The Skew-Planar Wheel Antenna

Introduction and Background

Interest in this antenna design arose when the West Carleton Amateur Radio Club in Ottawa decided to erect a beacon transmitter in the 902-928 MHz band. Discussion led club members to debate what characteristics the antenna should have. It was quickly decided that the antenna must have horizontal polarization, in keeping with weak-signal conventions. I voiced the opinion that ideally, the antenna should be circularly-polarized, so that the beacon signal might be received well on both vertically and horizontally polarized antennas. I was immediately delegated to devise, construct and supply such an antenna for the beacon project. So much for passive and innocent contributions to the discussion!

The Lindenblad antenna [1] design is familiar to many amateurs. This antenna has a circularly polarized response with a low horizontal pattern, so it is useful for satellite passes as the bird rises or sets near the horizon. An example of the Lindenblad antenna is illustrated for the 2 Metre band in the Satellite Experimenters' Handbook published by ARRL. This particular design uses four folded dipoles fed together using paralleled 300 ohm twinlead. Suitable instruments were not readily available for measuring impedances and for matching at 903 MHz when I was considering antenna designs, so I could foresee some difficulties with constructing and matching a Lindenblad for transmitting purposes.

Stuck with the need to produce or shut up (the latter was not really an option), I considered the situation for a time. I remembered seeing information on an antenna design with circular polarization that was used for mobile work many years ago on the 2 Metre band. This was back in the days when such activity was mostly on AM, usually using Halo antennas on the mobiles. This antenna, the Skew-Planar Wheel, was described in QST in November 1963 [2] and is illustrated in the 1964 edition of the ARRL Antenna Book. As far as I know, it has seldom been referred to since that time. A search of the Internet did not produce any further examples or information on it beyond my web page [3]. It appeared that the amateur community had forgotten this antenna. This is interesting in itself, because the same amateurs who designed the Big Wheel Antenna built the Skew-Planar Wheel antenna, Carl Milner, W1FVY, and Robert Mellen, W1IJD.

The Big Wheel antenna design [4] is quite widely used today on the 144 and 430 MHz bands. It is horizontally polarized, so in fixed use it has some gain advantage over a single circularly polarized antenna in working locally with other horizontal antennas. However, the Skew Planar is preferable to meet the objectives for the beacon antenna and for other applications with its an omnidirectional low angle pattern and circular polarization – useful both for working repeaters and mobiles, and for local SSB nets where the other stations are using horizontal antennas. The broad frequency response of the Skew-Planar antenna with low SWR is a big plus.

The Skew-Planar antenna is a bit of a beast for 144 or 222 MHz mobile operations because of its size at these frequencies, but could be advantageous for fixed-station use. Mobile operation on these bands has for many years been almost exclusively FM, using vertical antennas.

First Experiments

The first antenna built for the beacon is shown in **Photo 1**. This was constructed using #12 AWG copper wire. The dimensions were scaled from the original article in the 1964 Antenna Book. The lower ends of the elements are soldered into a ½ inch copper pipe cap. **Photo 2** shows the more robust antenna that has been constructed for 440 MHz. It is built on a plastic pipe cap.

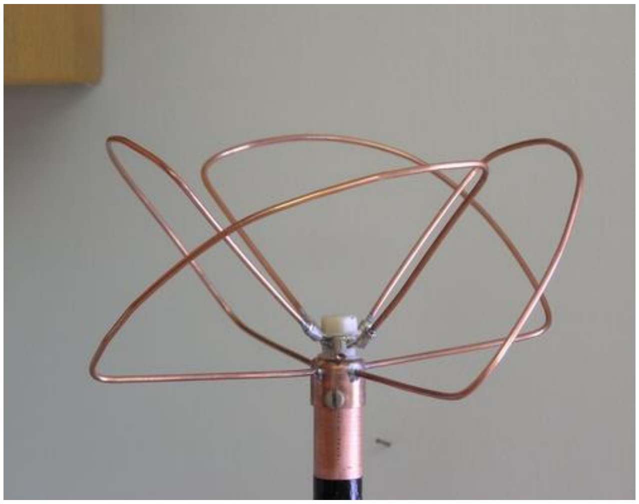


Photo 1. The Skew-Planar Wheel at 903 MHz.

