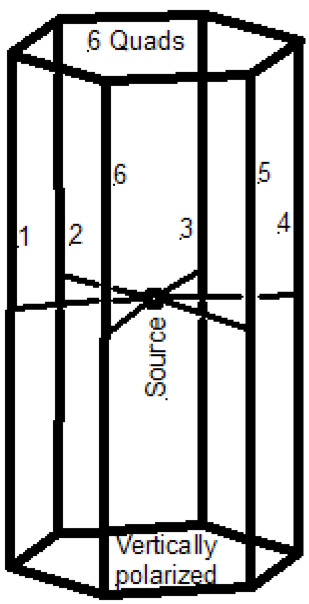
Some Prismatic Polygon Details

By Ed Shortridge, W4JOQ

Introduction

In June of 2001 *antenneX* online magazine published an article in issue #50 authored by Dan Handelsman N2DT, titled "A New Antenna – The Prismatic Polygon." This is a very unique antenna, which consist of multiple fed radiating elements arranged in a circular pattern. There are a variety of versions, which consists of 3 to at least 6 driven radiating elements. Dan has chosen to have these connected as, what he calls Multi-loops, and has named each of these antennas a Prismatic Polygon. I have chosen to look at these as a series of Quad antenna elements connected together in a circular pattern forming a polygon. Dan indicates that he started out with geometrical arrangements, such as linear loops, and then connected them in a circular pattern to form his Prismatic Polygon. In this article, I am presenting just one of many versions in reasonable detail.



Hex Prismatic Polygon

Figure 1

A Hex version of this antenna, which covers 10 to 30 MHz, is shown in **Figure 1**. This not a small antenna by any means, since the vertical radiators are 31.1 feet in Length, it is 20.34 feet in diameter and its bottom is mounted 10.75 feet above Average Soil. Don't get discouraged by its size, because scaling up to the VHF or UHF produces antennas with a very reasonable size. This antenna has six vertical radiators labeled 1 through 6. These radiators are tied together in a circular pattern, both on the top and bottom ends. If you look at each individual loop, you will find that they are configured as Quad radiators, except that all of the vertical radiators are driven. Each radiator is fed with transmission lines connected to a center point, which is the Source. If each of the radiators is fed directly, the source impedance of each appears to be approximately 400 Ohms in order to obtain the best SWR across the band. **Figure 2** shows this in detail.

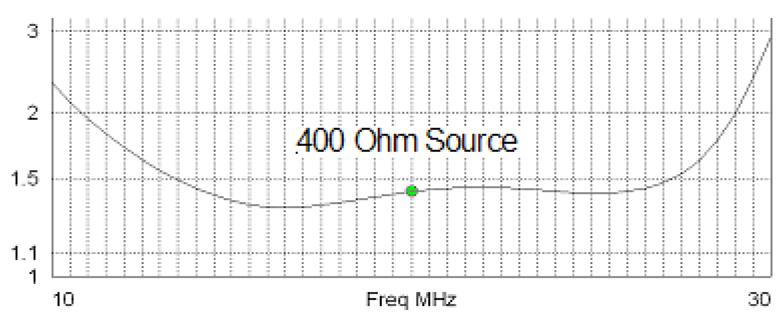


Figure 2

Individual measurements across the band show a resistive component that varies from 245 to 600 Ohms with a negative reactance that varies from 112 to 440 Ohms. With broadband antennas, it is not an easy task to simply match impedances at some particular frequency and expect this to apply to the rest of the bandwidth. Never-the-less, it is possible to make substantial improvements on the SWR as shown in **Figure 3**.

