Chapter 39

Verticals and More Verticals

There have been verticals around for a very long time, beginning with Marconi. They have been marketed and made in untold varieties, but most all following the same designs. There are even multi-band models have been on the market for years and the manufacturer can't tell you how it works. It seemed time to venture into verticals and see if there were improvements to be made so we could enjoy radio with this type of antenna, particularly for restricted space.

What in the world is this antenna?

Well, folks, that strange looking black "thing" is the first 3-band ZR antenna. "ZR" for Z-axis Radiator. It covers all of 20, 15 and 10 meters and is a full size vertical dipole. It doesn't look like it, being only 6' tall, but it is. This antenna became known as the "ZR-3". This original proto-type is on a mobile mount plugged into the trailer hitch and in use for the California QSO Party with the buttes in Butte County in the background. In the dark area of the vehicle is a 4.5KW generator and a KW amplifier to go along with it. It was driven more than 700 miles going through many counties. Who thought this up?

This is one antenna type that had its core design done by someone other than me. I wrote a specification for an efficient antenna that could be basically hidden behind a typical fence for restricted areas. A good friend, Ken K6HPX, suggested he could give it to Dr. Joe Boyer (now an SK), as he was an expert in small antennas. He had developed the D.D.R.R. and many others for the military. Dr. Boyer eventually sent his 20-meter unit to us and we tried it out. It was only 3' tall and didn't cover the whole band, but that was solvable. Being a bit skeptical, we tested it for a week.

Our test antenna was a full size 20-meter rotatable dipole up at about 35' and in the clear. We made comparisons every day, at all hours of the day (and night) between the dipole and the shrimp 3' tall antenna. What do you think was the result? We were amazed, to say the least.

Most of the stations we tested with were in the mid-west, but many were on the East Coast. The tiny vertical dipole was averaging equal with the horizontal dipole. There were times when one or the other was superior, but the 3' antenna was truly amazing. It was technically magnetic, being less than 0.1λ tall. It was made of copper tubing and contained a full half-wavelength total in the upper ring, vertical portion and lower ring. The rings were square and open at one end. This deserved much more investigation. As it sat, it couldn't be put into production, but we could at least figure out that part.

Team Vertical had already been racking up impressive contest performances from Jamaica using verticals. Those were either full size, or linear loaded for the low bands. They all were working great and the Team was discovering more and more about verticals, salt water and how to wed the two together.

We made another 20-meter antenna similar to the original, but it was twice as tall. That made it 6' and the upper and lower rings were about 4' per side. This size looked like it could be produced and shipped. It performed just as well as the original copper model and covered the whole 20-meter band. The trick now was to make it multi-band.

The computer model tracked the single-band version, but was incapable of indicating anything on how to add a second band. We punted and worked with lots of tubing, a TIG welder, grinder and lots of notes. Eventually we were able to add 15 meters and it found its way to the Visalia DX Convention that April and was on the air during the cocktail time late Friday. It sat in a 5-gallon bucket of cement and they were working South America with 100 watts. Hardly anyone believed what it was doing.

More work and we managed to add 10 meters. That looked like a reasonable product. Many were made using the curved tubing as in the photo. This was, however, very expensive to make and we tried several more iterations to reduce cost while maintaining its excellent performance. We finally

made had all straight pieces of tubing and machined corners:

We finally decided it was both too difficult to make and too expensive to sell. We did not, however, give up on the vertical dipole concept we had discovered. This concept was utilizing end loading. We also mad another 3-band vertical dipole for a while. It was essentially the 3-element driver portion from the C-3SS, but re-engineered to stand up. This means the tubing elements were a reverse taper,

larger at the bottom and tapering all the way up. It looked like this:

That photo is from a contest DXpedition to Venezuela. The antenna was located a long way from the operating position and 450-ohm ladder line with special baluns were used to span the 900’ distance.

Team Vertical decided to do more research to determine the effective distance from the salt-water boundary. Team co-founder Kenny, K2KW wrote some articles,, we both wrote some articles, Kenny made a few presentations and I made a lot of them at conventions and clubs. The following is a compilation of our collective sharing of information regarding verticals:

The selection of using vertical antennas was not a natural choice. The "conventional wisdom" for contest-expeditions and DXpeditions was to use Yagi antennas when ever possible, regardless of the height. "Conventional wisdom" would tell you that a 3-element Yagi at 25' to 30' high on 10 meters, 15 meters, or 20 meters would be the correct (if not only) choice.

