An EZ-Lindenblad Antenna for 2 Meters

This easy to build antenna works well for satellite or terrestrial communication, horizontal or vertically polarized.

Anthony Monteiro, AA2TX

Lindenblad is the name of a type of antenna that is circularly polarized yet has an omnidirectional radiation pattern. With most of its gain at low elevation angles, it is ideal for accessing low earth orbit (LEO) Amateur Radio satellites. Because it is omnidirectional, it does not need to be pointed at a satellite so it eliminates the complexity of an azimuth/elevation rotator system. This makes the Lindenblad especially useful for portable or temporary satellite operations. It is also a good general purpose antenna for a home station because its circular polarization is compatible with the linearly polarized antennas used for FM/repeater and SSB or CW operation.

This type of antenna was devised by Nils Lindenblad of the Radio Corporation of America (RCA) around 1940.1 At that time, he was working on antennas for the then nascent television broadcasting (TV) industry. His idea was to employ four dipoles spaced equally around a $\lambda/3$ diameter circle with each dipole canted 30° from the horizontal. The dipoles are all fed in phase and are fed equal power. The spacing and tilt angles of the dipoles create the desired antenna pattern when the signals are all combined. Unfortunately, the start of World War II halted Lindenblad’s TV antenna work.

After the war, George Brown and Oakley Woodward, also of RCA, were tasked with finding ways to reduce fading on ground-to-air radio links at airports.2 These links used linearly polarized antennas. The maneuverings of the airplanes often caused large signal dropouts if the antennas became cross-polarized. Brown and Woodward realized that using a circularly polarized antenna at the airport could reduce or eliminate this fading so they decided to try Lindenblad’s TV antenna concept.

Brown and Woodward designed their antenna using metal tubing for the dipole elements. Each dipole element is attached to a section of shorted open-wire-line, also made from tubing, which serves as a balun transformer. A coaxial cable runs through one side of each open-wire-line to feed each dipole. The four coaxial feed cables meet at a center hub section where they are connected in parallel to provide a four-way, in-phase power-splitting function. This cable junction is connected to another section of coaxial cable that serves as an impedance matching section to get a good match to 50 Ω. While the Brown and Woodward design is clever and worked well, it would be quite difficult for the average ham (including this author!) to duplicate.

The major cause of the difficulty in designing and constructing Lindenblad antennas is the need for the four-way, in-phase, power splitting function. Since we generally want to use 50 Ω coaxial cable to feed the antenna, we have to somehow provide an impedance match from the 50 Ω unbalanced coax to the four 75 Ω balanced dipole loads.

Previous designs have used combinations of folded dipoles, open-wire lines, twin-lead feeds, balun transformers and special impedance matching cables in order to try to get a good match to 50 Ω. These in turn increase the complexity and difficulty of the construction.

1Notes appear on page 40.

Figure 1 — Smith Chart showing transformation along a 75 Ω transmission line to yield 200 Ω.
The EZ-Lindenblad

An antidote to these difficulties is the EZ-Lindenblad. The key concept of the EZ approach is to eliminate anything that is electrically or mechanically difficult, leaving only things that are easy. This leads to the idea of just feeding the four dipoles with coax cable and soldering the cables to a connector with no impedance matching devices at all. This would certainly be easy but we also want the antenna to work! Without the extra impedance matching devices, how is it possible to get a good match to 50 Ω?

If we could get each of the four coax feed cables to look like 200 Ω at the connector, then the four in parallel would provide a perfect match to 50 Ω. We could do this if we used quarter-wavelength sections of 122 Ω coax to convert each 75 Ω dipole load to 200 Ω. Unfortunately, there is no such coax that is readily available.

But we can accomplish the same thing with ordinary 75 Ω, RG-59 TV type coax if we run the cable with an intentional impedance mismatch. By forcing the standing wave ratio (SWR) on the cable to be equal to 200/75, or about 2.7:1, we can make each cable look exactly like 200 Ω at the connector as long as we make them the right length. It is easy to make the SWR equal 2.7:1 by just making the dipoles a little too short for resonance. An EZNEC antenna model can be used to determine the exact dipole dimensions.5

The conversion from the balanced dipole load to the unbalanced coax cable can be painlessly accomplished by threading each cable through an inexpensive and readily available ferrite sleeve making essentially a choke balun. The only remaining issue is the required length of the feed cables, and this can be easily determined using a Smith Chart.