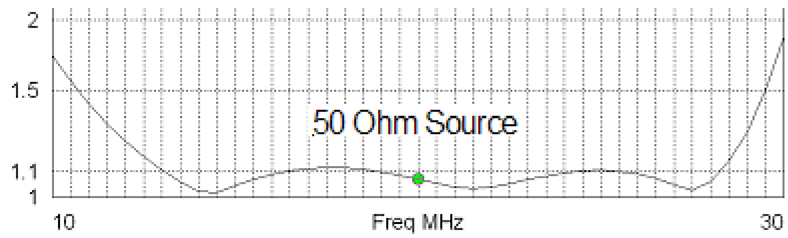


Figure 3

Since it is necessary to combine and match the six radiators to a 50-Ohm source, each of the six transmission lines must have an impedance of 300 Ohms. Unfortunately, each radiator has a high negative reactance, but with a more moderate range of the resistive component. The reactive component can readily be compensated to some degree by inserting positive reactance at the feed point of each of the radiators. Good results have been achieved by using fixed inductors or shorted stubs at each of the 6 feed points. From a fabrication standpoint, this does not seem like the most desirable method to use. Instead, it is possible to achieve the proper compensation by inserting reactance in each of the transmission lines going to the central 50-Ohm Source. This was accomplished by using a 5.36 feet section of 440-Ohm ladder line in series with the 4.81 feet of 300-Ohm line connected to the Source. When the six 300-Ohm lines are connected in parallel at the Source, there is a good match so the 300-Ohm line lengths can be any length. The use of transmitting quality twinlead is advised.

Components -
6 Vertical Radiators 31.1 ft.L 2.75in. od Alum.. Radius 10.17ft..
12 Horizontal tubes - 10.17ft. L 1.25 in. od Alum. Xmission lines from W1 thru 6 - L1 5.36ft.L 440 Ohm Ladder-line vf=0.91, losses 0.08dB/100ft./10MHZ. Line L2 (extension from L1 to Source) 4.81ft. 300 Ohm twin line vf=0.8, losses 0.2 dB/100ft./10MHz.

Source - 50 Ohm balanced. A 50/50 Ohm Balun is required, and additional traps and/or Ferrite bead required on the coax down-lead to counteract the induced currents from the radiators.

Mounting -
Bottom of antenna at 10.75ft. and exending up to 41.86ft.
Mounted above Average Soil.

Figure 4

Figure 4 shows all of the components, and particulars necessary to achieve a very low SWR across a 3/1 bandwidth. If the antenna is lowered down to 1 foot above ground, there is a ground effect which can extend the bandwidth somewhat. In the case of this antenna, it was extended to 9 MHz. Unfortunately, the 440-Ohm line had to be extended slightly in order achieve the bandpass shown in **Figure 5**. It not a nice symmetrical SWR across the band, but is still very good.

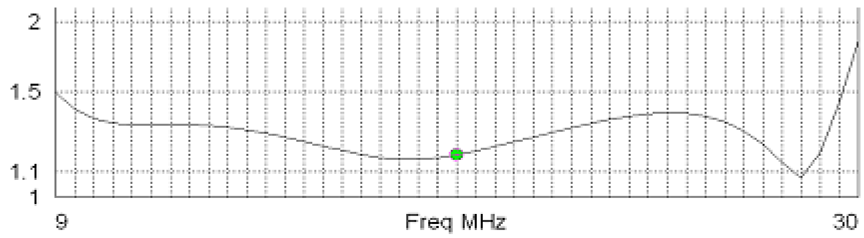


Figure 5

One of the great problems encountered with this antenna is with the transmission line, which is required to runs down from the Source to ground and then to the Transmitter/ Receiver. The lines from the Radiators to the Source are balanced and therefore a 50/50-Ohm Balun can to be used to prevent RF currents from flowing on the outside of this downward coaxial transmission line. That can be done readily but the big problem is the induced currents on the outside of this 50-Ohm coaxial cable from the radiated field. These currents can be substantial and will affect the SWR across the band, can cause radiated gain changes and high angles of radiation. Adding Ferrite beads on this transmission line can have some affect, but generally one or more coaxial chokes are necessary.

Rescaling to a 144 to 432 MHz bandwidth

If this antenna is scaled from 10 MHz to 144 MHz, the physical dimensions will become smaller by a factor of 14.4/1. This would then produce an antenna that is approximately 26 inches high and 17 inches in diameter. This is a very practical size to work with. The 2.75-inch diameter radiators will be reduced to 0.19 inches OD while the horizontal top and bottom wires become 0.086 inches OD. These can be increased to 0.19 inches OD similar to the vertical radiators without any problems.

The 440- and 300-Ohm balanced lines would also be decreased in the same proportion. The resulting antenna, when mounted at a 30 foot height above Average Soil, would have the same percentage bandwidth and SWR across the bandwidth from 144 to 432 MHz. Its radiation gain in the 2 m band would be approximately 6.4 dBi which is very similar to that of a standard half-wave radiator. As the operating frequency is increased, the radiation gain will increase.