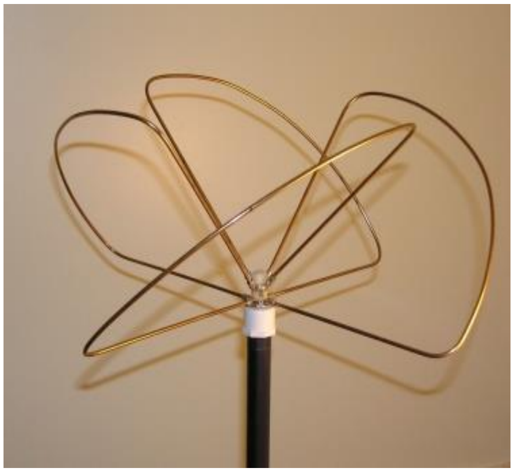


Photo 2. The Antenna at 440 MHz.

Doug Leach, VE3XK, and I investigated the beacon antenna using a network analyzer, and it looked pretty good with broad frequency response and a good match for 50 ohm cable, although the one wavelength-long elements put the optimum resonant frequency a little high. The analyser showed that the elements should be somewhat longer than the one wavelength suggested in the original article on this antenna.

This first antenna did radiate quite well. Even though the beacon location and height were far from ideal, the beacon had a strong signal received on a hand-held with rubber duck antenna at the maximum range checked, out to 8 km (5 miles) or so. No thorough range or polarization tests were conducted at that time. Not very long after its installation, it became necessary to change the location of the beacon. The antenna suffered some damage in the process so the beacon was put up in its new location using a temporary horizontally polarized antenna.

We were pleased with the apparent performance of the Skew-Planar antenna. But the question of its actual characteristics remained. We wanted to verify that the antenna does in fact produce circular polarization, and to determine its radiation pattern in the horizontal and vertical planes. We needed to satisfy ourselves that it was doing what we were hoping it was.

Antenna Simulations

David Conn, VE3KL, conducted extensive analyses of the design at various frequencies. David used EZNEC [5] and programming in Visual Basic to determine the complex wire descriptions needed for the skew-Planar antenna. The resulting Elevation plot of the antenna at 440 MHz is shown in **Figure 1** and the Azimuth plot in **Figure 2**. This antenna, designed for right-hand circular polarization, has a left-hand component as well. It responds to and produces left-hand circularly polarized radiation at 13 dB below the right-hand polarized component.