Smith Chart

The Smith Chart was invented by Phillip Smith of The Bell Telephone Laboratories in 1939.4 As a high school student, Phillip had been a ham radio operator and used the call sign 1ANB. After graduating from Tufts College, he went to work for Bell Labs in the radio research department. As part of his job, he needed to make many impedance calculations that in those days required doing many complex computations by hand. Phillip realized he could create a chart that would allow the solution to be plotted on a graph making his job a lot easier. Phillip Smith’s chart was soon adopted by other radio engineers and quickly became a standard engineering tool that is still in use today. Technical information and free downloadable Smith Charts are available via links on the ARRL Web site.5 Please see the Smith Chart in Figure 1.

With a Smith Chart, we can easily determine the required length of 75 Ω coax to provide a 200 Ω load. The Smith Chart shown is normalized to 1 Ω in the center so we must multiply all impedance values by our coax impedance of 75 Ω. An EZNEC antenna model was used to simulate cutting the dipole lengths until the SWR on the line reached 2.7:1. The model showed that the dipole load impedance would then be 49.3–55 Ω and this is plotted at point A on the chart. The desired 200 Ω impedance at the connector is plotted at point B on the chart. A constant 2.7:1 SWR curve is drawn between the two impedance points. The length of cable needed is read clockwise along the scale labeled, WAVELENGTHS TOWARD GENERATOR from the lines drawn through points A to B. From the chart, the length of the line needed is 0.374 λ.

The EZ-Lindenblad was designed for a center frequency of 145.9 MHz to optimize its performance in the satellite sub band. At 145.9 MHz, a wavelength is about 81 inches and since the coax used has a velocity factor of 0.78, we need to make the feed cables 81 x 0.374 x 0.78 = 23.6 inches long.

There are several computer programs available today that can also be used to do the Smith Chart calculations. These include TLW, provided with The ARRL Antenna Book and MicroSmith formerly offered by the ARRL, which was used as a cross check.6

Construction

This antenna was designed to be rugged and reliable yet easy to build using only hand

Table 1

<table>
<thead>
<tr>
<th>Required Materials</th>
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<tbody>
<tr>
<td>Quantity one, unless noted.</td>
</tr>
<tr>
<td>Aluminum angle stock, 8” length of 2” x 2” x 3/16”,</td>
</tr>
<tr>
<td>Aluminum angle stock, 2” length of 2” x 2” x 3/16” for mounting connector.</td>
</tr>
<tr>
<td>Screws, #8 x 1/2” aluminum sheet metal, quantity 12.</td>
</tr>
<tr>
<td>Screws, #8 x 1/8” aluminum sheet metal or 3/8” aluminum rivets, quantity 12.</td>
</tr>
<tr>
<td>PVC insert T-connector, 1/4” x 1/8” x 1/8” grey for irrigation polyethylene tubing. LASCO Fittings, Inc. Part# 1401-005 or equivalent. Available from most plumbing supply and hardware stores.</td>
</tr>
<tr>
<td>Ox-Gard OX-100 grease for aluminum electrical connections.</td>
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</tbody>
</table>

Figure 2 — Close-up of dipole electrical connections.

Figure 3 — View of cross booms mounted to mast.
Aluminum Tubing Lengths

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipole rods</td>
<td>8</td>
<td>14½&quot;</td>
</tr>
<tr>
<td>Cross booms</td>
<td>2</td>
<td>23&quot;</td>
</tr>
</tbody>
</table>

The screws will be used to make the electrical connections to the dipoles at the center. The screw holes should be about ¾ inch from the end of the tubing.

The dipole assemblies are attached by gently tapping the PVC insert-T into the end of each cross-boom with a hammer. The dimensions are shown in Figure 5.