This VHF antenna will cover all frequencies from the 2m band to the center of the 420-450 MHz band. In order to have it cover the entire 420-450 MHz band, slight adjustments of the 440-Ohm line length, along with slight changes of the antenna aspect ratio of height to diameter, generally will produce an antenna with a 3.125/1 bandwidth and will nicely cover this band. In doing this, the low SWR characteristics as shown in **Figure 3**, will not be achieved, but instead a good symmetrical bandpass with the SWR below 1.5/1 can be obtained.

Expected radiation patterns and gains

The antenna shown in **Figure 1** and **3**, along with its components shown in **Figure 4** were used to generate a series of elevation radiation patterns and gains with the Antenna Mounted 10.75 feet above Average Soil. This is shown in **Figure 7** for frequencies at or near actual amateur radio bands.

The gain shown at 10 MHz seems quite typical and as we go to the higher frequency bands the gain continues to increase. At 29 MHz, the greatest gain has been achieved but there is a hint of possible problems if the bandwidth could be extended beyond the 30 MHz. As you can see on the 29 MHz display, there are the slightest beginnings of high angle radiation shown in the center of the radiation pattern. As the Prismatic Polygon antenna is altered to achieve a greater bandwidth, the high end frequencies become vulnerable to losing low angle of radiation gain and thus, having most of the radiation gains at high angles. This begins with about a 3/1 bandwidth and can become serious when the bandwidth exceeds 3.125/1. When this occurs, it makes these higher frequency ends of the band unusable and there is little need to try to expand the bandwidth higher in frequency. Nevertheless, other variations of the Prismatic Polygon have been able to overcome this limitation to some extent. On this particular antenna shown, there would be no problem up to 30 MHz.

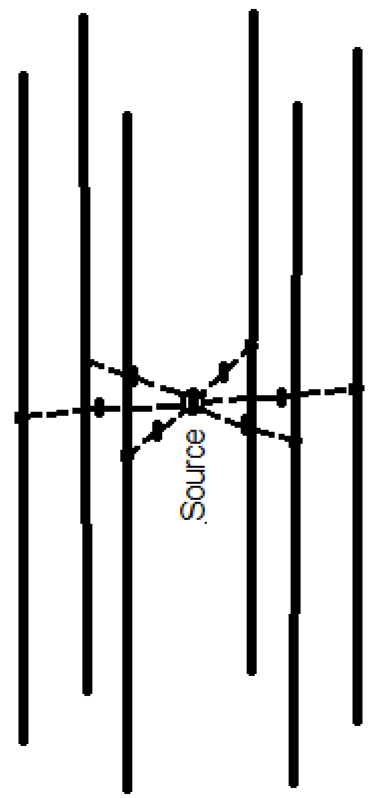


Figure 6

Alternative prismatic polygon configurations

Throughout Dan Handelsman's June 2001 article, the makeup of the Prismatic Polygon was described as being composed of loops and I have indicated that I look at these as Quad Radiators coupled together. Other configurations using full half-wave Hex radiators seems to work equally well and in some instances can achieve slightly greater bandwidth. There does not seem to be any more difficulties with the high angles of radiation at the high end of the bandwidth, than with the regular Prismatic Polygon. **Figure 6** shows a view of such an antenna, and as one can see, there is little difference except that the horizontal wires at the top and bottom of the Prismatic Polygon have been removed and the six radiators have been extended to a typical one-half wavelength.