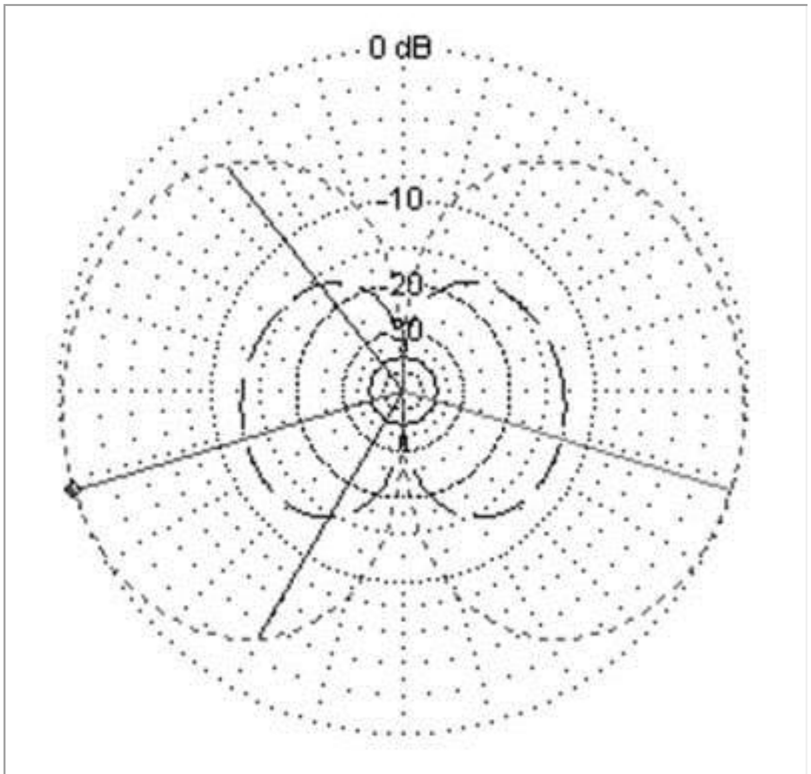


Figure 1. Elevation Plot

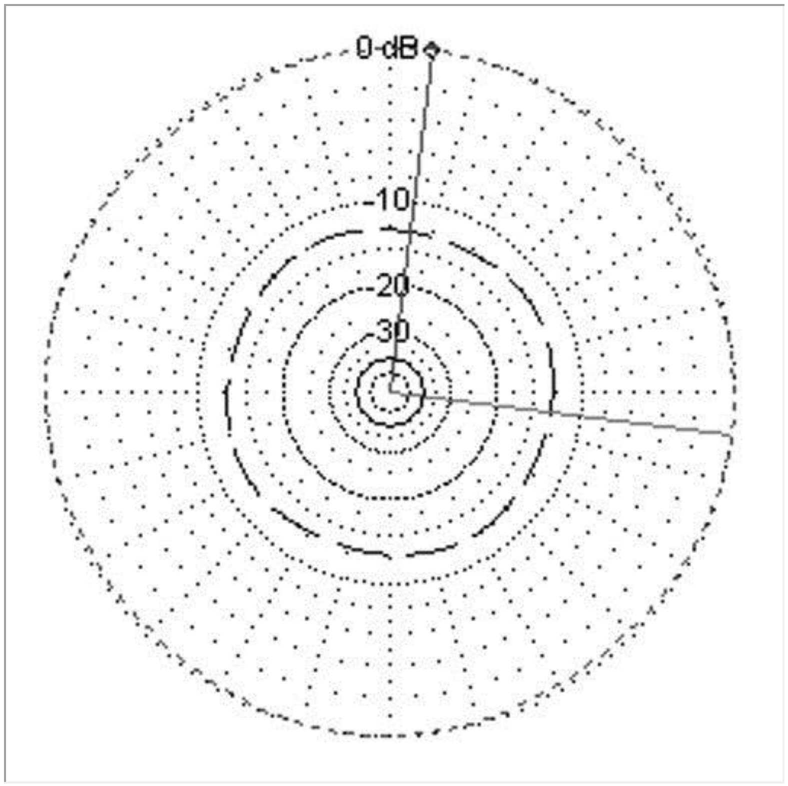


Figure 2. Azimuth Plot.

David's analysis of the Skew-Planar antenna confirmed that the element lengths should be longer than a free-space wavelength at the chosen design frequency – by a factor of about 4½ percent. Element lengths for various bands are shown in**Table 1**.

Table 1 Dimensions for some bands

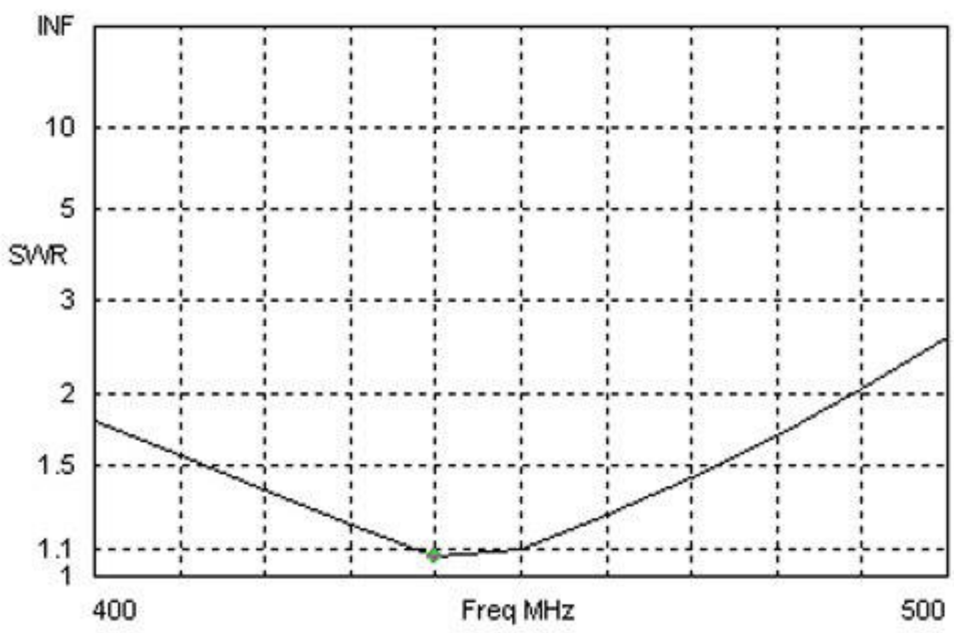
F MHz	Wavelength		Length Each Element		1/4 Element Length	
	Cm	Inches	Cm	Inches	Cm	Inches
1290	23.3	9.16	24.3	9.56	6.1	2.39

915	32.8	12.91	34.2	13.48	8.6	3.37
440	68.2	26.84	71.2	28.03	17.8	7.01
223.5	134.2	52.85	140.2	55.19	35.0	13.80
144.3	207.9	81.85	217.1	85.48	54.3	21.37

To find the element lengths for other frequencies, divide 31329 by the frequency in MHz for the length in centimetres, or 12334 by the frequency for the length in inches.

