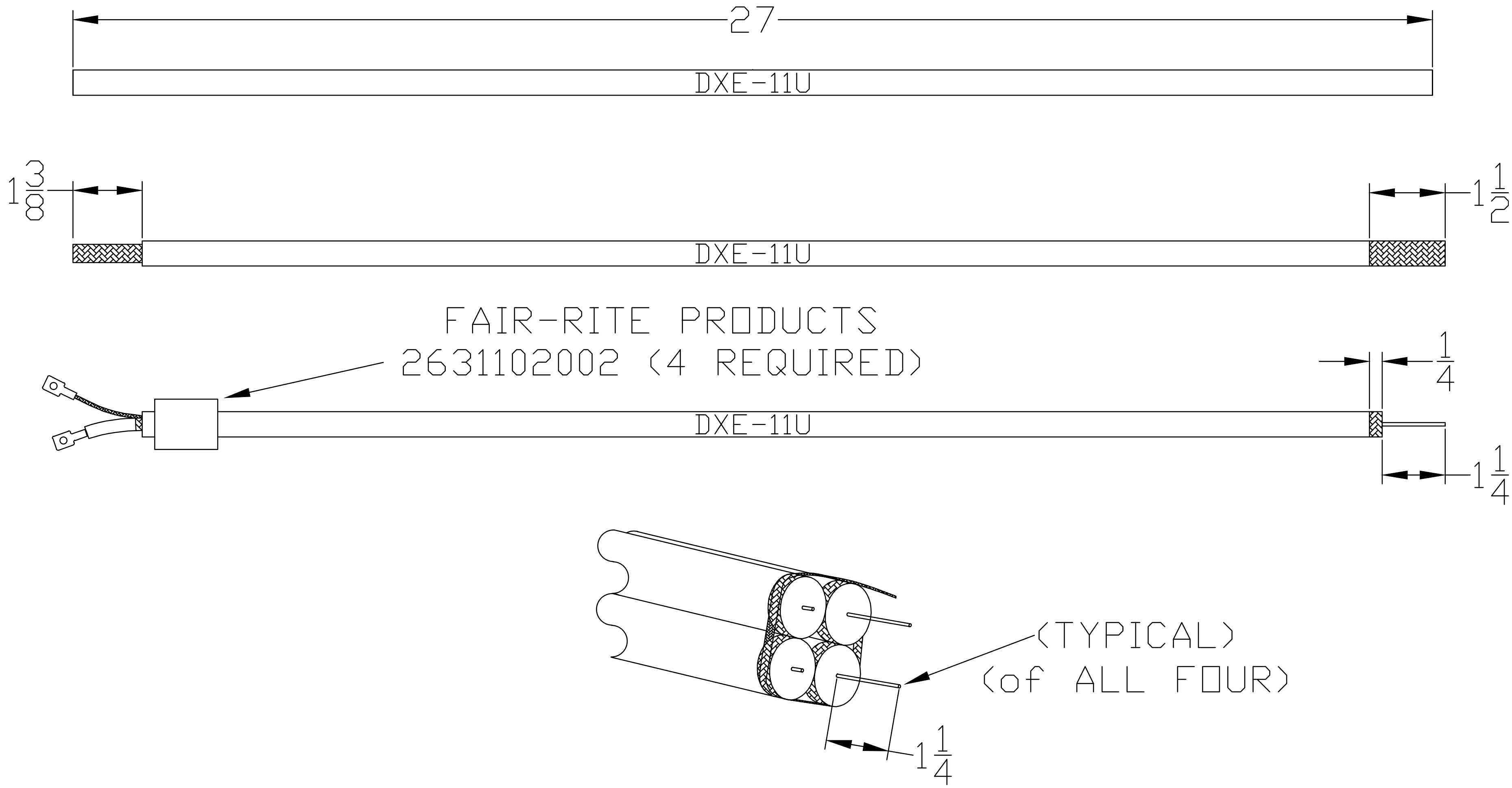

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