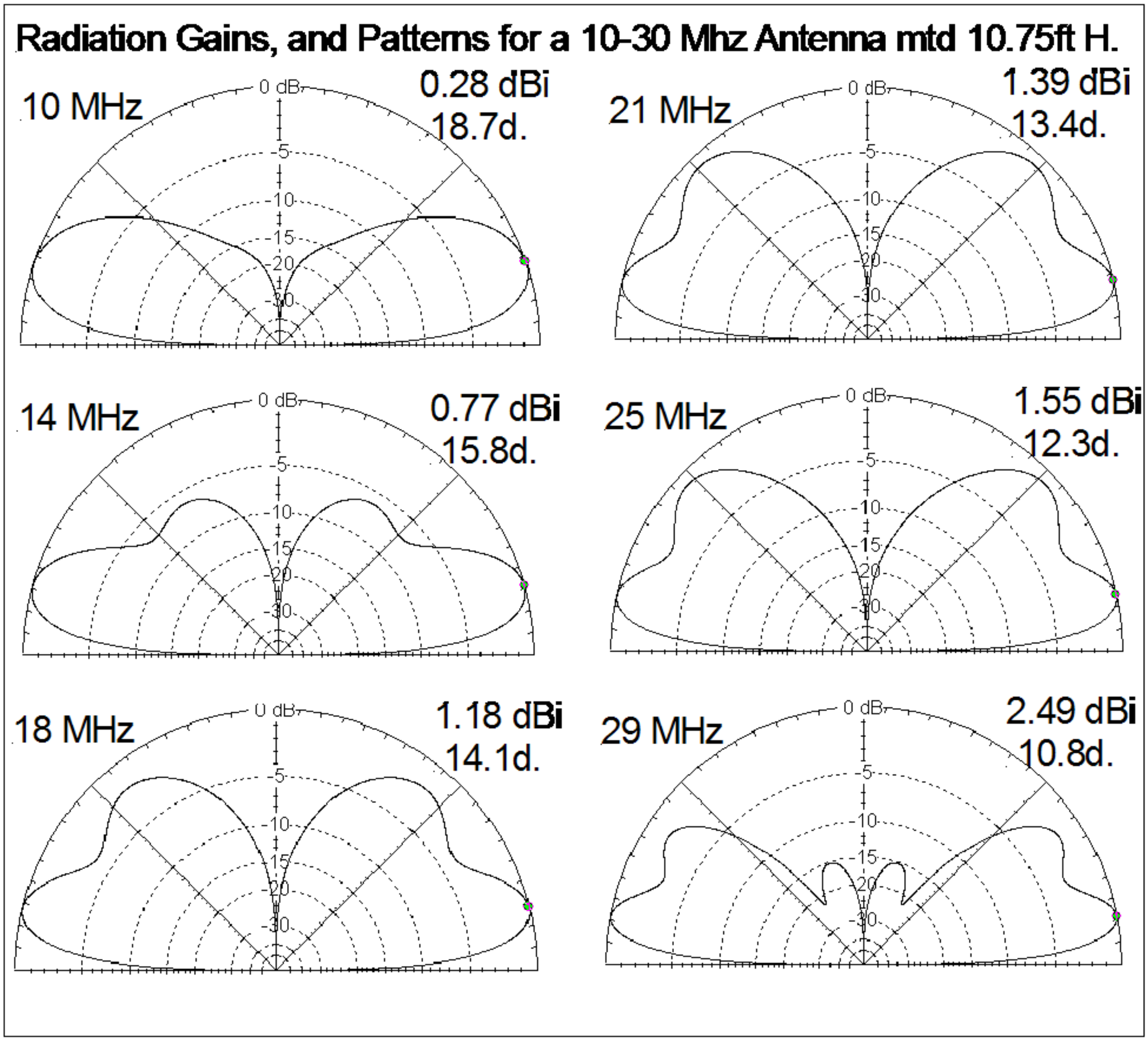


Figure 7

The Prismatic Polygon, when used in the HF range, has one distinct advantage over having full half-wave radiators, because it significantly reduces the overall antenna vertical dimensions. When this same antenna is scaled for the VHF or UHF ranges, the horizontal portions of the radiator do not present any problem, and tend to to tie the radiators in place. Full one half wave radiators on the other hand, are simpler to build, and work equally well. Using full wave radiators could conceivably require some changes in the antenna height to diameter ratio, and the 440 Ohm line impedance, or length.

How does the Prismatic Polygon achieve such good SWR bandwidth?

I do not pretend to know the real reason, but I have several theories, which may or may not be valid.

1. I have modeled six one-half wavelength vertical radiators mounted linearly and spaced at 0.25 wavelengths apart, and there are no signs of broad-banding. This tells me that there is something special about having these radiators in the circular arrangement.

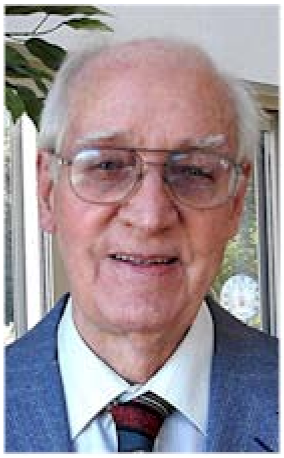
2. When six one-half wavelength driven radiators are assembled in a circular pattern, all of these are tuned circuits coupled together equally. This is far different than having them in a linear arrangement, where the end radiators are not coupled in the same manner as those in-between. This reminds me of broadband filter design, where multiple tuned circuits are used to achieve a wide bandwidth.