Construction of the Antenna

While perhaps not many readers will want to construct this antenna for the 902-928 MHz band, some of you might want to apply its advantages to other bands. The example shown in this article was built for 440 MHz. It covers 430 to 450 MHz and beyond with a low SWR as shown in **Figure 3.**



SWR = 1.08 @440 MHz
Zo = 50 Ohms
Z= 186 –j4.9 Ohms
Reflection Coefficient = 0.04 @ -160 degrees

Figure 3. SWR Plot.

For the materials and parts required, refer to **Table 2** (at the end of the article). The hubs where the elements come together can be made in a variety of ways. Sheet metal could be cut and formed – this would be suitable for the lower bands such as 144 or 222 MHz. As in the example for 903 MHz (**Photo 1**, above), the bottom ends of the elements can be soldered into a copper pipe cap. Probably the easiest method for 440 MHz and above is to use stacks of electrical wiring lugs at the top and bottom ends of the elements. These are soldered together, four lugs to each stack for the elements, plus one on each stack for the feedline attachment. In assembling the hubs, the lugs for the elements are oriented progressively at 90 degrees to each other and the lug for the feedline is between two of the element lugs. Refer to **Photo 3**.

Photo 3. The antenna hub, showing the stacks of lugs and element attachments. The unused lugs here are for attaching the coaxial cable.

The feedline lug is placed on the top of the stack for the bottom ends of the elements, and at the bottom of the top end stack - so these lugs will be close together when the antenna is assembled. Lugs for 10-12 gauge wire are a good fit for number 8 wire or 1/8 inch rod. The lugs can be opened up a little if you are using a heavier gauge element. Look for lugs designed for a ¼ inch stud. If you are using 5/16 nylon threaded rod in the final assembly rather than ¼ inch stock, the lug stacks can be drilled out after they are soldered together. The lugs on the stack for the upper ends of the elements are bent up to a 45 degree angle – after soldering the stack together.

To facilitate assembly, a jig to align the lugs is helpful and a short length of steel threaded rod, spacers and nuts to fit is needed as a jig for holding each assembly of lugs for soldering. These jigs are shown in **Photo 4**. Soldering is best done with a small torch. Don't try to solder the stacks (or the coaxial feedline) while they are on the nylon rod – the nylon will not survive the experience.

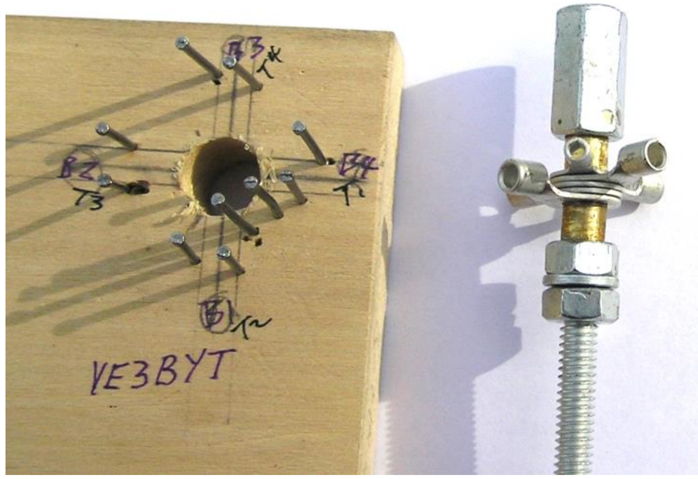


Photo 4. Jigs for aligning the lugs and for holding the stacks for soldering.

When the two stacks of lugs are assembled and soldered, place them both on the steel rod jig with a metallic spacer between them. Line up the lugs for the coaxial cable attachment. If the elements are copper, bronze or brass, they will be soldered in the lugs while on this jig; if they are aluminum they will be cleaned and crimped.