When first researching our antenna selection, most of the major contesters in the USA said that the Caribbean stations ALWAYS came in at a high angle. Again, more "conventional wisdom" indicating that a low Yagi would be the best choice from Jamaica.

When we were running our propagation programs, the team noticed that the take off angle to the USA was actually a 1-hop LOW angle. Not the high angle that most people indicated.

Which was right: conventional wisdom or the computer models?

In our first trip to Jamaica during the ARRL DX CW contest, the group used a blend of antennas:

- Verticals for 40m-160m
- Both a horizontal Yagi & vertical array for 20m
- Yagis for 10m and 15m.

The use of Yagis on the high bands seemed appropriate, as we would elevate them between 0.5

and 1.0λ (1 wavelength) high. The computer models indicated that the Yagi should perform just fine.

While in Jamaica before the contest, the team ran extensive tests with the 20m 2-element Yagi (45' high) and the 2-element parasitic vertical array. The results were astonishing. Hundreds of comparisons were made. Out of all those, only a handful of times was the horizontal Yagi better than the vertical array and then it was only by a small margin.

Most of the time, the vertical array was 2 S-units stronger than the horizontal Yagi. In fact, there were many occasions when a signal was an honest S-9 on the verticals (on the FT1000-MP) and S-0 and almost unreadable on the horizontal Yagi. Please read that again, as it boggles the mind and I was there. How could this be? After many conversations, especially with Dean, N6BV, who was the leader in researching propagation and related software, we concluded that

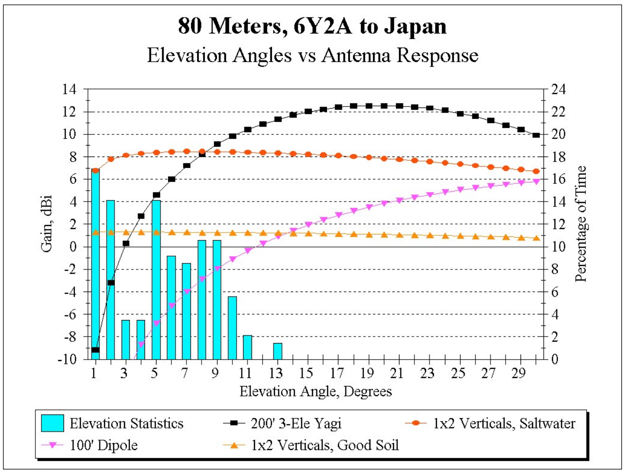
this extreme difference could only be attributed to a signal arriving at a VERY low angle, where the Yagi had little, or no gain.

These results, amidst many additional months of research, convinced the team that verticals by the ocean were the only logical choice for competitive contest-expeditions. They would have a side benefit in that it would be much less aluminum and much easier to install without masts and rotators.

The following graphs were created by N6BV of the ARRL. The first chart shows an analysis of the take off angles from 6Y2A to Japan on 80m compared to various antenna choices.

First, look at the vertical bars (light blue). This is a statistical grouping of all take off angles between 6Y2A and Japan over all times of the sunspot cycle, over all months of the year, and over all conditions. The data is displayed in the percentage of times a signal will arrive at a given angle: right X-axis is the % of time, and the Y-axis is the take off angle.

Thus by looking at the first bar on the left, we can see that on average, signals will be arriving at 1° take off angle nearly 17% of the time. In fact, you can see that ALL signals will arrive at or below 13° on all occasions. Those are very low angles!!



Overlaid on the take off angles is the elevation-plane analysis of "standard" 80-meter antennas. Lets look at the 80-meter dipole at 100' (pink with inverted triangles). By most standards, this is a very good antenna. But you can clearly see there is little gain at the low angles.

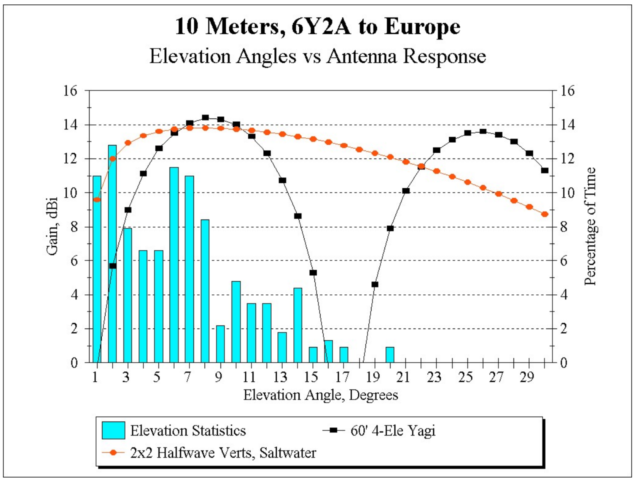
Look next at the 1x2 verticals over good soil (2-element parasitic vertical array). This antenna provides you with a large improvement over the dipole.