3. Everyone seems to know that increasing the diameter of a radiator generally improves the SWR bandwidth. This is taken to an extreme when building a Cage radiator for the 75/80-Meter band. The ARRL has used such an antenna for many years in order to cover the entire band. You can look upon the Prismatic Polygon as a vertical version of the Cage antenna taken to a far extreme of over 20-feet in diameter. The 10-30 MHz Prismatic Polygon shown in **Figure 1** seems to have a radiator impedance of approximately 400 Ohms to achieve the best SWR bandwidth as shown in **Figure 2**. If we take the normal source impedance of a one-half wave radiator in free space, which is 72 Ohms and multiply it by six, it will equal 432 Ohms, which is approximately the 400-Ohm source that we used in **Figure 2**. At this time, I am of the opinion that the Prismatic Polygon has achieved its bandwidth primarily due to a diameter of the antenna. What I cannot account for is that the SWR is so flat and low across such a wide bandwidth, so there must be other factors such as the Mutual Coupling of the six radiators that is accounting for this superb performance.

I hope this short article is simple enough so that everyone can appreciate the superb characteristics of the Prismatic Polygon. Possibly in future articles I can show some of the VHF or UHF versions of both the Hex, and Penta antennas. **-30**

Brief Biography of Author

Edward J. Shortridge, W4JOQ has been a licensed amateur for 70+ years. Ed began his interest in radio and electronics at the early age of 14, when the VHF/UHF state-of-the-art was super-regenerative tube detectors, Long-Line oscillator transmitters, using #45 or #10 tubes. The only choice of frequency measuring devices



at that time was Lecher Wires. He became a licensed Amateur radio operator at 18 years of age.

He joined the Naval reserves as a radioman in order to save money for college. After radio school, he was assigned to the Key West naval base. He had duty in the radio laboratory, radio receiving room, and was in charge of the main transmitter room.

Ed met his wife Marilyn while stationed at the Key West Naval base (NAR) and they were happily married together for only a short period of time before a national emergency was declared and he was soon shipped overseas during World War II. He had to remain in the U.S. Navy for a total of five years. He was chief radioman for two years as part of Admiral Hall's staff of the "5th Amphibious Force" and participated in invasions of Algeria, Italy (Salerno), Normandy (Omaha Beach), Philippine Islands and Okinawa. After returning to civilian life he fathered two children and worked at the following companies in Miami, Florida:

- Communications Company- Chief engineer-22 years
- Microtenna-Chief engineer-2 years
- Wackenhut Electronics-Chief engineer-3 years
- Shakespeare Marine Electronics-Chief Engineer - 7 years
- Hallicrafters-Director of radio engineering-3 years
- Aerocom-Chief engineer-7 years

Profession was directly involved in the design and development of:

- First VHF/UHF land mobile radio, and repeaters
- Balloon mounted VHF/UHF repeaters for Vietnam war
- Moon Landing VHF radio communication simulation
- Ground base to satellite communications
- HF and VHF Marine radio
- Marine depth finding equipment
- US military radio equipment
- Antenna design and manufacturing

Constant study, correspondence and seminar courses, along with professional engineering study groups, provided him with a background for continued electronic knowledge enhancement. His antenna design experience at several of these companies propelled his interest and experience in antenna design.

He retired in 1990, built a very nice retirement home. But in 1992, one third of it was destroyed by Hurricane Andrew, with all the ham radio, very good test equipment and the entire engineering library. In 1999, Ed bought a 116 acre mountain cove in western North Carolina and built another home.

Being in a mountain cove, there were concerns about what type of antenna could be used to get signals out of the cove, so the purchase of an EZNEC antenna modeling program helped. Over his engineering career, he designed many types of antennas, but had to do it the hard way without the new technological tools that emerged. There were many ideas over the years, but they had been too difficult, and time-consuming to pursue.

With the new modeling program, it became much easier to come up with designs. Several basic ideas that seemed a standout were worked on. They worked out quite well and were expanded into a large variety of antennas. First it was wideband antennas, but another basic idea was adaptable to widening most narrow-band antennas.

So far, Ed has spent 9 years of constant full-time effort on antenna designs, and is very excited about many ideas and concepts. There is not enough time in the day to satisfy his curiosity.

In July 2009, Ed turns 89 years of age, still in relatively good health. His Grandfather lived to be 98 and was quite active throughout. Possibly, Ed can equal or even outlive him and have many more years of productive life ahead with the hope of contributing to the understanding of antennas.

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