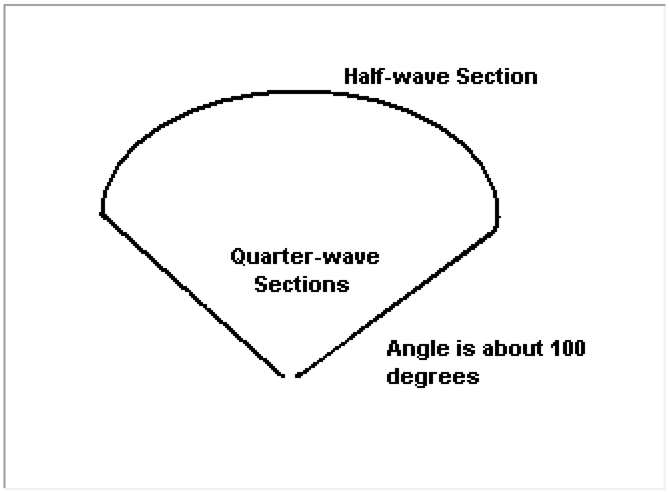


Figure 4. Shape of the Elements

Each element is shaped as shown in **Figure 4** and in **Photos 1** and **2**. On each end of an element at the ¼ length point, make a bend around a fairly short radius – for the 440 MHz antenna this was around a radius of about ½ inch. The half element portion is curved out so that the straight ¼ length sections meet and form an angle with each other of about 100 degrees. If necessary, adjust slightly the curvature where the one-quarter and the half element lengths meet.

Referring to **Photo 2** and **Photo 3**, you can see how everything fits together. The elements are assembled on the hub with the long section of each element (the half element length part) at 45 degrees to the horizontal, for right-hand circular polarization slanted up to the right when you are looking at the closest element. The upper end of each element goes into the lug on the top stack at 90 degrees counterclockwise from its lug on the bottom stack. This is easier to accomplish than it is to describe.

The coaxial cable should be attached while the assembly is on the steel rod before transferring it onto the pipe cap. The coax centre conductor is soldered to the top stack and the shield to the bottom. When all the elements and the coax are soldered to the lug stacks, the assembly becomes quite manageable and the steel rod can be easily be removed and replaced by the threaded nylon rod and the plastic spacer, and the whole thing mounted on the pipe cap. The antenna is then mounted on its mast pipe. If you wish, a hole can be made in the mast pipe to pass the feedline coax through and down inside the pipe.

Waterproofing

Coat the centre hub (nylon rod, spacer and nuts, and the lug stacks), and the feedline connections with PlastiDip or Liquid Electrical tape to seal against moisture. Use at least two coats on all of these areas. If you use copper or bronze for the elements, they should be sprayed with several coats of the acrylic spray to protect them against discolouration and corrosion. If aluminum is used for the elements, the area where they are crimped into the lugs should be coated with PlastiDip.

Mounting the Antenna

If the antenna is to be mounted on a metal mast, it must be at the top, or the antenna can be offset from a metal mast or tower by about 60 cm (two feet) or more. Ensure that the coaxial feedline is taken away from the antenna at a point lower than the antenna elements. There should not be any metal near the antenna in the plane of the elements.

On the Air Test

Construction of this antenna was completed shortly before our local Tuesday evening SSB net on the VHF and UHF bands. I was anxious to test the antenna so I mounted it temporarily on a fibreglass pole at a height of only 5 metres (16 feet). The large diameter feedline I tried at first turned out to have a problem in a connector, so I had to substitute with a handy 50-foot length of RG-58U cable – far from an optimum set-up. Nevertheless, I was pleased with the performance of the antenna under these conditions. With about 5 watts at the antenna, I was heard by most net stations in the area. I had reports of strong signals with VE3BBM at over 6 km (4 miles), VE3NPC at 16 km (10 miles) and VE3CVG at 40 km (25 miles), among others. Most stations were using high gain antennas.

Following the net, Clare Fowler, VE3NPC, gave me reports using first his right-hand circularly polarized helical antenna and then compared my signal as received on a helix wound for left-hand polarization. The results showed that this Skew-Planar is strongly right-hand circularly polarized, as expected. At my end, Clare's signal was S8 with his right-hand helix, and dropped to S1 when he switched to his left-hand helix. This is a remarkable difference in received signal level – much more than should be expected. This was probably because my S-meter has not been calibrated (and perhaps it is trying to make me feel good about the Skew-Planar antenna).