Next, temporarily attach the mounting bracket to a support so that each of the cross booms is perfectly horizontal. Measure this with a protractor. Now, using the protractor, rotate the dipole assemblies to a 30° angle with the right-hand side of the nearest dipole tilting up when you are looking toward the center of the antenna. Drill a small hole through the existing cross-boom holes into the PVC insert-Ts and then use the machine screws to fasten the dipole assemblies into place. For a nice finishing touch, the dipole ends can be fitted with ¾ inch black plastic end caps.

Next, make the four feed cables by cutting and stripping the RG-59 coax as shown in Figure 6. On the dipole connection side, unwrap the braid and form a wire lead. Apply the smaller ring terminal to the center conductor and use the larger ring terminal for the braid. At the other end of the cable, do not unwrap the braid but strip off the outer insulation. Slip a 1 inch piece of shrink wrap over the coax and apply to the dipole side. Next,
slip a cable ferrite over the cable and push all the way to the dipole end as far as it will go (ie, up to the heat-shrink tubing.) The fit will be snug and you may need to put a little grease on the cable jacket to get it started.

Prepare each dipole for its feed cable by first cleaning the area around the screw holes with steel wool and then applying Ox-Gard grease. This is to ensure a good electrical connection. The coax center conductor goes to the up side of the dipole and the braid goes to the down side. To make a connection, put a machine screw through the ring terminal and gently screw into the dipole tubing. Do not overtighten the screws or you will strip the tubing.

Apply Ox-Gard or other corrosion resistant electrical grease around the hole for the N connector. Take the 4 inch piece of braid and put the end of it through the hole for the N connector. This provides the ground connection. Secure the N connector in the mounting hole to clamp the braid. Use a wire tie or tape to hold the four feed cables together at the connector ends. Make sure to align the cables so that all the ground braids are together and the center conductors all extend out the same amount. Do not twist the center conductors together. Carefully push the four cable center conductors into the center terminal of the N connector and solder them in place. Wrap the exposed center conductors of the cables and the connector with electrical tape.

Take the piece of braid that is clamped to the N connector and wrap it around the four exposed ground braids of the coax cables. Solder them all together. This will take a fair amount of heat but be careful not to melt the insulation. After this cools, apply electrical tape over all the exposed braid and fix with wire ties. The cables should be secure to the cross booms with wire ties.

The mounting bracket provides a way to attach the antenna to a mast using whatever clamping mechanism is convenient. For a permanent mount, drill holes in the bracket to accept a pair of U bolts. The author’s antenna was intended for portable operation and the bracket was drilled to accept two #8 stainless steel screws. These screws pass through a portable mast and the antenna is secured with stainless steel thumbscrews. This allows the antenna to be set up or taken down in less than a minute. The completed portable antenna as used for Field Day 2006 is shown in Figure 7. The little antenna at the top is for 70 cm.

**Standing Wave Ratio**

The antenna impedance match to 50 Ω was tested using an MFJ-259B SWR meter, which has a digital readout of standing wave ratio (SWR) and frequency. The frequency accuracy was verified using an external frequency counter and the 1:0:1 calibration was checked with a Narda precision 50 Ω load.

The antenna was connected to the SWR meter with a 6 foot coax jumper made of Belden 9913F7, which has very low loss. The SWR was measured at 1 MHz intervals over the 144-148 MHz range. As can be seen in the chart of Figure 8, the antenna provides an excellent match over the entire 2 meter band.

**Power Handling Capability**

This antenna was designed to safely handle any of the currently available VHF transceivers. The power handling capability was tested by applying a 200 W CW, signal, key down for 9 1/2 minutes. Immediately after the test, the ferrites and cables were checked and there was no noticeable temperature rise.

**Radiation Pattern**

The antenna radiation pattern predicted by the EZNEC model is shown in Figure 9. This is the elevation plot with the antenna mounted at six feet above ground although it can be mounted higher if desired for better coverage to the horizon. As shown in the plot, the pattern favors the lower elevation angles.

Tony Monteiro, AA2TX, was first licensed in 1973 as WN2RBM. He has worked in the electronics industry for over 25 years starting as a member of the technical staff at Bell Laboratories and later as an engineering director at several telecommunications companies. You can reach Tony at 25 Carriage Chase Rd, North Andover, MA 01845 or at aa2tx@amsat.org.

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