Now lets jump to the "ultimate" 80-meter antenna: a 3 element *full* size Yagi at 200'!! There aren't many of those around, and those who use them generally rule the band, at least based on conventional wisdom again. The 3-element Yagi really does a great job over most arriving signals.

Let's now finally look at the 1x2 verticals over salt water (orange with circles). We can see that the verticals have a large advantage over the 80-meter Yagi at the very low angles. In this example, the verticals have a 16dB improvement (3 S-units!) advantage over the Yagi. On the higher angles, the vertical still performs well. Overall, we believe the 2-element vertical array over salt water is a better all around antenna than a full size 3-element 80-meter Yagi at 200 feet!

The next graph examines the take off angles on 10m to Europe. The reference antenna is a 4 element Yagi at 60', an excellent contesting antenna. You can see that the 10-meter horizontal Yagi still does not cover the very low angles, and there is a null where there are still many signals arriving.

The comparison array is the 2x2 vertical array. The 2x2 verticals match the peak gain of the Yagi, but also offer excellent coverage over all arriving



angles. A learned opinion by Team Vertical, to use current slang a bit, is that "verticals by the beach rule"!

The team has done extensive modeling to all areas of the world on all bands, the results are typical of the examples above: Vertical arrays over salt water are very competitive antennas.

Testing the verticals

To be certain that vertical antennas were the right choice for their waterfront location, the team did extensive testing of the arrays to ensure they could reproduce the results in the field. For more detailed results and installation tips, read the article written by both of us (N6BT and K2KW) that appeared in CQ Contest Magazine in the May 1998 issue. That article is now 10 years old, but the data obtained is still valid. Below are photos of the antenna testing.

Reference antenna on the land-water boundary

We build a ZR vertical dipole for 20 meters to use for our reference antenna. It was built as described above, being 6' tall and fed in the center, like a typical dipole would be. Calibrated receiving test equipment (+/- 0.5 dB) and reading in 2dB per division was located on the other side of the San Francisco Bay, approximately 17 miles away. This allowed us to measure the RF energy at less than 0.5° take-off angle, which is what is called the "pseudo Brewster angle.

The ZR is sitting right on the salt water boundary.

Immediately to the right and down about 3' from the 5-gallon bucket is salt water.

Testing the Pseudo Brewster Angle

The team wanted to know how far from the water could they go before they would loose the enhancement of the salt water. According to our research, the vertical would have energy in a single lobe, going down to maybe 1°. After researching information on the affect of the land-water boundary on the pseudo Brewster angle, the team realized there were no definitive studies on this subject.

A vertical over land has little radiation below 12° take-off elevation angle. This is a result of the so-called pseudo Brewster angle, and the lack of a highly conductive plane underneath. When a vertical antenna is placed over a highly conductive plane (e.g. salt water) the antenna effectively radiates energy all the way down to the horizon. We were ready to make some tests.

Our pending question was, "At what distance away from the water will the land start detracting from the low angle energy?"

The team set the vertical on the land-water boundary (above), and moved the vertical away from the water in 3' steps.

The land-water boundary was the reference point (0.0), but when the antenna was backed up and reached approximately 1/4λ from the water, the signal level increased + 3 dB over the reference point! The zone of this enhancement was fairly small. As the antenna reached 1/2λ from the water, the antenna was now -2 dB from the reference point! At the 3/4λ point, the signal was now back up to +2 dB from the land-water boundary position.

Obstacles prohibited us from going farther than 3/4λ back from the land-water boundary. It was clear, however, that the land-water boundary had a significant impact on the low angle energy (in the pseudo Brewster angle region). It was also clear that additional research was needed in this uncharted area.

Unfortunately, it appears that the gain enhancement is only in the immediate direction of the water. In directions other than the closest point of water, there is more land, thus impacting the pseudo Brewster angle in those directions. While having 3dB of gain is desirable, it was our conclusion that the vertical should be placed as close to, or over salt water to ensure optimum performance in as many directions as possible. This will take into account changing tides and potentially difficult installations.

We also concluded that more research was needed. Team Vertical continued to perform tests in various locations and with many antenna types for several years.

Our article from CQ Contest Magazine that was noted earlier continues in the next chapter.