Summary and Future Plans

This is possibly the first time that this antenna design has been analysed, constructed and tested on the air since its introduction in 1963. It has been found to meet the objectives for an omnidirectional antenna that can work effectively with both horizontally and vertically polarized stations. Based on this preliminary testing of the Skew-Planar Wheel, I am confident that when I switch to more appropriate feedline (Heliax) and mount the antenna in the clear at its final dizzying height of 10 metres (33 feet), it will meet my expectations for local work with repeaters and mobiles and with weak-signal stations using horizontal antennas.

The 440 MHz antenna is not very large in size, so I have begun to build a second one. They will be stacked one above the other to achieve 3 dB of additional gain. I will rebuild the antenna for the 903 MHz beacon. When I figure out where I could mount it, I may put up a Skew-Planar Wheel antenna for the 2 Metre band as well. And there is a possible variation of the design that I want to investigate with David, VE3KL.

Stacking of Two Antennas

Two or more of these antennas can be stacked, but not one above the other on a metal mast. There must not be metal in the plane of the elements. The optimum stacking distance is 5/8 wavelength for 3 dB of gain compared to a single antenna. Stacking for two antennas is done by putting the pipe cap for the lower antenna on the top of its assembled hub rather than on the bottom. Then the antennas are separated using the correct length of plastic pipe or other non-conducting material, such as sealed wood. You could use a pipe 'T' in the middle of this pipe to carry a horizontal standoff to your tower or mast, or use some other standoff arrangement. It is also possible to put an additional pipe cap on the bottom of the lower antenna and mount the two antennas on their own mast, although this arrangement may not be sufficiently sturdy to withstand wind and icing conditions. The two antennas should be fed with equal lengths of coaxial cable from a two-port power divider. Again, the coaxial feedlines must not be in the horizontal plane of the antenna elements near the antenna.

Acknowledgements

Many thanks are due to David, VE3KL, for his considerable efforts on the analysis of the Skew-Planar Wheel and for his production of the figures for

this article. It was a real pleasure to work together on investigating the merits of this antenna. Thanks too to Jim Dean, VE3IQ, for finding and copying the original QST articles for me.

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Table 2 – Materials and Parts

1 Pipe Cap, to fit mounting pipe – plastic or copper

1 Length of small diameter pipe for mast

1 T fitting to fit mast (optional, depending on your mounting method)

4 Lengths of #8 AWG copper wire, 1/8 inch o.d. copper tubing, or brass or bronze brazing rod can be used. For 440 MHz these will each be 28 inches (71.2 Cm) long. You could use aluminum wire or rod, and crimp the elements in the lugs.

1 ¼ or 5/16 inch diameter threaded Nylon rod – the length will depend on your chosen band and your construction method.

1 Spacer, about 3/8 inch long for 440 MHz – a length of inner insulation from RG-8 coaxial cable, nylon nuts or washers or other low loss plastic - to fit over the threaded rod to separate the upper and lower lug stacks (element attachment assemblies).

2 Nylon nuts to fit the ends of the nylon threaded rod. Brass or steel nuts could be used.

8 Crimp type lugs to fit the #8 wire, tubing or rod elements, with a stud hole to fit your threaded nylon rod. (Lugs sold for #12-10 AWG wire are a nice fit for #8 AWG or 1/8 inch rod)

2 Crimp type lugs for #16-14 AWG with stud hole to fit the threaded nylon rod (attachment points for coaxial cable)

PlastiDip or Liquid Electrical Tape – (preferably white, yellow or red) to seal the hub of the antenna and the coaxial cable end from moisture.

Clear acrylic spray, for exterior use, ultraviolet radiation resistant, such as Krylon UV-Resistant Clear (available through art-supply stores).

References / Links

All of the links listed here are available in active form in Hot Links on the Radio Amateurs of Canada web site. Go to <http:www.rac.ca>, then to TCA, then click on Hotlinks.

[1] The Lindenblad Antenna – example for 2 Metres from the Satellite Experimenter's Handbook <http://www.amsat.org/amsat/articles/w6shp/lindy.html>

[2] The Skew-Planar Wheel Antenna, by Robert H. Mellen, W1IJD, and Carl T. Milner, W1FVY. QST, November 1963, page 11.

[3] VE3BYT web page on the Skew-Planar Wheel Antenna <http://www.slvrc.org/902band/skewplanar.htm>

[4] The Big Wheel on Two, by Robert H Mellen, W1IJD, and Carl T. Milner, W1FVY. QST, September 1961, page 42.

[5] EZNEC antenna analysis software authored by Roy Lewallen, W7EL <www.eznec.com/>